INTERACTIVE SIMULATION OF A CONJUNCTIVE WATER SUPPLY SYSTEM

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A THESIS FOR THE DEGREE OF
MASTER OF ENGINEERING SCIENCE

CIVIL ENGINEERING DEPARTMENT,
UNIVERSITY OF ADELAIDE, 1983

This thesis embodies the results of supervised project work making up all of the work for the degree.

ACKNOWLEDGEMENTS

The author wishes to thank his supervisor, Mr. R. Culver, Reader in Civil Engineering, for his many hours of patient listening, valuable discussion and constructive criticism. His enthusiasm and support were of utmost importance during the author's candidature.

Acknowledgements are also due to Mr. K.W. Lewis, Director-General and Engineer-in-Chief of the Engineering and Water Supply Department, for sponsorship of this research through the Department, to Mr. P. Manthey, Mr. F. Flood and Mr. M. Bormann, for their time and patience in answering questions and using the model, and to the other officers of the Department who were responsible for the high quality of typing and draftsmanship in this thesis.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text.

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DATE 18.1.83

TABLE OF CONTENTS

Chapter 5.

Chapter 6. MODEL DESCRIPTION

Chapter 7. MODEL OPERATION AND CONTROL

Chapter 8.

Chapter 9. PROGRAM STRUCTURE ANS SUBROUTINE DESCRIPTION

9.4 Subroutines

10.3 Output Data

Chapter 11 EXPERIMENTAL RESULTS AND ANALYSIS

SUMMARY

This study is directed at the investigation of the management of the metropolitan Adelaide Water Supply system in South Australia using an interactive simulation model. This supply system serves a consumer population of about one million people and is derived from ten major storage dams, and three large pumping systems which draw water from the River Murray approximately 60 kilometres to the east of the ranges in which the dams are located.

Without augmentation of supply from the Murray, and relying only on local rainfall, Adelaide in particular and South Australia in general, could maintain neither the level of industry, standard of living, nor development which are currently required for viability as a modern population centre. Due to the irregular distribution of rainfall, both spatially and temporally, the tuning and specification of pumping operations vary over a wide range of possible combinations particularly with the high demand resulting from a usually long and dry summer.

No direct optimising algorithm has yet been developed to manage the system for least cost. The relative constancy of most operating and maintenance costs throughout any year leaves the highly variable pumping cost of the River Murray supplies as a most significant cost item in system operation.

Due to the complexity of the system and supply irregularities, sound operator experience is shown to be

vital for the successful operation of the system.

To investigate the effect of this personal experience on the efficiency of operation, and to facilitate the rapid learning and practicing of control skills which are needed to build experience with the real system, an interactive, graphic simulation model is used. This model is not designed to define or optimise a management policy, but rather to provide the rapid, interactive tool by which the human operator may simulate his own desired management strategy over an extended time period, given unknown system inflows and demands. The model also enables the close scrutiny of different individuals' personal approaches to water supply management, and what, if any, similarities or differences become apparent in their performances.

CHAPTER 1

1. INTRODUCTION

1.1 Management of the System

At present, the efficient operation of the Adelaide metropolitan water supply system is dependent on very experienced Pumping Engineers of the Engineering and Water Supply Department in South Australia. To manage the system competently these individuals must develop an acute awareness of the interrelation among inflow (rainfall), reservoir storage and demand. This can be gained only by experience in managing the water supply system over a wide variety of conditions extending over many years.

The method of controlling the system is to combine an initial prediction of each month's demands, based on historical data, with average inflow values for each catchment to determine the monthly variations in reservoir storages over the whole financial year, July to June. The resulting reservoir storages indicate to the engineers how much pumping from the River Murray is required each month to maintain adequate supply levels, and safe storages in the reservoirs.

This predicted strategy is updated each month or at shorter time intervals if unexpected and significant changes in predicted demand and/or inflow occur; for example, sudden heavy rain or long dry periods.

Thus the management policy is adjusted as further data comes to hand, to gradually return it to the desired safe strategy and to obtain the "target" storages in the reservoirs required at the end of the year.

The "adequate" storage levels and "safe" strategy are highly dependent on the engineers' knowledge and experience with the system. It can be appreciated that the lower the desired storage volumes, the smaller the pumping required from the River Murray, resulting in a smaller pumping budget to meet a given demand.

However all the calculations are performed at present with the assistance of only electronic calculators. This makes the job a highly time consuming task requiring at least one day per week of full time application.

Due to this large time element, investigation of alternative strategies sometimes proves prohibitive, and so the results of the predictions, while adequate and often economical due to the engineers' experience, are rather more a satisfactory solution than the best of a series of calculated alternatives.

1.2 Objectives of the Research

The Adelaide water supply system has been expanded over the years to match the steadily growing demand, and so it may be expected that little insight into system operation could be gained by optimising system characteristics and components already designed to fulfil certain supply requirements. However, using these existing system features the operation of the system may be investigated on the basis of the relative efficiency of human management, since it is the ability of the human decision maker that will ensure the greatest operational efficiency from each individual unit and the system as a whole.

The interest in this current research is to try to determine the effect of the individual engineer's operating skills on the overall efficiency of this water supply system. Since the whole management policy as previously stated is dependent on the engineer's experience, and experience is a very subjective and qualitative comodity, the method used to ensure an "adequate" supply of water through years of high rainfall and years of drought will depend on the nature of the human operator.

A degree of conservatism or flambuoyance would tend to govern his attitude towards the problems confronting him at every decision.

How much is a gamble?
What are the priorities?
What risk is acceptable?

These are some of the questions which if considered and if capable of being answered, will reveal to some extent how the engineer "drives" the water supply system.

The aim of this research is to investigate some potential answers to such questions as these. An interactive simulation program using computer graphics has been created which models the system previously discussed. It is used to examine the performance of several individuals who operate it as they would the real water supply system.

It is intended to discover whether personal attitudes towards risks and trade-offs affect an operator's management of the system, or if the teaching/learning process on the simulator is sufficiently thorough to make all operators behave in a similar fashion.

Simulation is used because the objective of the model is not to obtain an optimised computer-algorithm result, but rather to allow the operator to choose his own best solution to each operational situation as it presents itself.

The program is interactive because the operator must be in total control of the model, just as he is with the real system, at every point in its behaviour.

Computer graphics are used to enhance the ease of interaction and level of communication.

Far more can be shown to the operator through the use of pictures than with any number of tabulated values, and lightpen communication allows rapid, natural and error free communication between operator and model.

Thus there are two goals which the computer model is designed to achieve:

- firstly, the simulation of the supply system with sufficient operator control to enable the system to be altered, adjusted and controlled as the real system.

- secondly, the implementation of these controls in graphical form and with enough explanatory elements to facilitate easy understanding, learning and usage of the program by the operator.

CHAPTER 2

2. WHY INTERACTIVE GRAPHIC SIMULATION?

The lack of any appreciable amount of information concerning the use of interactive graphic simulation in water supply/reservoir management systems has prompted this introductory chapter. Both optimisation and simulation are reviewed and arguments are presented for the consideration of simulation as a justifiable alternative or adjunct for use in the analysis of water supply systems.

It is true that there are few other techniques, if any, besides simulation which will model a system interactively while still allowing complete "hands on" operation control, which is the basic requirement for this research. Nevertheless there are valid applications for interactive computer graphics combined with simulation or other techniques of modelling and some of these are highlighted in the literature review of Chapters 3 & 4.

2.1 Mathematical Analysis

The two general categories of mathematical analysis, optimisation and simulation, may be considered as loosely dividing the techniques available for the investigation of reservoir systems. Under these headings there are literally hundreds of procedures and models proposed and used for analysing reservoir systems from planning, through design, to operation. No single ubiquitous method of analysis exists - all have strengths and weaknesses.

In a water resource system investigation, the optimisation of system design and operation is usually the major thrust of all analyses. When deciding which approach to use, the problem is not one of identifying which method is better than another but rather a determination of the desired compromise among the ranges of information each type of solution can provide given the limitations of time, manpower, money and computing capacity. Each valid model type has some place in river basin analysis.

Two important factors to be considered in the choice of a modelling technique are the complexity of the proposed model, and the desired detail of the information to be obtaind as output. For example, a model required to give intimate detail of system operation must be much more complex and accurate than one in which the aim of modelling is to plan out long term efficiency of water resources investment. In the general case of water resources investigations, as one proceeds from planning to operation the level of complexity required and the attendant need for accuracy increases.

In planning and design studies, information is usually needed to refine the size and location of specific facilities intended to satisfy current and/or future needs. This results in the often used title of "capacity expansion". On the other hand, in operation studies information is sought to improve the operation of an existing system.

2.2 Optimisation

Optimisation attempts to find a solution to the modelled problem which cannot be improved with respect to chosen objectives; for example, minimise loss, maximise benefits, or maximise expected economic income.

This is accomplished through the use of one of the available mathematical techniques which either solve directly, or search iteratively, for the optimal solution.

In the field of optimisation there are many algorithms and methods which have been applied to the study of water resource systems. Their degree of usefulness ranges from almost purely academic exercises to more practical approaches which may be applied to a particular water supply system.

If the system can be described analytically, such mathematical programming may be used to find the optimum operating strategy. Thus a system may be defined by a set of input variables subject to constraints, and an objective function of these variables. The objective function is to be optimised by finding permissible values of the variables which yield a best solution to the function.

The advantage of such analytical methods is that they involve a direct quest for the optimum solution. However there are several characteristics associated with most of them which affect their application.

Since the search for the optimum solution is based on mathematical theory, there are associated mathematical constraints imposed on the model. Prerequisites such as linear or piecewise linear objective functions and constraints, or restrictions on the characteristics of the objective function such as convexity or continuity must all be satisfied before the model can be used with confidence of obtaining an optimum result. These restrictions on the form taken by the model require approximations of the real system elements to be used, since rarely do systems exist which by their nature satisfy all the necessary conditions. The degree to which modifications must be made to implement an optimisation technique governs the accuracy and realism of the results that can be obtained.

Besides these mathematical constraints, the economics of certain techniques may affect the model.

In order to ensure that the cost of modelling does not become prohibitive, it is often necessary to eliminate many of the detailed considerations which occur with operating multi-reservoir systems in practice. Simplification of the system and reduction of its operating procedures to fixed operating rules facilitate the formation of a solution, but do not reflect the real life nature and interaction of the system in terms of flexibility and variability of operation.

The problem of dimensionality in optimisation is also of concern. To obtain an optimum result within the limits of the real system, constraints must be included in the model to define the region of feasibility for the analysis. It can be appreciated that as the size and complexity of the system increases, so also do the number and complexity of the constraints, increasing the dimensionality of the model. Despite the use of high speed digital computers, the adverse economic and time factors of large dimension models preclude their use in most cases.

In many systems it is also difficult to define the objective in mathematical terms. While the defining of economic benefit functions for some water-based needs (e.g. hydro-power and irrigation) is reasonably well established, this is not the case for systems which produce certain other water based benefits such as recreation or environmental harmony. Within a single reservoir system, it is not easy to satisfy all possible design and operating policies, and there is often no assurance that the best combination of policies and structural measures can be found. As a result the pure definition of optimisation is sometimes not applicable, and the best that can be achieved is a satisfaction of the demands placed on the system.

To define the most satisfactory solution for the chosen objectives, the "decision maker" must define the relative levels of benefit, or dis-benefit, to be used by the model as the limits to the objective values. This set of trade-offs establishes the level of desirability of achieving each objective with respect to all the other objectives.

2.3 Simulation as a Technique

Simulation methods unfettered by the rules and restrictions of mathematical theory have a great freedom and flexibility in modelling systems too complicated for direct optimisation by analytical techniques. Since there is not the same demand for simplification, the model can more closely simulate the functions of the real system with an attendant potential increase in model detail and accuracy.

Greater flexibility in deriving responses which are defined in non-economic terms is also possible, and from the operational point of view, they provide a more effective focus for dialogue between computer system and operators, since the ideas inherent in simulation modelling can be understood more easily than those associated with optimisation of a frequently "cut-down" system. However no direct answers for the best solution can be obtained with certainty, and most responses must be expressed in statistical terms. Thus to obtain confidence limits on the results, a large number of trials is required.

Simulation can be used very successfully, especially when combined with sound operator experience and human judgement. In addition, for systems which have a substantial portion of their water based benefits expressed in non-economic terms, simulation modelling will continue to be almost the only practical approach for some time to come.

The statement of these advantages does not mean to imply that simulation as a technique completely avoids the pitfalls of the analytical methods. In many cases it may suffer from exactly the same problems.

Some operations are so variable that they cannot be described mathematically in a way that provides the necessary and sufficient criteria for decision making over all possible events and states. In such cases either some of the "offending" interactions are ignored completely or so simplified that the problem ceases to exist. In either case, the quality of the results obtained from the simulation suffer correspondingly. A further consideration is that, since no direct indication of the optimum is given, further techniques must be applied to the results of a simulation in order to move towards the "best" solution.

Despite such drawbacks, simulation can often facilitate investigation into mathematically intractable systems, and may indirectly supply data to allow an improvement in operational procedure using further techniques.

2.4 Interactive Graphic Simulation

The general technique of batch mode simulation, outlined in the previous section, does not usually allow an operator to see readily how the problem is developing through time, nor does it provide the facility for direct interaction. At the end of individual simulation experiments, only statistical answers are produced.

The great usefulness of interactive simulation is based on the following considerations:

While the human mind is highly inefficient in processing large amounts of data and coping with mathematical calculations at speed, it is eminently suited to making decisions and considering alternatives. The high speed digital computer on the other hand, has no difficulty executing immense data processing tasks and high speed calculation, but very complex programming is needed for even relatively simple decision processes to be accomplished.

Therefore, if each side of the man-computer system is to do the job for which it is best suited, then interactive simulation appears to be a particularly efficient method of dealing with system simulation.

The development of video display (graphics) computer terminals has been important to the further enhancement of this method's efficiency.

In its simplest terms, the reason for using graphic displays is that they convey more information to the user. The brain perceives a picture in a glance - a process called preattentive perception - but it must comprehend text or numbers in a more laborious, one-at-a-time fashion. During this serial decoding operation, the user must make an effort to concentrate. In comparison, viewing pictures seems effortless.

Not quite so fundamental, but nevertheless still basic to overall effectiveness, are the considerations that graphic displays add flexibility to the communication methods available for model control, so that the operator may communicate with the computer in visual symbols that represent his concept of the system being modelled. As a result, a graphics interface allows the user to interact at the level of his own intuitive sense of structure and function.

It can be appreciated that interactive graphics provides a unique tool that can be used in simulations of complex systems. The model user can thus make decisions quickly which can then control the ongoing simulation on the basis of intelligence generated by the simulation. This capability not only gives the model a more realistic control mechanism, but also provides the user with information concerning the entire operation of the model, rather than just the end results.

Thus the philosophy of a visual interactive simulation system may be understood as being that an operator should be able to watch a simulation model of his problem situation develop through time. Meanwhile he is able to apply his knowledge and experience to the model in order to explore alternative strategies, decisions or directives.

On the programming level, because much of the control logic is removed from the computer program, a simulation program using the graphics approach is much easier to write, test and modify. Furthermore, this lack of programmed control logic means that the simulation is versatile in that it can utilize more than one control doctrine.

2.5 Deciding on a Technique

While expounding the virtues of interactive graphic simulation it is important not to lose sight of its perspective relative to other techniques. Certainly it is ideal for the study reported in this thesis and a wide range of other variable decision-making models, however as pointed out earlier in this chapter it is only one of the valid approaches suited to a particular type of problem. Its justification will depend on the particular problem in hand.

On the basis of using an interactive as opposed to a batch mode (closed loop) program, the interactive form requires constant attention and, due to the inclusion of "slow" human decision-making on-line, the time taken for a single program execution is relatively large and the cost correspondingly high in comparison with batch programs.

A further consideration is the fundamental question of determining the aim of the analysis - whether it is to be the system or the operator under scrutiny. For example, if the testing of a standard operating rule is required, which is to be repeatedly used without modification, then a closed loop simulation is adequate, since it is redundant to involve human interaction if the input required is solely repetitive.

Often the stimulus for analysis is the envisaged precipitation of an optimum policy. Small systems can be relatively easy to optimise and may not be considered worth the trouble of a non-optimising interactive graphics solution. Large systems are sufficiently important in the economic sense to be able to justify highly complex optimisation analyses, since a small improvement in operation may be of considerable economic benefit.

CHAPTER 3

3. LITERATURE REVIEW

3.1 General

The literature review aims to set the scene for later chapters by supplying information and examples relevant to systems analysis and the human aspects of man-machine communication. This subdivision serves to emphasise the importance of these factors in the current research and prepares the way for recognition of their importance in following chapters dealing directly with the study detail.

Due to the clear distinction which can be made between the two areas of interest in this review, two separate sections have been used.

This first section of the literature review examines water resource system optimisation and simulation and discusses problems of their use in very complex systems.

Sigvaldason (3) points out limitations in the application of optimisation models for defining multi-reservoir operating policies where systems are composed of many reservoirs.

These models become computationally expensive as the number of reservoirs increases and the length of the hydrologic sequence increases. For larger systems of more than five or six reservoirs he suggests that the most successful modelling strategy is simulation. An exception is given by Maidment (4) who reveals that specialized forms of linear programming have been used to optimise river systems containing as many as 48 reservoirs, although a number of simplifications had to be introduced to obtain the solution.

Also Croley (5) gives a modified application of the deterministic optimisation technique for which the computational requirements of optimisation can be reduced. Thus larger systems may be analysed than might otherwise be possible.

3.2 Simulation and Optimisation: Applications

While computer modelling has the ability to solve otherwise intractable analytical problems, Singh et al. (6) point out that accuracy and simplicity in modelling are competitive. This sentiment, which is echoed throughout the literature, points towards a division in the application of computer modelling techniques.

In the context of the previous chapter's introductory remarks concerning simulation and optimisation, the following guidelines may be inferred.

Where detailed information on system operation is desired, as in analysis of system functions where an accurate and hence complex model is required, a direct simulation of the reservoir system is used in most cases. Alternatively, when some form of best solution must be chosen from a group of possible solutions, a mathematical optimisation analysis is often applied. Examples of this situation arise in design decisions for optimum dam heights, siting and timing of reservoirs and associated works, or as planning strategies in proposing reservoir operating rules for hydro-power generation, irrigation, flood control or water supply. Needless to say there are exceptions to this categorisation. Sometimes optimisation is used in detailed analysis, and repeated simulation is used to evaluate a statistically optimal result.

While a useful guide, such a division must also be viewed as being somewhat arbitrary in nature, since several other factors may influence the choice of procedure. These include the amount and accuracy of available data, the time available for producing a solution, and the computing power at the disposal of the analyst. In addition, Kisiel (7) highlights the importance of the form of the objective function and state transition function on the choice of solution method:

i.e. objective function -

output = G (S(t), X(t))

state transition function -

S(t+1) = F (S(t), X(t))

where S(t), S(t+1) = states (storages at times t and t+1 respectively).

X(t) = system input for time t.

For deterministic 'F' both mathematical programming and simulation are employed. However, for stochastic F, optimisation has greater difficulty dealing with the problem than simulation. Examples of procedures which optimise under stochastic conditions are given by Croley (8) and Rohde et al. (9).

Chow (10) reports on discussions of the different aspects of both optimisation and simulation. He considers simulation models to be justified for long range planning, but when approximate answers are needed quickly he suggests that analytical procedures applied to simplified models must be tried first.

Loucks (11) however sees simulation and optimisation as complementary techniques. Simulation may be used to evaluate alternative system configurations, but optimisation is more effective for defining the initial combination of reservoir capacities, target storages and policies. Even if the best solution is not found, at least the worst solutions are eliminated from further consideration. Loucks acknowledges that the limitations of optimisation restrict its use to preliminary screening, followed by a more detailed simulation of the system to check the proposals in a more realistic context.

These references indicate that, while general rules can be found, the realms of application for simulation and optimisation also vary according to the opinion of the individual and preference for a particular technique.

3.3 Uncertainty and Risk

Despite the variations in the use of simulation and optimisation, a common concern expressed in the literature is the importance of considering the probability of the outcome (risk) in any analysis. This concern stems from a realisation that while optimisation can yield an optimal result, there is no indication in the solution of the probability of obtaining either the solved optimum or complete system failure while implementing the optimum strategy. In fact analytical methods can give solutions with significant probabilities of failure.

Protagonists for simulation use risk evaluation as a further justification for their cause.

Askew et al. (12) point out that once the optimal solution is found, some form of Monte Carlo analysis is still needed to check the associated probability of failure. This extra step reduces a complex optimisation analysis to little practical value, and it is considered quicker and simpler to use simulation involving Monte Carlo techniques right from the start. Harboe and Schultz (13) cite an application of simulation to a reservoir in West Africa for which one of the main objectives is an acceptable risk of failure.

With reference to optimisation Kisiel (14) acknowledges the uncertainty in defining accurate objective functions and constraints: "To the extent that many constraints, state transition functions and objective functions are well defined or known, might our confidence in the optimal solutions be strong. On the other hand, if such prior knowledge is not available, then varying degrees of risk must be taken in the use of the results".

Hall (15) considers risk and uncertainty as a set of objectives within optimisation which are inherently non-commensurate with the other objectives, or for that matter even among themselves.

The lack of a standard approach to the specification of risk objectives is due to the infinitely possible number of system risk levels. Determining an acceptable answer to the deceptively simple question, 'Risk of what?' gives a starting point. The tentative evaluation of some of these objectives is explored by Haimes and Hall (16) as part of the optimisation process. Aspects of risk indentified as being important in the final solution are given as stability, sensitivity, irreversibility and responsivity. It is suggested that these additional constraints help to better define the best workable solution (acceptable risk) rather than simply the best mathematical result regardless of the risks involved in obtaining it.

Nazar et al. (17) use a simulation of a river system involving irrigation and hydro-power for analysis of the risk of obtaining given target levels. The results enable suitable trade offs between risk and the other objectives (e.g. hydro-power) to be established, and it is suggested that these could be used in a multi-objective optimisation, thus explicitly including risk as an objective.

Morel-Seytoux (18) emphasises that the particular optimisation formulation chosen will depend on the actual characteristics of the system under investigation.

3.4 Optimisation Considerations

The following sections contain discussions on topics which for the most part are techniques for solving the problems that can occur in optimisation analyses and not in simulation studies.

This is simply due to the fact that simulations do not contain objectives to be internally satisfied by the model before a satisfactory solution can be formulated. Information is presented to the analyst who must then decide on what modifications are required. The necessity in optimisation to chose internally between alternative plans or strategies, on the basis of an objective function, brings the associated problems of finding common ground for comparisons, and coping with the dimensionality of a large reservoir system model.

3.4.1 Multi-objectivity

As long as the objective to be optimised within a reservoir system can be expressed in terms of a single utility, such as dollars of benefit/loss, then a direct comparison of alternative values can be made within a straightforward optimisation analysis, and a single best solution may be easily achieved. In practice, however, individual reservoirs and systems of reservoirs of any significance are seldom designed or operated to fulfil only a single function. The mammoth capital investment involved in such structures demands that any such installation be used to satisfy as many different needs as possible for maximum efficiency. This involves the simultaneous consideration of several objectives, any or all of which may be conflicting in their requirements from the system, and may be expressed in values not amenable to direct comparison. Hence the use of multiple objectives and multi-criteria optimisation are important in reservoir management.

The political nature of such policy planning is discussed by Haith and Loucks (19).

It can be appreciated that the establishment of trade-offs is a critical step in system optimisation. Any errors or unrealistic limits will ultimately affect the relevance of the final solution. In order to avoid such pitfalls often associated with the evaluation of trade-offs before commencing the analysis, Beeson and Meisel (20) advocate the evaluation of trade-offs only after the analysis. The problem is not treated as a direct optimisation resulting in a single best value. Instead the multiple criteria are maintained as separate entities in the objective function to be optimised, and due to the vector nature of the optimisation result, a set of "non-inferior" solutions is obtained. The significance of this solution set is that no other solutions exist which are better in terms of all the criteria. They represent the alternatives available to the decision maker, and the associated values of the objective function show the trade-offs available. This avoids the usual problems of including trade-offs as constraints - requiring that the trade-offs be determined before their effects can be fully assessed. Thus an examination of alternatives is advised in multiple criteria optimisation rather than obtaining results by a fixed assignment of weights or constraints.

The examination of alternatives by the decision maker is a theme also taken by Croley and Raja Rao (21). They point out that the use of subjective trade-offs between objectives by involving the decision maker, who chooses the desired balance in benefits and costs, avoids having to bring all non-commensurable quantities to a common value base, which would have to be done before the interactions can be modelled.

The essential feature of the proposed method is that the subjective choice of the importance of objectives is made after all operating consequences with respect to each objective are evaluated.

The example given is a single reservoir with the conflicting objectives of recreation and flood control.

An alternative form of avoiding premature trade-off determination is proposed by Neuman and Krzysztofowicz (22). An interactive form of trade-off analysis is used in which the decision maker is asked to progressively refine system trade-offs during the analysis. This allows him to see the effect of the previous trade-off sequence and modify the limits towards a more acceptable balance in the criteria. The procedure iteratively refines the search for the best solution on the basis of each new trade-off definition.

A general review of multi-objective techniques was made by Cohon and Marks (23). The various procedures were evaluated according to three operational criteria:

1. computational efficiency and feasibility.

2. explicit quantification of trade-offs among objectives.

3. provision of sufficient information that an informed decision can be made.

Their results indicated that, while some techniques are not applicable to water resources multi-objectives planning, the size of the problem (number of objectives) governs the choice of the optimisation method in order to capture the important elements of the problem and still maintain computational feasibility. However it was acknowledged that for high dimension problems very extensive calculation is inevitable.

3.4.2 Multi-Level or Hierarchical Modelling

Up to this stage, analytical techniques have been discussed which can successfully be applied to only a small number of reservoirs.

Different methods are needed for the optimisation of large and complex reservoir systems. Haimes and Macko (24) use the California Water Project as an example in which the operation of four rivers, their associated dams, ten reservoirs, and power plants is optimised.

The technique used for such applications is a hierarchical or multi-level decomposition approach (Haimes and Macko (24), Haimes (25)). The approach recognises a complex system as consisting of a number of interacting subsystems, each having its own objectives and operating constraints.

These subsystems are co-ordinated at a higher level of the hierarchy, where the overall system's objectives are specified and achieved through resolution of interactions and conflicts between subsystems.

The decomposition of a complex system into simpler subsystems yields a reduction in the dimensionality of the problem at the expense of having to solve several subproblems of lower dimensionality. This in turn reduces the computational effort involved.

Decomposition is accomplished by introducing into the model new variables known as pseudo-variables.

These variables are used to uncouple the common variables of two or more subsystems at a lower level in the hierarchy. This uncoupling allows each subsystem to be separately and independently optimised, with perhaps different optimisation techniques being applied, based on the nature of the subsystem models as well as on the objectives and constraints of each subsystem. The subsystems are joined together by coupling variables which are manipulated at a higher level in order to arrive at the optimal solution of the whole system.

An example of such a decomposition and optimisation is given by Bonazountas and Camboulives (26). A five reservoir system is decomposed into three separate subsystems for short term, long term and water quality control, each subsystem requiring a different optimisation technique.

It should be noted that decomposition results in a number of layers or levels of which the lowest level represents the subsystem of sufficient simplicity for modelling.

Nainis and Haimes (27) use the technique in a general method proposed to facilitate planning for optimal long term economic expansion in water resource systems. The modelling system is composed of two major interacting components - a supply model and a demand model. The supply model is used to determine the scale, timing and location of water resource projects to satisfy given water withdrawals over time. This is accomplished by decomposing the supply system into subproblems according to separate subregions and optimising each subproblem. The demand model predicts water demand functions for the supply model. The overall control routine is iterative and seeks to simultaneously equalize the models' marginal costs and benefits.

Herath and Chong (28) report on the use of the hierarchical multi-level optimisation approach to determine optimum timing of structural augmentations to a system of 8 main reservoirs and two major and one minor pipeline.

3.5 Simulation Considerations

Having established the approximate nature of an optimum solution it is clear that simulation has a role to play in refining such results so that they may be confidently implemented on a real system. An accurate simulation model may bring to light certain flaws in the optimum which, due to the necessary assumptions in the original analysis, may have remained unnoticed.

Maidment (29) considers that the most appropriate approach to the solution of water resource problems is some combination of the flexibility of simulation (to avoid approximation errors) and the efficiency of optimisation (to rapidly find the best solution). Such a combination is currently possible through either sequential or conjunctive use of the two techniques. Cole (30) gives an example of sequential use. An optimal solution for a single multi-purpose reservoir problem is obtained using dynamic programming, and in order to evaluate the results more fully he suggests simulation of the output.

Wilkinson and Smith (31) discuss a procedure for conjunctive application. A purpose-designed iterative search procedure uses the output from a simulation model to evaluate the required incremental changes to be made in order to move towards the optimal solution.

It is often assumed that the analyst or policy planner has no prior knowledge of the system, or that the system is too complex for an optimal or near optimal solution to be found without the aid of an optimisation analysis. The philosophy of the Hydrologic Engineering Centre of the U.S. Army Corps of Engineers (32) does not concur with this attitude.

Their opinion is that in system design, with an adequately detailed simulation model, essentially good engineering judgement may be used in lieu of optimisation models to determine preliminary location, type and sizing of components in reservoir system configurations. This approach may be extended validly to the area of system operation where the experience gained by individual managers over many years gives them significant insight into the likely effects of changes to the system. Thus, sound human experience combined with effective simulation modelling may prove to be as efficient as an optimisation study. The work by Toebes and Rukvichai (33) is one of the few studies which acknowledge the important process of model adjustment by using the experience and insights of the real-system operators.

Unlike optimisation, in which a reasonably standard form of problem specification is required by each analytical technique, irrespective of the actual configuration of the system, the "free form" nature of simulation allows each model formulation to be problem specific, if so desired, from its conceptualization to its implementation. As a result, many examples of simulation models to be found in the literature are totally independent in methodology. By the same logic, this freedom of modelling allows a general program to be created which can, for the single programming effort, be used to simulate a wide variety of different systems by the inclusion or exclusion of various subroutines.

An example of such a program, is given by Ford (34) for design and operation augmentation.
Ashkanasy (35) uses recursive programming which allows full generality, since the model itself chooses the most rational order of element analysis, depending on the month to month changes in conditions.

The Hydrologic Engineering Centre has been active in the area of simulation for many years. Beard (36) describes the application of the HEC-3 reservoir simulation model, from the Hydrologic Engineering Centre, to a system of eighteen reservoirs and fifteen additional control points. HEC-3 (37) is a traditional simulation program for any configuration of reservoir system. Reservoirs are operated by maintaining the user specified balance of storage in each for every time interval. The time interval is specified by the user, and the system is solved in a sequential downstream operation. McMahon et al. (38) use a second and similar simulation model HEC-5C, from the same institution, to simulate the multi-purpose operation of a reservoir system for recreation, environment, hydro-power, water supply objectives as well as the economic impacts of a pumped storage.

A second large scale general simulation program, developed at the Massachusetts Institute of Technology, is reported by Lenton et al. (39). The model can be used to obtain estimates of physical and economic performance of river basin developments for an arbitrary system. It is predominantly a planning tool and uses the Monte Carlo method to evaluate indices of physical and economic performance. A time interval of one month is used. As in the HEC programs, water is allocated to users in an upstream to downstream order with constraints on minimum flows to ensure that downstream users are given due consideration.

CHAPTER 4

4. LITERATURE REVIEW - MAN AND COMPUTER SYMBIOSIS

This chapter concentrates on the man-machine aspects of interaction. An examination is made of the literature which reviews the current potential of computer graphics and the need for consideration of efficient communication between operator and computer, with finally some examples of operating systems which have some similarity to the current research.

As has been shown in the previous chapter, a wide variety of computer techniques exist for the analysis of all types of reservoir systems. In planning and design many procedures do not require direct human intervention since the decisions to be made can be determined faster and more efficiently by utilising mathematical analysis alone. However in the area involving continual human judgement, that is system operation, models positively benefit by the inclusion of human interaction. To ensure this benefit is not at all diminished through vague or confusing communication between man and machine, the formulation and results of the analysis must be arranged to suit the input/output demands of the human.

4.1 Interactive Graphic Simulation

While simulation per se may prove to have intrinsic advantages over optimisation in some applications, a particularly important aspect of the interactive graphic method is the ease with which a human operator may be included in the control loop. This enables the removal of much of the necessarily restrictive decision logic required by a stand-alone (closed loop) simulation model, since instead the operator is asked by the model to make decisions to further the course of simulation, based on continuously updated visual data indicating the system conditions. Although seven years separate their research papers, both Frankhauser and Kidwell (40) in 1971, and Hurrion and Secker (41) in 1978, stress the advantages of this approach. Not only are the results from a system so modelled more realistic, due to the human decision making involvement, but also the operator gains greater insight and understanding of the real system and its processes, rather than simply receiving the end results. The graphics interface is seen as an indispensable highly flexible interface between operator and computer model.

4.2 Human Factors in Interactive Graphics

To establish the significance of the human psyche on the design and implementation of an interactive graphics program requires an excursion into some aspects of psychology. An oft quoted article by George Miller (42) indicates the severe limitations placed on the amount of information the mind can receive, process and remember using the short span of absolute judgement and immediate memory. The logic behind this initial psychological approach is that once the limits and characteristics of the mind's processes are known (albeit not necessarily understood) the man-machine interface can be designed so as to avoid reaching these limits, and also be accommodating to human ideosyncrasies.

David (43) concentrates on human perception and information transmission factors and shows, through references to many experiments, some further limits to the adaptability of the mind. Many of the points discussed are acknowledged as being qualitatively clear, but quantitatively ill-defined.

Rather than writing in general physiological and psychological terms, Robert Miller (44) concentrates on response time ramifications for interactive systems. It is shown that a standard short response time (low variability) suggested by some researches is neither mandatory nor even desirable for all computer interactions. Illustrations of this philosophy include the highly variable time dependency of spoken conversation, and the different acceptable waiting periods for answers after completing tasks of different complexity - known as psychological closure.

Seventeen separate categories are supplied as a guide to possible response time variations.

Hanson (45) on the other hand is concerned with the whole arena of interaction. A set of "User Engineering Principles" is outlined for the design of interactive systems.

The first principle and central theme is "Know the User". From this knowledge all interactions can be tailored to the user's requirements, helped by further principles of "Minimise Memorisation". "Optimise Operations", and "Engineer for Errors".

James Martin (46) considers interactive graphic systems in the context of man-computer dialogue. The important limitations of the human are discussed in the context of design for beneficial man-computer interactions. Principles of good interface design are suggested to avoid most pitfalls.

Folley and Wallace (47) wrote a definitive paper on man-machine interaction in 1974, and its quality is acknowledged even now, since most current researchers refer to it. The approach used was hinted at but not developed by researchers before that time in attempting to define problem areas in interface design. The theme is simplicity itself; language is the basis for inter-human communication and so, logically, the same principles and conventions which govern spoken language can be the models on which human-computer interaction may be built. The aim of this philosophy is that such interaction should be so natural to the user that he becomes unaware of it, his mind thus being freed for efficient problem solving. The psychological principles which are discussed build on this foundation and also refer to the response time variations of Robert Miller, and Hanson's principles.

Spence (48) acknowledges this philosophy in his article outlining considerations and techniques in interactive graphics. As an example of the application of many of the design principles discussed so far, Simanis (49) combines most of the accepted techniques for effective communication in an interactive graphics package for data display and analysis.

Using experience and extensive experiments on human characteristics, the previous references have established those factors which each author considers important for effective communication with the computer user. The somewhat simpler method of asking the operators just what they require can be equally as successful.

Herda et al. (50) using a large sample of interactive system users, have used this method to obtain a set of seven independent characteristics of interactive systems which the users desire. This pragmatic approach to the definition of system characteristics is accepted as a valid procedure since it is almost the only method by which all the user-identified requirements can be evaluated. Schneiderman (51) defends the approach, explaining that while experiments are no guarantee of quality, at least they are better than informed guesswork. The experimental method can be further justified by considering the difficulty in directly quantifying the beneficial effects of many largely unmeasurable elements in the system design.

Newman and Sproull (52) supply a comprehensive systems approach to interactive graphics, and discuss the design of the user interface. Advice and examples are given on the subjects of the user's model, control language, feedback and information display.

4.3 Applications to Reservoir Management

The scarcity of published material dealing with applications of interactive graphics to reservoir systems begs the question, "why is this so?".

System managers may have neither the time nor the inclination to become involved in the direct strategy formation process. They may rather prefer to leave the formulation of feasible policies to the analysts, and exercise their decision making powers only after a series of alternatives have been chosen (see Haith and Loucks (53)).

Interactive graphic simulation is, however, particularly useful where the role of the system manager is of paramount importance for the successful operation of the reservoir system, since the model then not only simulates the system configuration but also the control mechanism involved. Along similar lines, this simulation method is useful for operator experiencing so that the potential hazards of management can be understood and the necessary skills developed. Absolute freedom for experimentation with different control strategies is a third application.

This avoids the sometimes awkward problem of attempting to define fixed operating rules based on complex management processes which have a multitude of objectives and dependencies, and also allows the flexibility of operator redefinition of system trade-offs to carry the simulation through crisis periods.

With these factors in mind, French et al. (54) describe a highly flexible water resources planning system involving colour graphics in which one of the four major applications is as a multi-reservoir simulation for water supply.

User control of this simulation includes fully interactive graphical input of data and output of results. Reservoir release rules, storage limits, and reservoir balancing curves must be supplied, and the actual simulation operation takes place as a closed loop. Hence it does not take advantage of the inclusion of the operator to be directly involved as part of the operation. The model is shown to somewhat circumvent this problem by having the facility to rapidly change operating policies and resimulate the problem. The system uses the necessary compromise between a fully interactive simulation and a generalized program capable of accepting any reservoir configuration.

Shafer (55) also considers the inclusion of the system manager as fundamental to any model's real-world significance for solving water management problems. His work has involved the synthesis of a new river basin model from the large number of such models already in existence. It is designed to enable the analysis of water availabilities throughout a river basin resulting from alternative water management policies over long term planning horizons. He stresses that it is necessary for such models to be used by the system managers themselves rather than computer programmers. To this end, data input is accomplished via an interactive conversational input file which allows a user with only rudimentary computing knowledge to operate the model.

In the real-world rather than the simulated time frame Abraham (56) dicusses a suite of computer programs for the day to day regulation and management of the Columbia River basin.

The computer system performs trial simulations for a given time frame with the capability for operator intervention through interactive graphics. This facilitates the evaluation of daily control decisions. A fast response time and interactive graphics are key features required for this complex, multi-purpose, multi-reservoir system.

CHAPTER 5

5.1 The Adelaide Metropolitan Water Supply System

In South Australia the capital city, Adelaide, and its general metropolitan area have a water supply system of moderate complexity involving the conjunctive use of pumped supplies and natural runoff stored in surface reservoirs. This system is operated to maintain an adequate supply for domestic, public and industrial use. It services nominally the Adelaide Statistical Division, with a population of approximately 1 million, although the eastern boundary includes some additional small townships. This Adelaide region is in fact only a subset of a much larger state-wide supply system based on the River Murray as the supply source, but the metropolitan system may be analysed as an isolated system with the rest of the region contributing only boundary conditions to the analysis.

The system under investigation includes ten reservoirs, four weirs and three pumping stations on the River Murray, the single main objective being water supply. The climate is described as mediterranean, however temporally and spatially erratic rainfall has made South Australia the driest state of Australia.

The majority of the reservoirs rely on natural inflow, supplemented to varying degrees by pumped water from the River Murray for maintenance of operating storage (figure 5.1, from ref. 1).

The amount of water pumped from the River Murray is directly related to the natural inflow to the reservoirs and their condition (i.e. volume held) at any particular time. For example prolonged dry weather resulting in increased demands without storage replenishment from rainfall results in the reservoirs being drawn down, thus requiring pumping from the River Murray to re-establish satisfactory storage volumes.

Pumped water is expensive, and annual pumping budgets of several million dollars are not uncommon. As a result, while some pumping to the metropolitan area is usually required, any extra pumping requirements are carefully controlled and minimised when this is possible.

5.2 Physical Extent of the Model

The metropolitan Adelaide headworks system is analytically cumbersome if all the storages are considered only as elements of a single large system. This difficulty can be overcome by decomposing the entire system using two levels of complexity. The metropolitan system can be divided into two zones, a northern and southern zone (fig. 5.2). Within each zone the reservoirs, pump

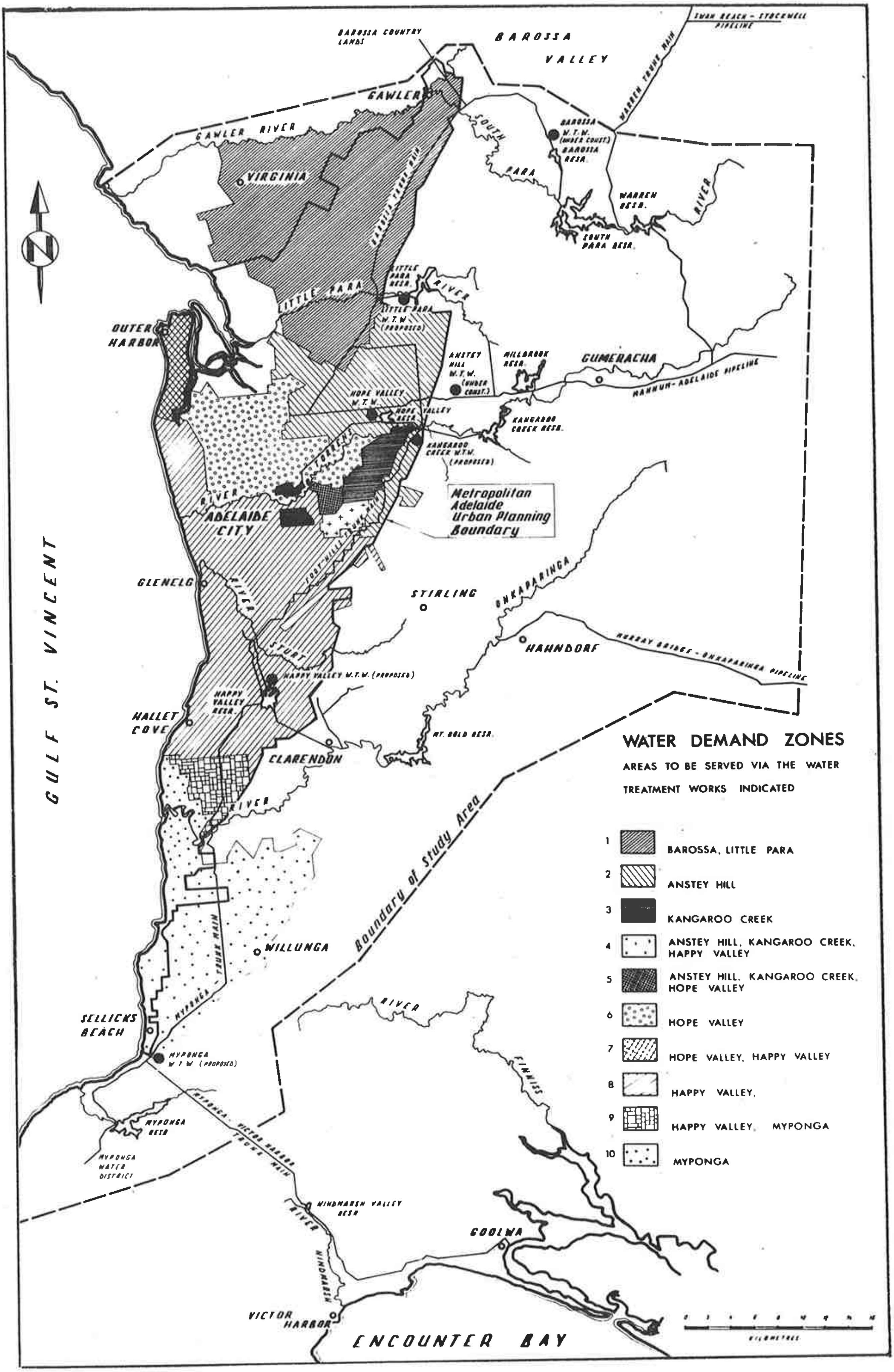

BAROSSA COUNTRY LANDS
BAROSSA VALLEY
SWAN REACH - STOCKWELL PIPELINE
WARREN TRUNK MAIN
GAWLER
GAWLER RIVER
SOUTH PARA
BAROSSA W.T.W. (UNDER CONST.)
BAROSSA RESR.
WARREN RESR.
RIVER
SOUTH PARA RESR.
VIRGINIA
BAROSSA TRUNK MAIN
LITTLE PARA RESR.
LITTLE PARA RIVER
LITTLE PARA W.T.W. (PROPOSED)
OUTER HARBOR
ANSTEY HILL W.T.W. (UNDER CONST.)
MILLBROOK RESR.
GUMERACHA
MANNUM-ADELAIDE PIPELINE
HOPE VALLEY W.T.W.
HOPE VALLEY RESR.
KANGAROO CREEK RESR.
KANGAROO CREEK W.T.W. (PROPOSED)
TORRENS
RIVER
Metropolitan Adelaide Urban Planning Boundary
ADELAIDE CITY
FOOTHILLS TRUNK MAIN
GLENELG
RIVER
STURT
STIRLING
ONKAPARINGA
HAHNDORF
MURRAY BRIDGE - ONKAPARINGA PIPELINE
HAPPY VALLEY W.T.W. (PROPOSED)
HAPPY VALLEY RESR.
HALLET COVE
MT. BOLD RESR.
CLARENDON
RIVER
GULF ST. VINCENT
Boundary of Study Area
WILLUNGA
MYPONGA TRUNK MAIN
SELLICKS BEACH
MYPONGA W.T.W. (PROPOSED)
MYPONGA RESR.
MYPONGA WATER DISTRICT
MYPONGA - VICTOR HARBOR TRUNK MAIN
RIVER
FINNISS
HINDMARSH VALLEY RESR.
RIVER
HINDMARSH
GOOLWA
VICTOR HARBOR
ENCOUNTER BAY
KILOMETRES
WATER DEMAND ZONES
AREAS TO BE SERVED VIA THE WATER TREATMENT WORKS INDICATED
1 BAROSSA, LITTLE PARA
2 ANSTEY HILL
3 KANGAROO CREEK
4 ANSTEY HILL, KANGAROO CREEK, HAPPY VALLEY
5 ANSTEY HILL, KANGAROO CREEK, HOPE VALLEY
6 HOPE VALLEY
7 HOPE VALLEY, HAPPY VALLEY
8 HAPPY VALLEY.
9 HAPPY VALLEY, MYPONGA
10 MYPONGA

FIGURE 5.1

DIVISION OF SYSTEM ELEMENTS INTO SUBSYSTEMS USED IN THE MODEL

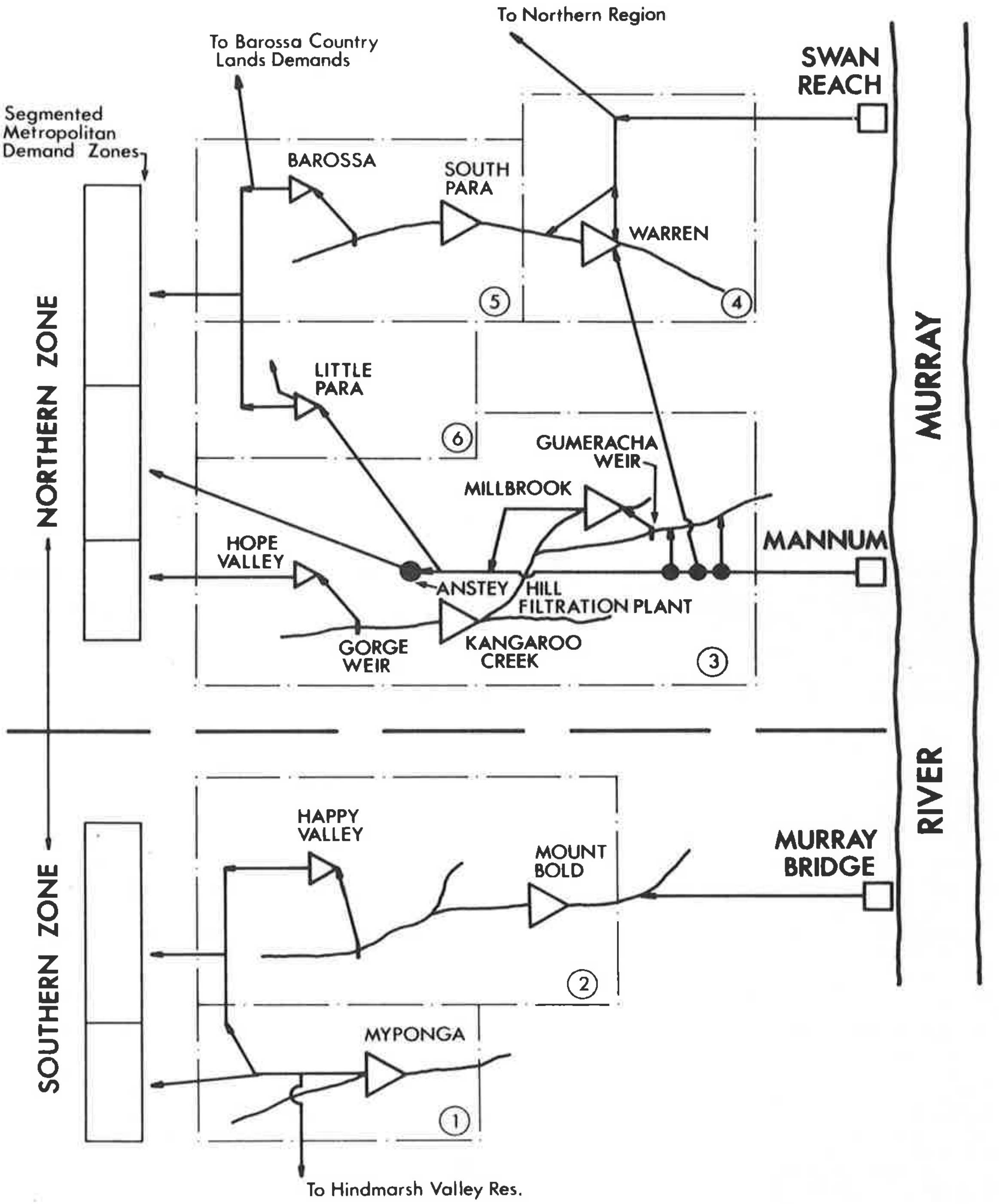


FIGURE 5.2

stations and demand areas are closely interconnected, however between the zones there is only a loose interconnection which has been ignored in the model without loss of realism. This distinct division of system operation has the added advantage that either zone may be simulated individually without fear of artifically presuming the outcome of the other. This method is often used in practice when one zone only is in a critical period of low storage and needs to be examined particularly carefully.

The second level of decomposition allows each zone to be divided into subsets or subsystems, each of which is centred on a major water-course used for water supply. The concept of a subsystem is quite common in water resources modelling, being simply a means whereby a large and/or complex system may be simplified for analysis by isolating its more or less independent components (subsystems), and examining each of these individually as discussed in Chapter 3, section 3.4.2. In this model, each subsystem contains storages, demand areas and natural inflows, while several may also be supplied from pump stations, or obtain transfers from storages in other subsystems.

The model includes the following elements in the analysis of the headworks system:

1. Ten reservoirs
2. Two weirs

3. Three pump stations

The configuration of these elements within the subsystem format is given in table 5.1 and shown in figure 5.2. Since the function of the system has been solely water supply for most of its operational lifetime, and this remains the highest priority, other proposed management avenues such as flood mitigation and recreation have not been considered. As a result this is a single objective system.

Myponga reservoir is the only storage which relies solely on its catchment inflow for replenishment. The Anstey Hill water treatment plant illustrates the opposite extreme at which supply in most years is derived directly from Mannum pump station.

A detailed study has been carried out already on the metropolitan Adelaide water supply system (1978) by the South Australian Government (ref. 1) with regard to system augmentation over the next 30 years. The report associated with that study is recommended reading since its description of the supply system provides background information on the starting point of the current model. Input data for the current model, in the form of natural inflows and demands, have been taken directly from the previous investigation. Reference will be made where appropriate to that study. The only modification to the system which concerns the current research since the publication of that study report is the commissioning of the Anstey Hill Water Treatment Plant, which has taken over the demand zones formerly supplied by Kangaroo Creek Reservoir.

A description of each of the subsystems included in the model is given in the following section.

SUBSYSTEM	RESERVOIRS	WEIRS	PUMP STATIONS
Myponga	Myponga	-	-
Onkaparinga	Mount Bold Happy Valley	Clarendon	Murray Bridge
Torrens	Millbrook Kangaroo Creek Hope Valley	Gumeracha Gorge	Mannum
Warren + Northern	Warren	-	Swan Reach
South Para	South Para Barossa	Barossa	Swan Reach
Little Para	Little Para	-	Mannum

<u>Table 5.1</u>

Elements in each subsystem of the Metropolitan Adelaide Water Supply System.

5.3 Subsystem Discussion

To define explicitly which elements of the system are included in the model, and which are omitted, each subsystem is discussed individually and its operation outlined.

5.3.1 Myponga Subsystem

The Myponga subsystem, containing only Myponga reservoir, forms the southern boundary of the model. Its only inflow is derived from catchment runoff, while demands consist of transfers to the Myponga Water District, southern metropolitan districts, and Hindmarsh Valley reservoir (not modelled). The Myponga trunk main, after passing through the previous demand zones, finally connects with Happy Valley reservoir in the Onkaparinga subsystem (fig. 5.3).

Since Myponga reservoir is at a higher elevation than Happy Valley reservoir, water may flow via the trunk main into the demand zones usually supplied by the Onkaparinga subsystem. This operation provides cheap water to the consumer. No pumping costs are incurred as they would be if the water originated from the Onkaparinga subsystem, since that subsystem can be augmented with pumped water from the River Murray.

Along the Myponga trunk main are several valve

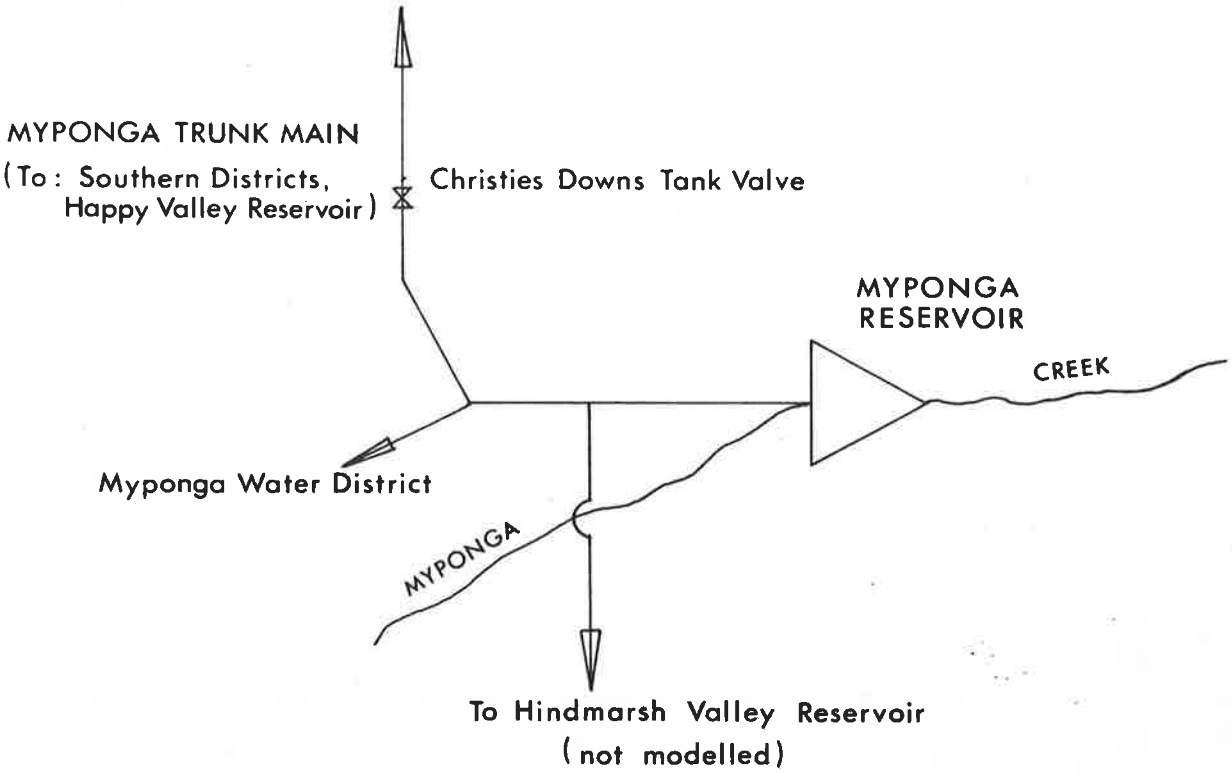


FIGURE : 5.3 MYPONGA SUBSYSTEM

stations at which the pipeline may be closed thus defining the fraction of the demand zones served by each subsystem. It was established that the valve on the main at the Christies Downs tanks is of greatest significance in the majority of cases. This valve has been included on the model to govern the demand sharing between the two subsystems.

If the valve is closed, Myponga reservoir supplies Myponga Water District, Hindmarsh Valley offtake, and the Southern Vales demand zone. In this case the remaining demands of the Onkaparinga subsystem are satisfied from the Onkaparinga subsystem. If the valve is open, the model prompts for the size of the transfer into the Onkaparinga subsystem from Myponga. The requested volume is used to reduce the demands on the Onkaparinga subsystem. If the transfer is greater than the demand to be satisfied, any excess is supplied to Happy Valley reservoir itself.

The magnitude of the transfer is limited by the available capacity of the Myponga trunk main after its direct demand from Myponga Water district is satisfied. Pipeline capacity is factored down between October and March to allow for excessive within-month peak demands (see Chapter 6, Section 6.10). Any transfer requested which is beyond the seasonal capacity is reduced by the model to the available limit.

The mechanism for indicating a transfer can only be used when the Myponga subsystem is being considered by the model, as the amount of water available for transfer is highly dependent on the operator perceived safety of the storage level in Myponga reservoir.

5.3.2 Onkaparinga Subsystem

Of the two reservoirs in the Onkaparinga subsystem, Happy Valley and Mount Bold, only Mount Bold can obtain direct natural inflow from the River Onkaparinga catchment. Local augmentation of this main supply source is available through catchment inflow at Clarendon weir, downstream of Mount Bold, and also via the Murray Bridge-Onkaparinga pipeline from the River Murray (fig. 5.4). Clarendon weir is not considered to maintain any significant monthly storage but its small catchment inflow can be used to replenish Happy Valley reservoir via a transfer main. Months may occur however during which natural inflow accumulates at the weir at a rate greater than the flow capacity of the transfer main, and some fraction spills over the weir to waste. An estimate of the "transfer function" for the transfer main is included in the model.

The third form of augmentation is the transfer of supplies from the Myponga subsystem which was discussed in the previous section.

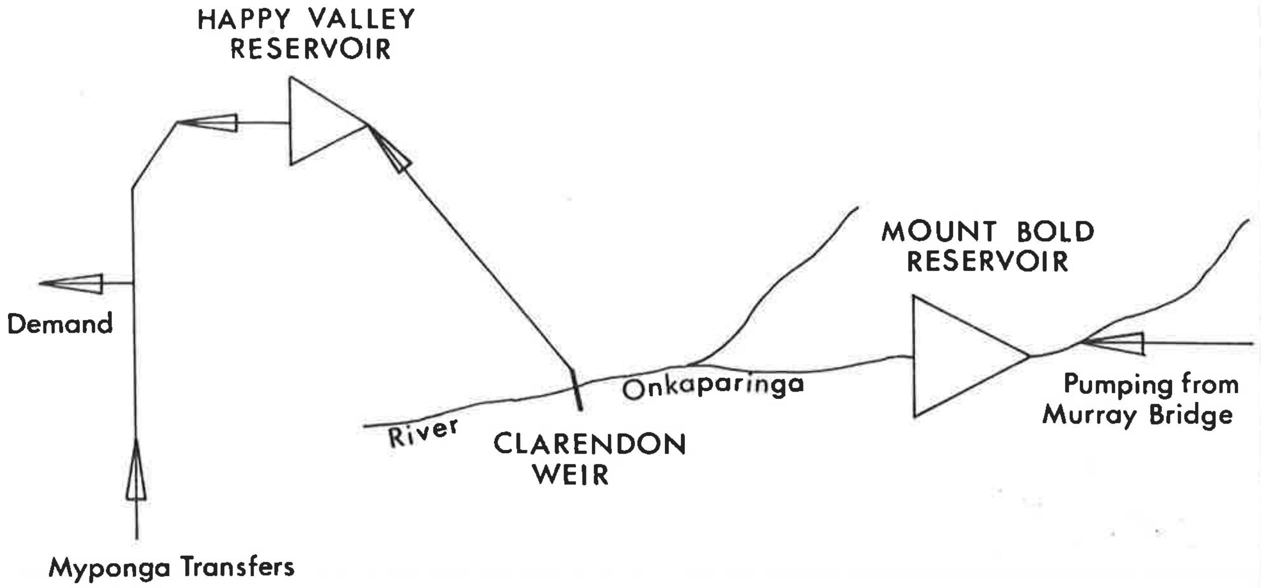


FIGURE: 5.4 ONKAPARINGA SUBSYSTEM

The volume of pumped water available to Mount Bold reservoir from the Murray Bridge-Onkaparinga pipeline is less than the total pumped at Murray Bridge due to the sundry offtakes to townships along the pipeline. These demands are not large but remove a significant portion of available pipeline supplies during summer months. Hence, even when there is no pumping to the Onkaparinga subsystem, Murray Bridge pump station supplies some flow to satisfy these demands.

5.3.3 Torrens Subsystem

With two weirs, three reservoirs and direct interaction with the Mannum-Adelaide pipeline to supply Anstey Hill Water Treatment Plant, the Torrens subsystem is the most complex subsystem to be included in the model (fig. 5.5).

Of the two weirs in the subsystem only Gumeracha is modelled, due to the lack of available data for Gorge weir. Gorge weir which receives Deep Creek natural runoff has a catchment area similar in size to that of Clarendon weir in the Onkaparinga subsystem. Inflows from Deep Creek are included in the model and supplied without modification (no transfer function) to Hope Valley reservoir. Although this causes an overstatement of the demand capable of being satisfied by Hope Valley reservoir, the Water Resources Study (Ref. 1 section 4.3.2) considers this distortion to be

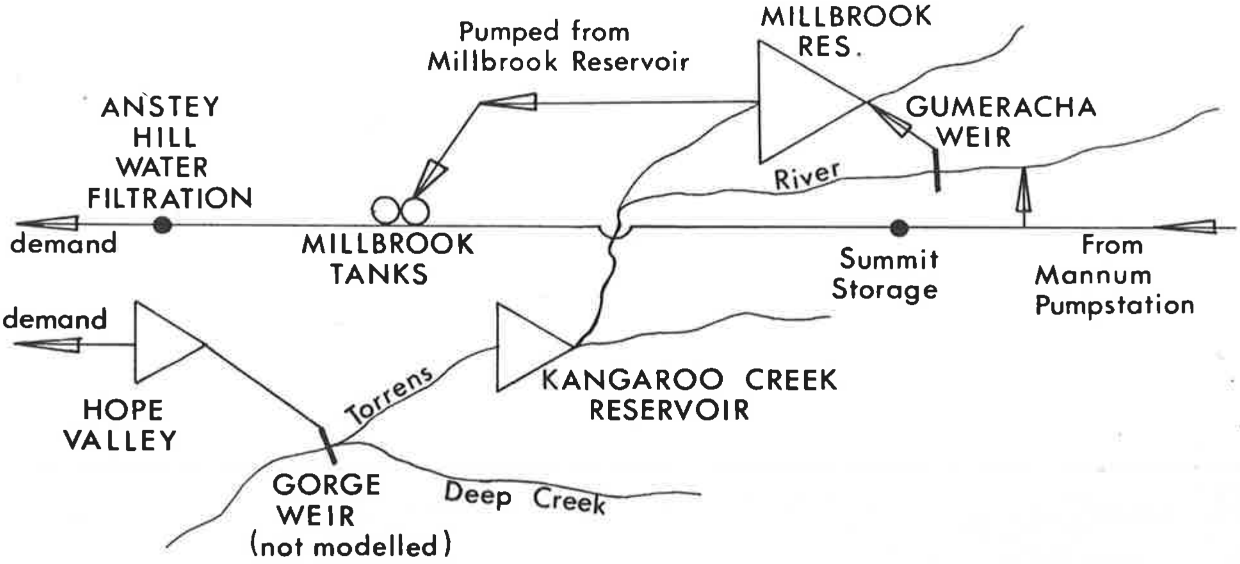


FIGURE : 5.5 TORRENS SUBSYSTEM

insignificant for the subsystem as a whole and the same philosophy has been adopted in the current research.

Gumeracha weir, like Clarendon in the Onkaparinga subsystem, has an empirical estimated transfer function associated with it. This transfer function governs the division of the weir's catchment inflow between Millbrook and Kangaroo Creek reservoirs. A fraction of inflow is transferred to Millbrook reservoir as required to maintain the operator specified storage and the remainder is released to Kangaroo Creek reservoir directly downstream of the weir. Pumping input to the subsystem also passes through Gumeracha weir and is shared between Millbrook and Kangaroo Creek reservoir. Pumped transfers are assumed to be sufficiently controlled so that they are not affected by the weir's transfer function.

The second factor of importance in the operation of the subsystem is its interaction with the Mannum-Adelaide pipeline, a direct supply line to consumers. Pumped water from the Mannum pump station travels directly to the Anstey Hill Water Treatment Plant, but in addition Millbrook reservoir can pump its storage to the plant also. Hence this reservoir has a dual role as a storage. Not only is it a supply storage for the Torrens subsystem, but it also behaves as a backup supply for the Mannum-Adelaide pipeline in the event of insufficient or failure of pumping at Mannum pump station. In a more frequently used role it can provide a cheaper source of water when it has large inflows and high storage levels, since pumping to Anstey Hill from Millbrook pump station is much cheaper ($8 per Megalitre) than pumping from Mannum (at least $24 per Megalitre).

An additional operation to which this storage may be applied is as a balancing storage for the Mannum-Adelaide pipeline. The section of pipeline between the summit storage and Millbrook tanks functions under gravity feed and so is of smaller capacity than the pumped rising main (fig. 5.6). This limitation can be overcome by releasing water into Millbrook reservoir from the rising main and pumping an equivalent amount into the pipeline from Millbrook reservoir at the Millbrook tanks, thus effectively bypassing the limited capacity section of the main. The disadvantage of this technique is its cost. Since the flow back into the pipeline at Millbrook tanks is pumped twice - once at Mannum and again at Millbrook pumping station - the final cost will be greater than the price associated with water pumped directly to consumption from Mannum pump station.

The three operating modes of Millbrook reservoir are included in the model. The operator must specify the desired storage in Millbrook reservoir, because of its dual role, and the decision whether

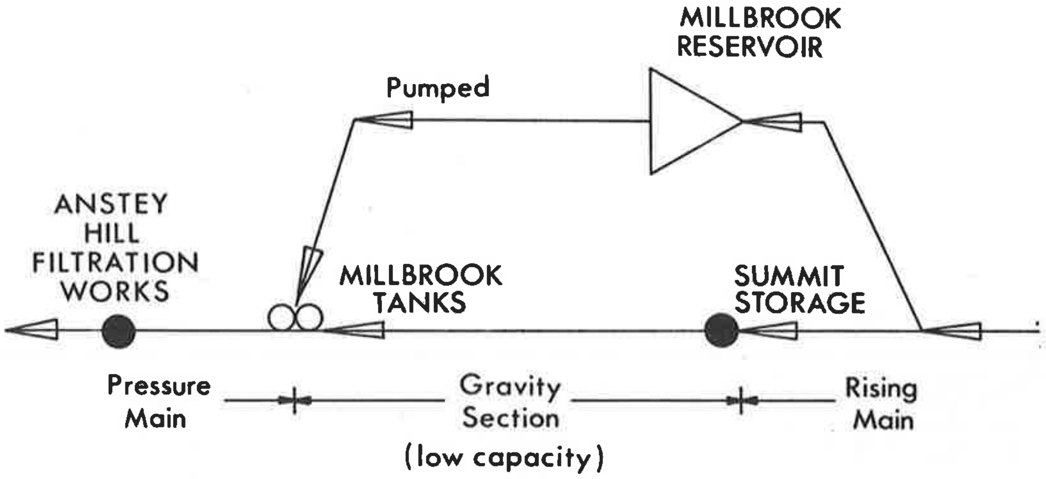


FIGURE 5.6 PIPELINE CAPACITY AUGMENTATION BY MILLBROOK RESERVOIR

to supply directly to pipeline demand from Millbrook reservoir must also be resolved.

Transfers of water through Millbrook in its third mode of operation are decided by the model due to the lack of demand information supplied to the operator. If the limited capacity main is overtaxed due to a large transfer to Little Para reservoir, the operator is prompted for a reduction in the transfer. If no modification is made, the model organises the extra diversion through Millbrook reservoir to make up the full demand quota. However, if the direct demand on the Mannum-Adelaide pipeline exceeds the limiting capacity, the model arranges the extra supply with no reference to the operator.

5.3.4 Warren Subsystem

This subsystem forms part of the northern boundary to the computer model and supplies to the northern region of the state as well as the Warren Water District (fig. 5.7).

Warren reservoir is the only storage in the subsystem. Augmentation of natural inflow can be obtained by a transfer from the Mannum-Adelaide pipeline at a constant rate (425 Megalitres per month). Pumping at Swan Reach reduces demand on Warren's storage by satisfying some northern region demand and in low demand periods may supply flow into Warren reservoir.

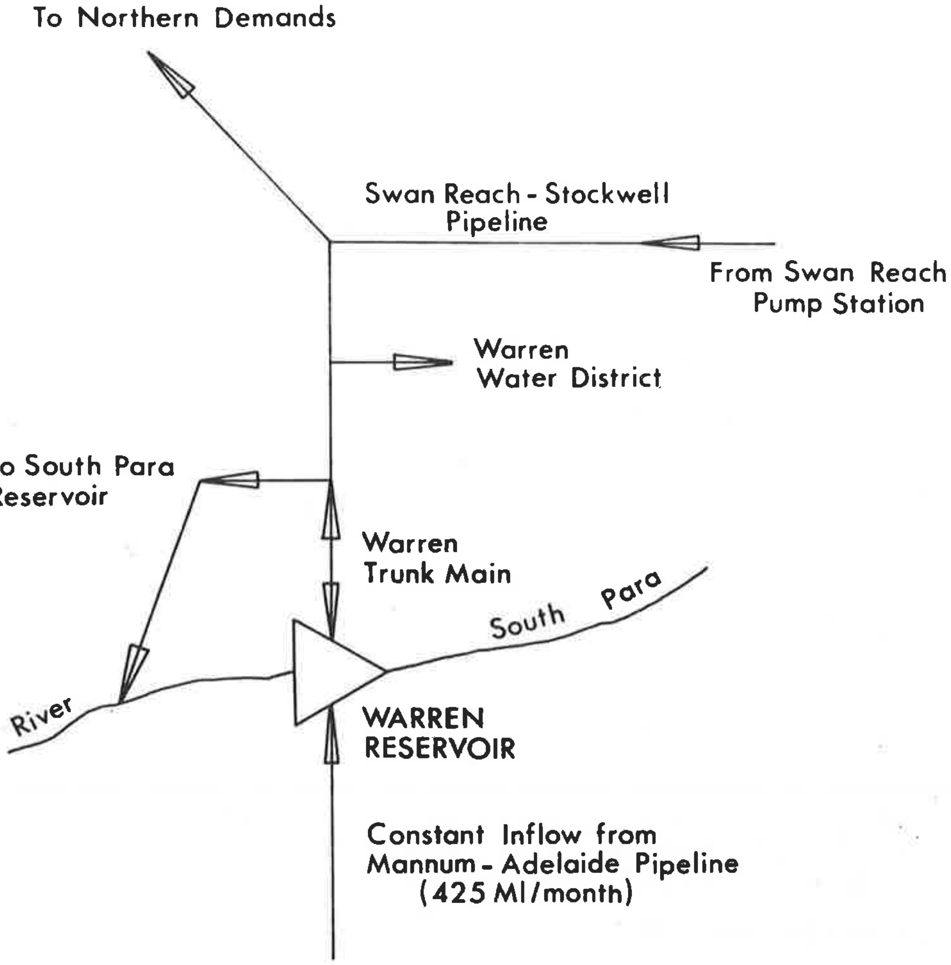


FIGURE : 5.7 WARREN SUBSYSTEM

Any spill from Warren reservoir is taken by South Para reservoir, and the Warren subsystem can supply operator specified transfers to the South Para subsystem. This quantity can be supplied by Warren reservoir alone or by a combination of Warren transfer and Swan Reach pumping after pipeline demands have been satisfied.

5.3.5 South Para Subsystem

This subsystem completes the northern boundary of the computer model. Its demands consist of the Barossa Country Lands region and the northern metropolitan area (fig. 5.8).

While both Barossa and South Para reservoirs are included in the model, the diversion weir downstream of South Para reservoir, Barossa weir, is not modelled due to its insignificant catchment. It is assumed that transfers to Barossa reservoir are so controlled as to never exceed the capacity of the transfer main.

As discussed under the Warren subsystem, South Para and Warren subsystems are interconnected due to the configuration of the Warren trunk main and Swan Reach - Stockwell pipeline. It is from Warren reservoir's storage and Swan Reach pumping that augmentation of South Para's natural inflow is obtained.

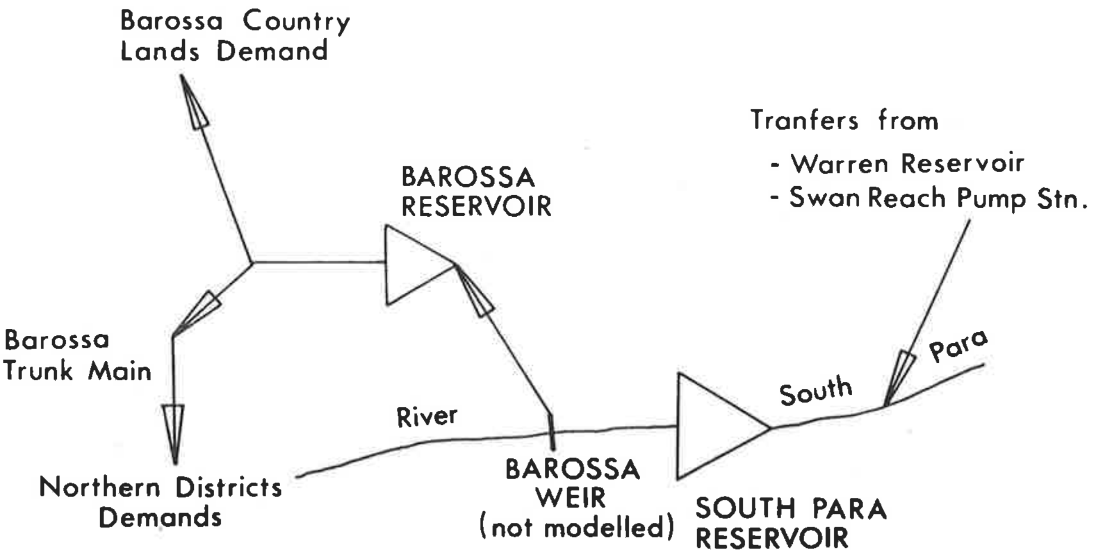


FIGURE 5.8 SOUTH PARA SUBSYSTEM

5.3.6 Little Para Subsystem

Little Para subsystem is a recent addition to the metropolitan headworks system - commissioned only in 1978 - and the operation of its single storage, Little Para reservoir, as a contributing element is yet to be defined precisely (fig. 5.9).

Transfers to augment its small catchment inflow can be obtained from the Mannum-Adelaide pipeline, subject to the existing supply conditions on the pipeline, as discussed under the Torrens subsystem. Its small catchment combined with the requirement of a significant volume of groundwater recharge cause Little Para to be primarily a balancing storage for the pumped supplies from the pipeline, supplying into the Barossa trunk main for northern metropolitan demand.

Barossa reservoir in the South Para subsystem also supplies water into the Barossa trunk main distribution pipeline. Hence the problem exists of what fraction of the demand in this region is supplied by each subsystem. The philosophy used in the model concerning the division of demand between the reservoirs results from the consideration of the economic cost of water within each subsystem. The South Para subsystem can make more efficient use of natural inflow than Little Para due to its large storage and catchment area, and so the water it supplies is cheaper, because less pumping is required to augment inflow.

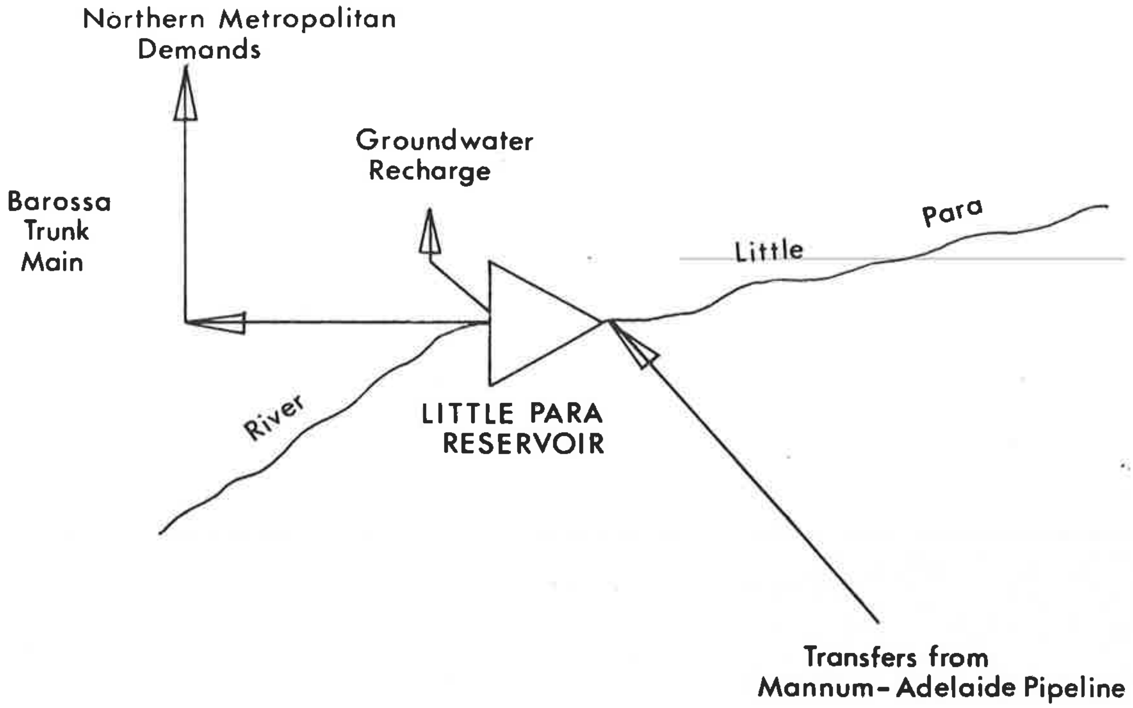


FIGURE: 5.9 LITTLE PARA SUBSYSTEM

Hence the supply for the consumption in the shared demand zones is first taken from the South Para subsystem up to the limit of the Barossa trunk main capacity. Thereafter Little Para supplies any remaining deficit.

A second reason for this decision rule is the previously mentioned lack of an operating strategy for Little Para.

It should be noted, however, that this decision rule is consistent with the present method of using Little Para's storage. To date, Little Para reservoir has been used only during months when high demands predominate; nominally from November to March. It is during such periods that the Barossa trunk main is potentially utilised to its full capacity, requiring some augmentation from other sources than the South Para subsystem.

5.4 Service Reservoirs

The Onkaparinga, Torrens and South Para subsystems include storages in a specific configuration as shown in table 5.2.

In each case a reservoir with a large storage capacity and large catchment is upstream of a small storage, negligible catchment reservoir supplying directly to demand. The small reservoir is known as a "service reservoir". It is kept in a near full

SUBSYSTEM	DOWNSTREAM RESERVOIR	UPSTREAM RESERVOIR
ONKAPARINGA	Happy Valley 12 700 Megalitre	Mount Bold 47 300 Megalitre
TORRENS	Hope Valley 3 470 Megalitre	Kangaroo Creek 24 400 Megalitre
SOUTH PARA	Barossa 4 510 Megalitre	South para 51 300 Megalitre

Table 5.2 Service Reservoir Configuration

condition throughout the year for either or both of two reasons:

1. The operating head in the water treatment works at the outlet to the service reservoir is dependent on a high level in the reservoir.

2. The supply pressure in the demand area is directly dependent on the level in the service reservoir to maintain the required head for consumption.

Operationally, with no inflow of its own, a service reservoir is fed from the upstream storage to keep the desired level. Thus a service reservoir is primarily a balancing storage for the demand zone.

The prescribed storage levels are maintained quite strictly, and any variation in storage is not significant over a monthly time interval.

In the model the storage levels of the three service reservoirs are rigidly set at the predefined amounts. They cannot be modified by the operator.

5.5 Pumped Supply

The three pump stations which supply water to the subsystem reservoirs and directly into demand zones may be operated in a number of different time-dependent modes. This choice of available pump operations in real life is naturally directly related to the cost of operation which is set by the Electricity Trust of South Australia (E.T.S.A.) through its time-dependent power tariffs. Different tariff rates apply to the electricity used depending on the time of day and the associated electrical demand in the metropolitan E.T.S.A. grid.

There are nominally three separate cost rates. The "off-peak" rate, which is the cheapest, occurs overnight. Next in order of increasing cost is the "on-peak" rate which applies during the majority of daylight hours. Finally the greatest cost is associated with the "special on-peak" tariff which operates during the morning and evening peak electrical load demand periods. The tariffs are also dependent on the type of day, that is, a week day

(Monday to Friday) or a weekend day (Saturday or Sunday) since the on-peak rate does not operate over weekends (table 5.3).

The amount and mode of pumping from each pump station is usually revised on a daily or weekly basis to ensure that pumping rates are well matched to system requirements and excesses are avoided. Such a short revision interval cannot be duplicated on the computer model due to the use of a monthly time interval between cycles (Chaper 6, Section 6.3). To allow some latitude concerning within-month pumping, the model does allow weekly increments of operation to be specified. The alternative time interval for operation of pumps, rather than from one week to the whole month, is "intermittent" usage. This corresponds to a rate of pumping which keeps pace only with direct pipeline offtakes and no transfers are supplied to the reservoirs.

The direct pipeline offtakes are the small townships along each pipeline which rely on the pumped supply for their existence. It is due to their need that neither Murray Bridge nor Mannum pumping is ever completely shut off and their demands in the summer months can reduce available pipeline capacity significantly. The Mannum supply to the Anstey Hill Water Treatment Plant (fig. 5.5) is an extreme example of a pipeline offtake. In past summers with heavy demands, the Mannum pump station supply rate has managed to match the Anstey Hill demand, but left

RATE	TIMES		TOTAL HOURS	
	WEEK DAY	WEEK END DAY	WEEK DAY	WEEK END DAY
Off Peak	2315 - 0730	0100 - 2300	8¼	22
On Peak	0930 - 2315	-	13¾	-
Special On Peak	0730 - 0930	2300 - 0100	2	2
			24	24

TABLE 5.3 Typical time dependencies of E.T.S.A. electricity tarrif rates.

no spare capacity for transfers to reservoirs in the Torrens subsystem.

While some of the previous factors can be considered as general in nature and apply to all the pump stations, each installation is different.

Murray Bridge and Swan Reach pumping stations each house three pump sets and the Mannum station four pumps, however the Swan Reach station operates only in off-peak and on-peak modes due to a different form of electricity tariff rating defined by E.T.S.A., based on changing costs as the volume pumped increases (table 5.4). The Swan Reach pumping station has the smallest capacity of the three and this combined with the rating system previously mentioned makes it the most costly to operate (table 5.5). This is also the reason why the intermittent pumping for Swan Reach in the model is zero, since usually the attempt is made to regularly supply most of the pipeline offtakes from the Warren subsystem rather than Swan Reach.

Mannum and Swan Reach pump stations have the additional capability of supplying to more than one subsystem (table 5.6). Mannum may supply not only the Torrens subsystem but also Little Para subsystem and a fixed offtake (425 Megalitres/month) to the Warren subsystems. Swan Reach may supply to both Warren and South Para subsystem. Such flexibility has required the inclusion of selective "PUMP" and

PERIOD	QUANTITY	TARIFF
off peak	first 1 000 000 kWh per month all additional consumption	2.96 ¢/kWh 2.09 ¢/kWh
on peak	all consumption	3.55 ¢/kWh

(a) Typical tariffs for electricity usage

PERIOD	TIMES		TOTAL HOURS	
	WEEK DAY	WEEK END DAY	WEEK DAY	WEEK END DAY
off peak	2 015 - 0730	0 730 - 0730	11¼	24
on peak	0 730 - 2 015	-	12¾	-

(b) Times for off peak and on peak tarrifs.

TABLES 5.4 Swan Reach pumping data

PUMPSTATION	MAXIMUM WEEKLY CAPACITY (Megaliltres)	COST (cents/kilolitre)
Murray Bridge	3 486	3.13
Mannum	2 611	3.48
Swan Reach	490	4.64

TABLE 5.5 Comparison of maximum pumping rates and their associated costs. (24 hours pumping, all pumps)

PUMPSTATION	RECEIVING SUBSYSTEM
Mannum	Torrens Little Para Warren
Swan Reach	Warren South Para

TABLE 5.6 PUMPSTATIONS WITH MORE THAN ONE SUPPLY DEPENDENCY

"NO PUMP" options in the program so that the subsystem to receive the pumped transfer may be specified by the operator.

CHAPTER 6

6. MODEL DESCRIPTION - GENERAL

This chapter introduces the detailed consideration of the model and its various facets. It is the first of five chapters dealing with different aspects of the whole model. It outlines general considerations for model control, calculation, data, economics, and explains some fundamental aspects of the whole model.

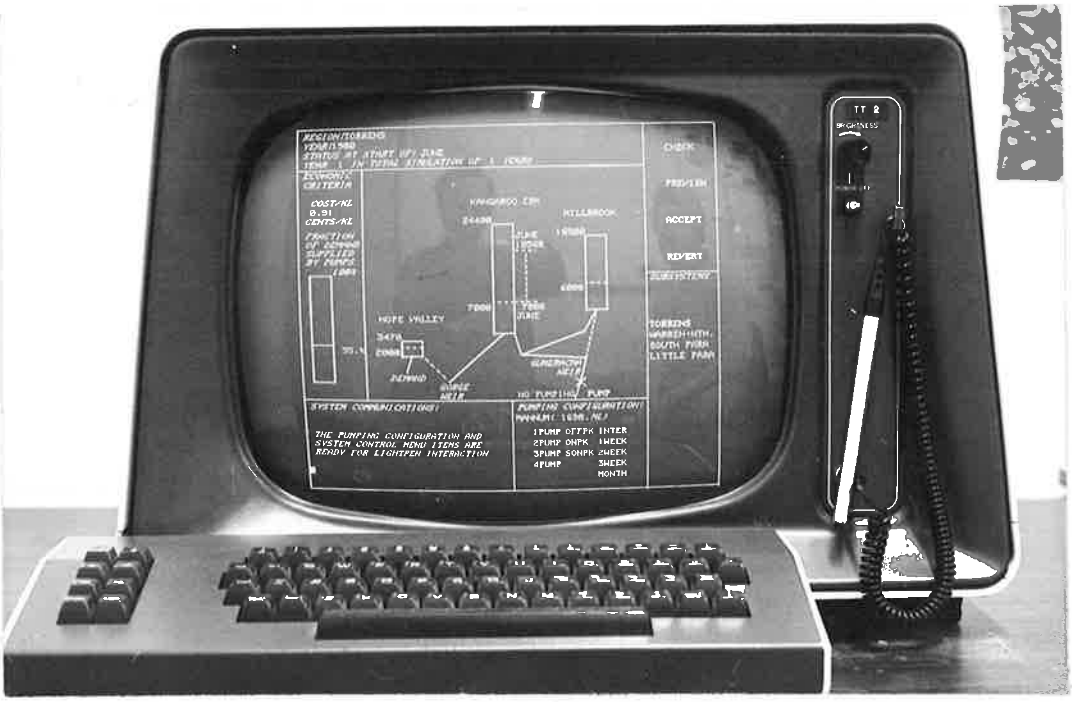
6.1 Model Perspective

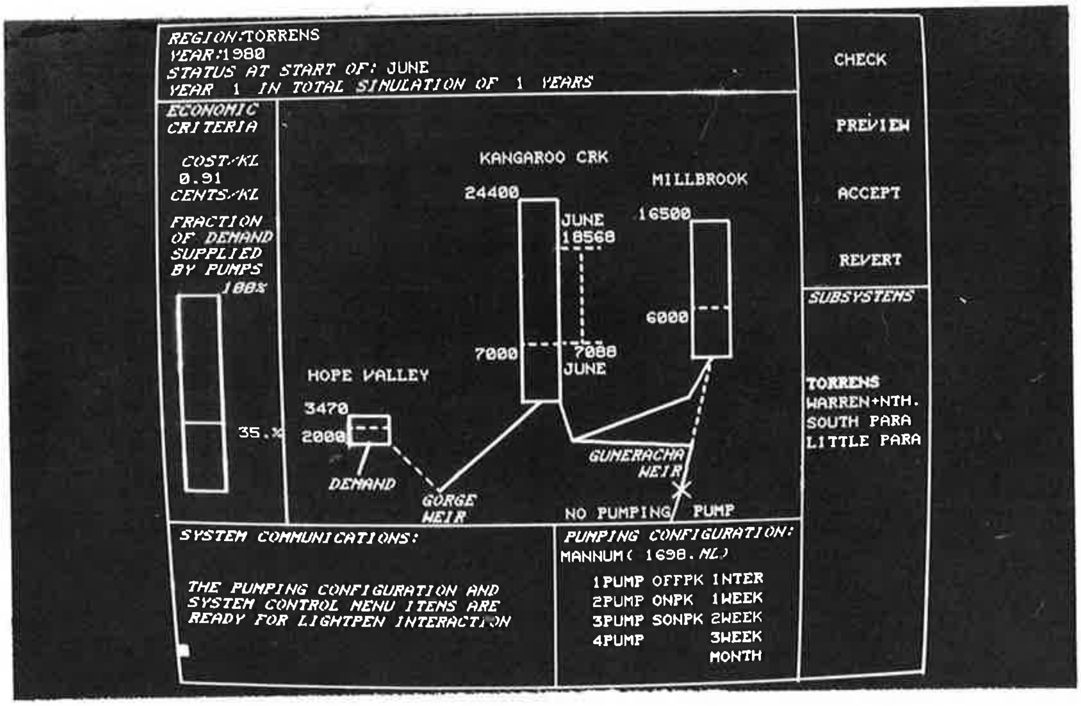
The simulation model consists of a total of twenty subroutines of varying length. It proved to be necessary to overlay the subroutines to avoid excessive memory requirements and thereby conveniently fit into the 32 K memory available for use. A detailed description of the computing aspects of the model will be found in Chapter 9.

The purpose of the computer model is not to investigate the water supply in detail, but rather to be a instrument which can be used to follow the decision processes of an operator through several years of simulated system operation. As a result of this particular emphasis there are certain aspects included in the model which might not normally be considered for the examination of a water supply system alone. Such characteristics include a totally interactive facility, full graphical output on a DEC-graphics terminal, and the calculation and storage of performance criteria based on the operators' decisions at each step of the simulation.

As the basic foundation of the program, a simulation model of the Adelaide metropolitan headworks system was designed and implemented. Detailed modelling is included only to that level which is of significance over a one month time interval. It is important to ensure that the operator has a similar degree of control over the simulation model as is available in the actual system operating in real time, and that the controls simulate those which are familiar. This was accomplished by structuring the model interactively and using computer graphics with lightpen and keyboard facilities. These considerations are designed to help the operator use the model without changing any usual habits of operation. In addition, the availability of computer graphics enables a suitable graphical substitute to be made for the data normally received by the operator in the real life situation. As a result the operators' personal "operations feel" associated with system management can be brought into play to help in choosing reasonable strategies for the more efficient and realistic operation of the system model.

A photograph of the visual display unit showing the Torrens Subsystem diagram as used in the research is given as figure 6.1.





REGION:TORRENS
YEAR:1980
STATUS AT START OF: JUNE
YEAR 1 IN TOTAL SIMULATION OF 1 YEARS

ECONOMIC CRITERIA

COST/KL
0.91
CENTS/KL

FRACTION OF DEMAND SUPPLIED BY PUMPS
100%
35.%

SYSTEM COMMUNICATIONS:

THE PUMPING CONFIGURATION AND SYSTEM CONTROL MENU ITEMS ARE READY FOR LIGHTPEN INTERACTION

PUMPING CONFIGURATION:
MANNUM(1698. ML)
1PUMP OFFPK INTER
2PUMP ONPK 1WEEK
3PUMP SONPK 2WEEK
4PUMP 3WEEK
MONTH

Figure 6.1 Visual display unit used for the research with the lightpen at the right of the screen. The Torrens Subsystem is being displayed.

An option of particular importance supplied to the operator by the model is the ability to investigate any strategy for a given month without being committed to that mode of operation. This is designed to enhance decision-making by enabling a suitable choice to be made from a series of quick preliminary "experiments" with different strategies.

In order to gauge the efficiency and effectiveness of program operation, various performance indices are calculated during the simulation, based on the progressive effects of the operational policy. These also provide an indicator of the philosophy of the operator on system usage.

6.2 Computing Requirements

The computer on which the program has been developed and finally used is a Digital Equipment Corporation PDP 11/34 with 126K of core memory, RSX.11M operating executive (version 3.2) and an RK05 disc storage facility.

The computer graphics is controlled by a second PDP 11/34 linked to the main computer, but dedicated to the graphics terminal, a type VT-11. This computer configuration is known as a "Host-Satellite" system. The main program resides in the main PDP 11/34 processor (host computer) and when required sends data messages via a moderate speed serial data link to the second processor (satellite computer) which is waiting to receive the information.

A second much smaller program task is executing in the satellite and processes the information supplied by the host, changing elements on the screen and storing data from the screen accordingly.

For this particular interactive application, the program used in the satellite computer is written specifically to reduce the response time for graphic attention handling, since the waiting period is unacceptably slow when lightpen interactions are processed in the host computer.

The simulation program is written in Fortran IV Plus and the graphics images are built using the Digital Corporation high level graphics language DEC-Graphic 11. (ref. 2).

The characteristics of the computer prevent a task accessing more than 32K of memory and so the program has been built as an overlaid task. This has been accomplished through the use of modular subroutines.

6.3 Choice of time interval

The amount of detail included in a simulation model of a water supply system is highly dependent on the time interval used for the increment of simulation. A time step of one month was chosen for the following reasons:

1. The operators of the real system use a monthly interval in determining and updating the system strategy. It was desired to use the time interval with which they are familiar.

2. A fully interactive program requires the operator to make decisions at the end of each time interval. Shorter time intervals would have protracted the amount of time required to complete any simulation period. This may have produced fatigue, boredom and/or frustration in the operator. It turns out that a one month time step allows one year's simulation to be modelled in about 50 minutes of concentrated effort.

3. Data on a monthly summary basis is readily available as a result of the previous system investigation (ref. 1). Data for shorter time intervals is not only more difficult to obtain in usable form but also less reliable.

4. The interest of the research lies primarily in the examination of the operation of the major storages over several years of simulated demand and inflow. Using time intervals of less than one month, such minor effects as changes in pipeline storage, changing levels in balancing tanks and general "noise" within the system become significant in the modelling process, and

a more highly detailed, and hence slower and more expensive simulation is the result. Over a monthly interval most if not all these operating fluctuations balance themselves out and the model can be simplified correspondingly, with an attendant increase in speed of execution and economy.

6.4 The Annual Cycle

To facilitate the consideration of realistic economic activity on the basis of the financial year, which is the time base around which the real system operation is moulded, the model progresses in monthly increments from July to June of successive years. Of course the interactive capability of the model allows simulations to start at any month chosen, however it should be noted that the simulation will stop in June of the final year, not in December. This is convenient since mid-year corresponds to the winter season, so that the model is not terminating in summer, when high demands and low inflows make system operation more taxing on the operator and hence more interesting analytically.

6.5 Time required for Simulation

The time required to complete one annual cycle of simulation is highly dependent on the ability or willingness of the operator to make decisions rapidly as opposed to slow deliberation. The potential speed of decision making supplied by the model can prove to be a shock to the operator, albeit only initially. It may require some readjustment in thinking patterns since operating decisions in "real life" system control can normally be made over an extended period of time - several days or a week.

On the present installation a period of 50 minutes per year of simulation is common. Implementation on a faster computer could reduce this time through smaller response times for commands. However, due to the availability of hard copy output at the end of each simulation session, an extended period of time may be simulated over several sessions, the output from the previous session providing the starting data for the next.

6.6 Operator Interaction

To avoid a lengthy familiarisation phase, an interactive model requires the minimum of commands to be learned by the operator. Each programmed command must be clear and unambiguous. A further, sometimes contradictory requirement is that these controls should be sufficiently powerful to perform the desired operations with little or no additional user input.

The accent in the model's interaction with the user rests with the use of a lightpen, since few operators are likely to be adept at the rapid use of a computer terminal keyboard. The lightpen is a pen-like device which, when pointed at sensitised areas of the display screen, will interrupt the program execution to enable user-written control subroutines to manipulate the display. These sensitised items (words or symbols), known as lightbuttons, function as on-off switches in the program.

Such simple switching, while avoiding complex interaction, poses some problems in fulfilling the requirements mentioned before. Fortunately the level of control to operate the model can be reduced to a limited set of simple on-off commands.

The facility to test run trial monthly operations of the system and see the results is the key feature which governed the design of the list of lightbuttons. Without the ability to experiment rapidly with a variety of alternative management strategies, the operator is in no position to decide on a best solution to his current system control problem. Hence the necessity for two modes of model function is immediately obvious, one for experimentation and another for tagging the final choice of operation. This need gave rise to both the "PREVIEW" and "ACCEPT" lightbuttons.

"PREVIEW" allows the operator to see the result of his proposed strategy on the current operation of the system at the end of the present month, given average data for calculation. "ACCEPT" informs the model that the operating strategy as shown on the display screen is the mode to be implemented for the present month interval.

Two further controls were considered necessary for the effective use of the model. The "CHECK" lightbutton allows the user to check the condition of other inter-connected subsystems before committing himself to a decision. The "REVERT" lightbutton returns the state of the subsystem on the display screen to that occurring at the start of the month, so that the incremental change in subsystem storage may be seen. This has been included, since after a series of experiments it is easy to lose track of the subsystem's starting conditions.

The remaining lightbuttons on the screen, used to choose the subsystem, set up pumping configurations, or set the flows between subsystems are simply "picks". That is, their on-off states do not control the simulation but rather fix the model operation in one of a number of alternatives.

6.7 Data influence on Calculation

As discussed in the previous section, the facility of an experimentation mode (PREVIEW), to test potential strategies, requires a separate set of data files of an average nature, to indicate the likely outcome of the operations, without revealing the secrets of the "real" stochastic data used in "ACCEPT" mode.

Average inflow data is available only on a total subsystem basis, in that it is given as a single total inflow to the subsystem with no indication of its spatial distribution. On the other hand, stochastic data for inflow is available as generated values for each individual storage.

Of the stochastic data sets available it was decided to use one with average characteristics. This investigation is aimed at exploring the operators' ability under normal conditions, and an average data file still supplies ample variability for the study.

The difference in the level of detail between the average and stochastic data sets results in different degrees of accuracy when each set is used for calculations. The individual treatment of storages in the stochastic data allows a check to be made on the new storage volume of a reservoir to ensure that it does not obtain more water than its inflow and transfers supply to it. Such a check cannot be made when using the average data.

This problem is currently only relevant to the Torrens subsystem which has three storages, but is not appreciable under the normal range of operating conditions. In "PREVIEW" mode, Millbrook reservoir may be programmed to obtain a higher storage, and hence Kangaroo Creek receives a lower storage, than may actually occur. This is not considered to be a serious problem since both reservoirs are dependent for some inflow on the same catchment area above Gumeracha Weir (fig. 5.4), and so their storage changes are interdependent. The discrepancy is rectified immediately when stochastic data is used.

6.8 Hydraulic Accuracy

Due to the choice of a monthly time step, the instantaneous dynamic hydraulic equations for flow and head-loss could not be used in the model. For these equations to be relevant, modelling intervals of minutes or hours would be required in the peak periods. In view of this limitation, monthly capacities for pipelines, transfers and offtakes are used to limit the system flows.

To allow for peak demand periods within a month, when demands could, for a short while, be greater than the supply capacity, the nominal monthly capacity of certain pipelines within the system are reduced during the summer months (October to April). These pipelines are the Myponga trunk main, Barossa trunk main and the Anstey Hill section of the Mannum-Adelaide pipeline. This procedure is in accordance with the water resources study (section 6.3.5, ref. 1).

Hydraulically calculated spill was also considered as a possible option to be included in the model, but several factors discouraged this:

1. Inflows, as monthly totals, give no indication of their time of occurrence within the month or the rate of inflow relative to demand. Thus the best approximation of spill is simply an aggregate total spill for each month.

2. Spill rates on some of the reservoirs can be controlled over a wide range of flows using radial gates on the spillways. Therefore there is no constant rate of spill.

3. Data on all the spillways in the system are not readily available.

As a result, the spill is calculated simply as that storage which exceeds the maximum storage of the reservoir after demands and transfers are satisfied.

When subsystems (Warren and South Para), or storages within a subsystem (Millbrook, Gumeracha, Kangaroo Creek) are in series along a single watercourse, spill from an upstream storage can be used by the next storage downstream. However, spill from storages with a weir and/or service reservoir downstream is considered as waste, since the operating rule for the service reservoir has already ensured that it contains sufficient water, so the weir allows the spill to be lost out of the subsystem. Hence the concept of "subsystem spill" rather than reservoir spill is used. This is calculated as the excess water in a subsystem which cannot be used by any downstream storage within the subsystem.

At the opposite extreme, deficits are assumed to occur when one reservoir in a subsystem runs dry. Service reservoirs cannot be drawn down to prevent deficits occurring since their operating rules are at present considered fixed. The simulation continues in spite of an empty reservior and the deficit and its duration are noted until inflows and/or transfers are supplied to bring the empty storage back into effective operation once more.

At present there is no means to include consumer restrictions as an alternative to recording a deficit. This is a highly subjective matter and needs a separate investigation of its own before being realistically included and considered as a quantifiable economic factor.

6.9 Inclusion of Economic Criteria

Including some form of economic assessment of system operation in the program is mandatory not only as a measure of the efficiency of operation, but also as a guide for the operator as to how effectively the chosen strategy is performing. This is a real life constraint of particular importance in defining the best path through the "grey area" of water management between the extremes of spill and deficit in any subsystem.

While the inclusion of a comprehensive economic analysis is certainly not beyond the available computing capability, discussions with personel familiar with the real system operation indicated that such an analysis would be of no advantage.

The costs associated with amortisation of capital investment, and the cost of operation and maintenance continue independent of high or low demand conditions. The result of this is that the segment of the total water budget which causes any appreciable variation in cost is the highly variable cost of pumping water from the River Murray.

Data for the variable unit cost of pumping water at each pump station are provided, so that the monthly pumping strategy for all pump stations can be costed, and the overall cost per kilolitre supplied for the month, displayed to the operator.

Without the inclusion of economic assessment, the subsystems can be operated without a great deal of difficulty, since in most subsystems pumping may be used at any time, regardless of cost to avoid supply problems. However, an economical strategy and efficient operation can only be formulated with some economic feedback from the model to the operator. The display of a calculated unit cost of supply provides that feedback.

6.10 Model Assumptions

As implied in chapter 2 there is rarely a combination of real life system and modelling technique for which at least a few simplifications need not be made. The Adelaide metropolitan reservoir system is moderately complex in its form and interaction, and an adequate model of its functions can be constructed only with appropriate assumptions and simplifications.

The reasons for using a one-month time increment in the model have already been outlined in this chapter, and several assumptions are required as a direct result of that decision. Included in this section are the assumptions which may not become apparent in the discussion of the program, but are fundamental to its design and methodology.

1. All system elements which vary over a time interval smaller than one month are considered insignificant.

2. Unaccounted losses within a subsystem are assumed to be insignificant on a monthly interval.

   e.g. seepage loss from storages

losses in transfers along water courses
leakage in pipelines

3. Transient lag times of flow between reservoirs, in pipelines or down stream beds are not significant in the monthly time step.

4. Certain nominal monthly pipeline supply capacities are factored down to allow for the real life situation of within-month peak demands exceeding pipeline capacity during the months October to March. The pipelines are the Myponga trunk main, the Barossa trunk main and the final section of the Mannum-Adelaide pipeline to Anstey Hill water treatment plant. The factor used is 0.68 (Ref. 1: section 6.3.5).

5. The storage assigned to each reservoir is the maximum usable volume of the particular reservoir. No restrictions on minimum storage levels are made.

6. Individual reservoir spill is calculated as the excess storage above maximum storage of the reservoir remaining after all demand on the storage has been satisfied. Total subsystem spill is based on the excess water within the subsystem not taken by any downstream storage in the subsystem.

7. A deficit in supply is recorded when a reservoir

in a subsystem empties before all subsystem demand is satisfied.

8. Evaporation loss from a reservoir is based on standard storage vs evaporation curves for each month of the year.

9. The model uses the financial year, July to June, as the annual simulation cycle. A simulation period may start in any month, but will always finish at the end of June.

10. Two weirs, Clarendon and Gumeracha, are included in the model. They are allowed to contribute their catchment inflows to other storages in the particular subsystems, but are assumed to hold no significant storage of their own. They also have no evaporation losses.

CHAPTER 7

7. Model Operation and Control

In this chapter the various aspects of model calculation and operation are noted and discussed. It is not intended to provide a detailed description of all subroutine operations, since each subroutine is well endowed with comments to describe its successive operations and needs no further explanation. These subroutines are outlined in some detail in Chapter 9.

However, the general procedures used in the model which may not be clear from reading through subroutine listings are included, as are the system controls and indices.

7.1 The Host - Satellite Configuration

An important feature of the model is that its control is divided between two interconnected computers (see Section 6.2). While the main body of the model's control and logic resides in the host computer, the libraries of graphic functions for creating images on the display screen are resident in the satellite computer. Under normal conditions it is adequate for any program executing in the host simply to call up the appropriate picture elements from the satellite libraries to form screen images. However when feedback from the display screen to the host program is required, an additional feature of the overall computer system becomes significant.

The particular installation used for this model is a time-sharing system which means that several tasks can be serviced at the same time. That is, the main processor is not dedicated to the completion of one program at a time, but swaps jobs in and out of central memory at appropriate intervals, so that a number of different jobs may execute. This system is highly satisfactory for batch mode tasks in which the executive control system of the computer remains autonomous. However the problem arises with lightpen-interactive tasks that the main program may be swapped out of central memory while waiting for the operator to make the next lightpen move. From the operator's viewpoint this situation presents itself as an unacceptably long wait for acknowledgement of the lightpen command, until internally the main program is swapped back into memory to continue executing.

To avoid this situation a program may be written for the satellite processor to register and accept the lightpen commands. Being independent of the host processor executive, there is no danger of the satellite program being halted or delayed while other tasks take their allotted place. The result is a vastly superior response time for the operator and due to the instantaneous "handshake" between satellite and host, a more efficient use of host computer processor time.

7.2 System Balancing - Subsystem Considerations

At the end of each monthly cycle, where all subsystem operations have been set by the operator and indicated to the model through the ACCEPT lightbutton, the model must use the prescribed subsystem strategies in conjunction with stochastic inflow and demand data to calculate the actual system response for the starting point to the next month. Due to the interactive nature of the model, a minimum "off-line" time, while the calculations are performed, is required. This naturally implies an avoidance of iterative procedures in favour of direct sequential processes wherever possible. Thus while the operator may chose any subsystem for investigation with the lightpen, the order in which subsystems are considered when the whole system is being balanced independently of the operator becomes significant.

Three subsystems - Myponga, Torrens and Warren - are capable of supplying transfers to other subsystems. In addition, South Para and Little Para subsystems both supply to a common demand zone and so the supply fraction of one subsystem must be determined before the demand on the other can be calculated. It is advantageous to consider such subsystems first, to confirm that the conditions for the requested transfer are satisfied and to avoid modifying the receiving subsystem storages if incoming transfers cannot be supplied. Table 7.1 indicates the main subsystem interconnections and dependencies. These considerations result in a clear, sequential order of subsystem calculation to ensure that iterative calculation is avoided. Table 7.2 shows the order in which the subsystems are placed to effect this desired calculation management.

Avoidance of iteration in the model calculation allows the adoption of a straightforward control doctrine.

INTERCONNECTIONS -	
FROM:	TO:
Myponga	Onkaparinga
Torrens	(Little Para (Anstey Hill Water Treatment Plant
Warren	South Para
South Para) Little Para)	common demand zones

Table 7.1 Subsystem links and their supply directions included in the model.

SUBSYSTEM	CALCULATION ORDER
Myponga	1
Onkaparinga	2
Torrens	3
Warren	4
South Para	5
Little Para	6

Table 7.2 Calculation order for subsystems in the model.

Since the level of operator interaction does not involve massive upheavals in program control but rather an interruption of the cycle before permitting it to continue, this potential trouble spot in system control is easily included in the monthly cycle along the same lines as the other stand-alone elements.

7.3 System Indexing

It has been shown in the previous section that certain subsystems require consideration before others. From this realistion it is a natural progression to number the subsystems according to their position in the calculation queue so that cycling through system calculation is a simple matter.

Similarly, the storages require an index for their reference not only within each subsystem but also on a total system basis. Numbering is set up in a downstream order in each subsystem commencing with the first subsystem (Myponga).

Pumpstations are also numbered simply according to their relative subsystem position.

These indices are used throughout the model for all arrays which concern the system elements. A summary is given in Table 7.3.

7.4 Subsystem Calculation

Irrespective of the mode of model operation, or whether calculating for the current month or future predictions, the same calculation routine is used throughout, modified only by data requirements.

The division of the whole system into sets of storages using the subsystem principle (Chapter 5, Section 5.2) somewhat supercedes the significance of storages operating individually to supply demand, in favour of the subsystem as the basic unit of supply. Nevertheless calculation is required on both the subsystem level and individual storage level of detail. For example, demand is defined in terms of demand zones supplied by a subsystem, but inflow and evaporation (and some

SUBSYSTEM	SUBSYSTEM INDEX	SUBSYSTEM STORAGES	RESERVOIR INDEX
Myponga	1	Myponga	1
Onkaparinga	2	Mount Bold	2
		Clarendon	3
		Happy Valley	4
Torrens	3	Gumeracha	5
		Millbrook	6
		Kangaroo Creek	7
		Hope Valley	8
Warren	4	Warren	9
South Para	5	South Para	10
		Barossa	11
Little Para	6	Little Para	12

PUMP STATION	INDEX
Murray Bridge	1
Mannum	2
Swan Reach	3

Table 7.3 System elements and associated indices.

transfers) are considered in terms of individual reservoirs.

7.4.1 Basic Calculation Methodology

All storage calculations and adjustments are based on the general water balance equation:

$$S(t+1) = S(t) + I(t) + P(t) + Ti(t) - D(t) - To(t) - E(t)$$

where $S(t+1)$ = subsystem storage at the start of time interval $(t+1)$

$S(t)$ = subsystem storage at the start of time interval t

$I(t)$ = natural inflow during time interval t

$P(t)$ = net effective pumping into subsystem

= (total pumping)-(other transfers)-(pipeline offtakes)

$Ti(t)$ = transfers into subsystem in time t

$D(t)$ = demand during time interval t, from demand zones associated with the subsystem

$To(t)$ = transfers out of subsystem in time t

$E(t)$ = evaporation from storage during time interval t

Elements in this equation are now discussed in the order of calculation within the model.

1. Evaporation E(t):

   From the appropriate set of evaporation tables (see Chapter 10), the evaporation corresponding to the starting volume of the reservoir is interpolated linearly for the month. This value is not removed immediately, but added to the demand value.

   No evaporation is taken from weirs since they are assumed to hold no significant storage (Chapter 6, Section 6.10).

2. Inflow, I(t):

   Natural inflow is provided as either total subsystem data or stochastic values for individual storages (Chapter 6, Section 6.7). In "PREVIEW" mode total subsystem inflow is added to the total subsystem storage to obtain a final gross total, whereas "ACCEPT" mode adds individual inflows to storages before summation to a total subsystem storage figure.

   (a) A Note on Weirs:

   The two weirs in the model contribute to the natural infow of their respective subsystems only in "ACCEPT" mode when they are assigned inflow. Augmentation of subsystem storage occurs with the transfer of their inflow, as much as possible, to the connected reservoir.

The method used to establish the amount of transfer has been provided by the water resources study (Ref. 1, Section 4.3.2). It can be appreciated that while the transfer tunnels between weir and reservoir have a peak instantaneous flow capacity, if inflow to the weir catchment occurs at a rate greater than the tunnel capacity, there will be some spillage of water to waste. Thus a limit on the available monthly transfer with respect to monthly inflow is required.

This has been modelled by using empiracle transfer function curves based on historical flows at Gumeracha weir. Their form is quite simple and using straight line approximations the volume transferable is easily determined, with any remaining inflow not transferred being spilled downstream.

With reference to figure 7.1, the points A and B are stored in the model according to their co-ordinates. Given

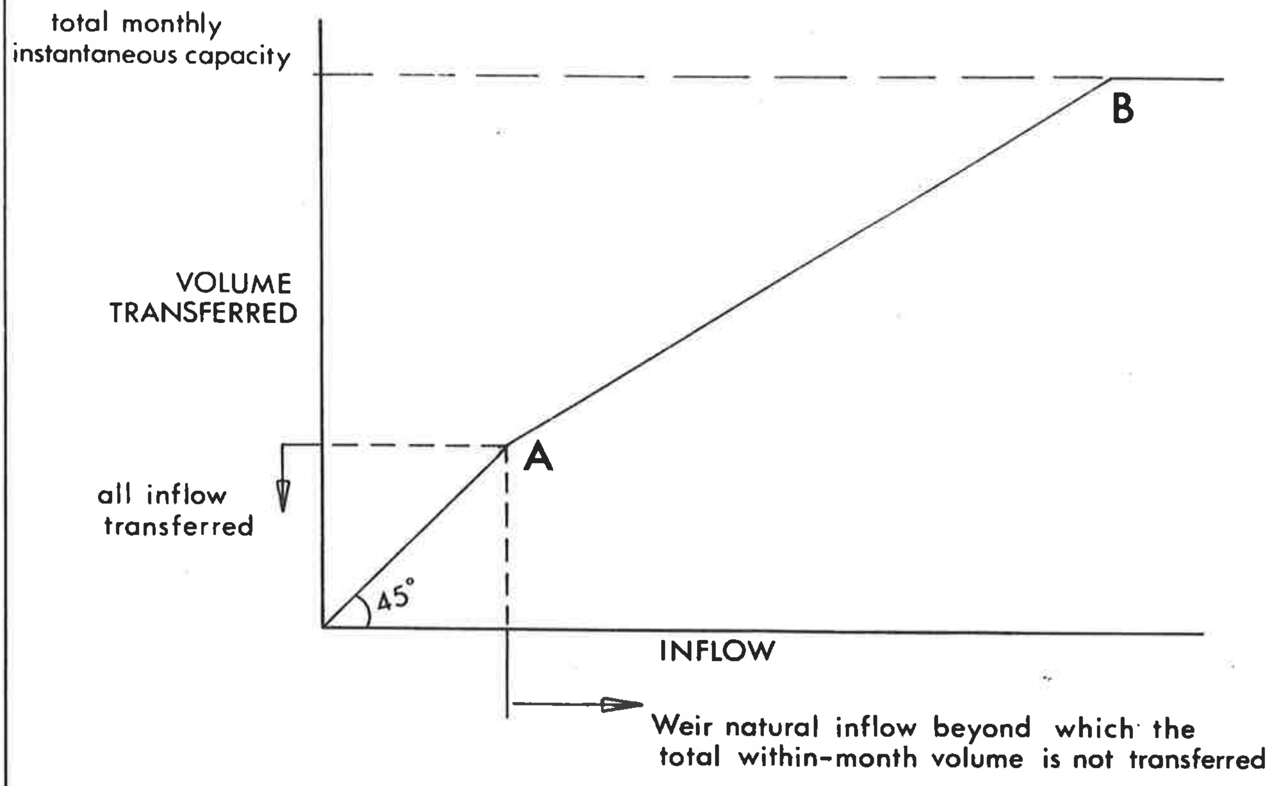


FIGURE 7.1 TYPICAL WEIR TRANSFER FUNCTION

the weir inflow, a straight line interpolation is made to determine the potential transfer volume.

Spill from Clarendon weir is added to the Onkaparinga subsystem spill, however spill from Gumeracha weir is taken by Kangaroo Creek reservoir, directly downstream, and so does not affect total subsystem spill.

3. Incoming transfers, Ti(t):

   Incoming transfers, namely Myponga supplying to the Onkaparinga subsystem, or Warren (spill) supplying to South Para, are added directly to the total subsystem storage. Checks for the correctness and size of the transfer are not required since they have already been made in the supplying subsystem.

4. Pumped transfers, P(t):

   When the operator makes a request for a pumped transfer to a subsystem, a series of calculations occurs.

   Firstly, using the pumping data for the associated pumpstation, the total quantity of pumping is calculated from the existing pumping configuration. Demands of sundry offtakes along the pipeline are then removed from the total pumped, as are any previously specified offtakes such as the Little Para transfer from Mannum pumping and South Para transfer from Swan Reach pumping. The remaining net pumping is available as the transfer into the subsystem. This is added to the summed subsystem storage.

5. Demands, D(t):

   The accumulated demands of the subsystem demand zones and subsystem evaporation are removed from the total subsystem storage as a single value irrespective of the result being positive or negative. Shared demand zones are facilitated by splitting up the monthly demands between subsystems at the time of data assignment, i.e. South Para and Little Para demands.

6. Transfers out of the subsystem, To(t):

   Transfers out of a subsystem are possible from the Myponga subsystem (Myponga to Onkaparinga), from the Torrens subsystem (Millbrook to Mannum-Adelaide pipeline) and from Warren subsystem to South Para. These operator-specified amounts are subject to two constraints.

   (i) there is sufficient volume in the subsystem to supply the transfer given the already set operating rules for some reservoirs.

(ii) there is sufficient capacity in the supplying pipeline to transfer the requested amount.

If either of these conditions are not met, a reduced or non-existent transfer occurs.

7.4.2 Subsystem Decomposition

After the total subsystem demand is removed from the subsystem, a net subsystem storage remains to be divided among several reservoirs.

The fixed storages of the service reservoirs are first removed, as also is Millbrook's specified storage (Torrens Subsystem), leaving a volume from which transfers and the remaining storage must be defined. At this stage, if the total storage value is negative, without augmentation from an upstream storage (Torrens Subsystem only), then a deficit equal to the negative storage is recorded, no transfers are supplied and the remaining subsystem storage is zero. If the total is positive, then requested transfers are supplied either until the storage runs out or they are fully discharged. If storage still remains positive after removal of transfers, then this final increment is assigned to the remaining reservoir in the subsystem.

In the event that more water is available than can be taken by the subsystem, then the excess is spilled from the subsystem and is defined as the subsystem spill.

7.4.3 Torrens Subsystem

The Torrens subsystem requires special explanation due to the operation of Millbrook reservoir as a supply route to the Anstey Hill Water Treatment Plant.

(i) Millbrook reservoir as a subsystem element.

While an increase in storage may be specified by the operator for Millbrook reservoir, it cannot obtain a greater storage increase then that supplied by the combination of its natural inflow and pumped transfers.

If a greater storage than possible is specified, the reservoir takes the value of its maximum available storage only. Conversely, if more inflow is available than is required to obtain the desired storage, any excess is immediately taken by Kangaroo Creek reservoir downstream.

(ii) Millbrook reservoir supplying to pipeline and plant.

The monthly subsystem inflow total used in "PREVIEW" mode is assumed to occur only above Millbrook reservoir and Gumeracha weir. This allows the option for the use of virtually all the subsystem inflow through Millbrook reservoir. This assumption is consistent with the operation of the real system for which an estimate of more than 80% of subsystem natural inflow occurs above Millbrook reservoir and Gumeracha weir.

(a) "PREVIEW" mode:

Since all inflow is assumed to be available to Millbrook reservoir, then the excess volume not used to ensure compliance with the operator specified storage is available to supply the pipeline: i.e.

EXSMIL = S(IMON,6)-S(NXTMON,6)

where S(IMON,6) = storage in Millbrook at start of month IMON

S(NXMON,6) = storage in Millbrook desired at start of month NXTMON = IMON + 1

EXSMIL = net excess storage in Millbrook after satisfying new storage level

then after inflow is added to the summed subsystem storages -

AVAIL = SUMSTR-ASTOR

where SUMSTR = total subsystem storage after inflow is added

ASTOR = total subsystem storage allowing for the change in Millbrook storage but without inflow

AVAIL = the available supply from Millbrook to Anstey Hill

(b) "ACCEPT" mode

The volume available depends on the inflow to Millbrook:

DEMMIL = S1-S2+STOINF+TRNSF1-EV

where DEMMIL = demand which can be supplied by Millbrook reservoir
S1 = initial storage for the month
S2 = new operator specified storage
STOINF = stochastic inflow to Millbrook
TRNSF1 = total of pumped transfer and transfer from Gumeracha weir to Millbrook
EV = evaporation from Millbrook reservoir

The demand on Anstey Hill is reduced only if the potential supply (AVAIL or DEMMIL) is positive. Thus if a sufficiently large new storage is requested for Millbrook, or little inflow is received, no supply may occur.

If the supply from Millbrook is greater than the demand of Anstey Hill a reduction is made in the supply to match the demand. This results in the excess supply being ultimately assigned to Kangaroo Creek reservoir instead of being held in Millbrook reservoir.

(iii) Millbrook reservoir used to bypass gravity section of pipeline.

Millbrook reservoir is used as a bypass of the gravity section of the Mannum-Adelaide pipeline if the Little Para transfer and Anstey Hill demand combine to exceed the gravity feed capacity.

If this is the case, the excess to be shunted through Millbrook is defined:

XSDEM = PIPOFT+TRAN-CAPSUM

where XSDEM = volume supplied from Millbrook
PIPOFT = Anstey Hill pipeline demand
TRAN = Little Para transfer
CAPSUM = capacity of the gravity section of the Mannum-Adelaide pipeline between summit storage and Millbrook tanks

This excess to be supplied through Millbrook is defined as a transfer into Millbrook reservoir and is added to the existing (if any) current transfers out from that storage.

7.5 Operation of Pumped Supply

There are two modes of operation of Mannum and Murray Bridge pumpstations due to their responsibility for several pipeline offtakes.

The first mode of operation is also used by Swan Reach pumpstation exclusively. When a pumped transfer is requested by the operator, the number of pumps to be used, and their control strategy must be set - for example: 2 pumps, offpeak for 3 weeks. The pumping for such an operation is calculated and supplied to the appropriate subsystem.

If no pumping is required from the pumpstation or intermittent pumping is specified, a second mode of operation is used. Due to the presence of pipeline offtakes along the Mannum to Adelaide and Murray Bridge to Onkaparinga pipelines, pumping must be maintained to supply their offtake demands. This requires the model to iteratively check the pumping data until a configuration is found that will satisfy the offtakes within the month time period. This desired setting is found by looping through the pump combinations, starting at the off peak rate, from one pump up to the pumpstation maximum and then incrementing the pumping rate by one hour and starting again until the demand is matched by the month's pumping. The strategy so determined is cheaper than looping the hourly pumping rates first before incrementing the number of pumps (Fig. 7.2).

① LOOP THROUGH PUMPS

② INCREMENT DURATION OF PUMPING

NO. OF PUMPS			1				2				3				4			
OUTPUT Litres/Sec.			1 290 ≡ 111 ML/D				2 410 ≡ 208 ML/D				3 450 ≡ 298 ML/D				4 320 ≡ 373 ML/D			
KWH/Kilolitre			1.63				1.69				1.74				1.83			
PUMPING HOURS			OUTPUT - ML			CENTS PER KILO LITRE	OUTPUT - ML			CENTS PER KILO LITRE	OUTPUT - ML			CENTS PER KILO LITRE	OUTPUT - ML			CENTS PER KILO LITRE
WEEK DAY	W.E. DAY	WEEK	WEEK DAY	W.E. DAY	WEEK		WEEK DAY	W.E.	WEEK		WEEK	W.E.	WEEK		WEEK	W.E.	WEEK	
8½	22	85½	38	100	390	2.49	72	183	726	2.59	102	256	1 022	2.66	128	313	1 266	2.80
9		89	42		410	2.54	78		756	2.63	112		1 072	2.71	140		1 326	2.85
10		94	46		430	2.59	87		801	2.68	124		1 132	2.76	156		1 406	2.90
11		99	51		455	2.63	95		841	2.73	137		1 197	2.81	171		1 481	2.96
12		104	56		480	2.67	104		886	2.77	149		1 257	2.85	187		1 561	3.00
13		109	60		500	2.71	113		931	2.81	161		1 317	2.89	202		1 636	3.04
14		114	65		525	2.74	121		971	2.85	174		1 382	2.93	218		1 716	3.08
15		119	70		550	2.78	130		1 016	2.88	186		1 442	2.96	233		1 791	3.12
16		124	74		570	2.81	139		1 061	2.91	199		1 507	2.99	249		1 871	3.15
17		129	79		525	2.83	147		1 101	2.94	211		1 567	3.02	264		1 946	3.18
18		134	84		620	2.86	156		1 146	2.96	224		1 632	3.05	280		2 026	3.21
19		139	88		640	2.88	165		1 191	2.98	236		1 692	3.07	295		2 101	3.23
20		144	93		665	2.90	174		1 236	3.01	248		1 752	3.10	311		2 181	3.26
21		149	98		690	2.92	182		1 276	3.03	256		1 792	3.12	313		2 191	3.28
22		154	100		700	2.94	183		1 281	3.05	256		1 792	3.14	313		2 191	3.30
24	24	168	111	111	777	3.10	208	208	1 456	3.21	298	298	2 086	3.30	373	373	2 611	3.48

FIGURE 7.2 METHOD USED BY MODEL TO DETERMINE APPROPRIATE PUMPING STRATEGY

This same method of pumping management is used whenever the operator specifies too much or too little pumping for the system.

7.6 System Parameters

Four calculations not directly required for furthering the simultion are performed to supply feedback to the operator and calculate parameters for his performance.

7.6.1 Feedback

(a) Cost of Supply:

After the pumping configuration on a pumpstation is set, cost data ($'s per megalitre) are used to establish the pumping bill for the month. This value is summed with the costs from the other pumpstations to give a total cost of pumping. This cost is shared over the entire demand region giving an average unit cost for the current month which is displayed to the operator.

i.e. COSTKL = TOTCST/TOTDEM * 10

where COSTKL = unit cost of water in cents per kilolitre for the month

TOTCST = total cost of pumping from all three pumpstations ($)

TOTDEM = total system demand (megalitres)

(b) Fraction of Demand supplied by pumps.

This is given as a percentage value. The total pumping from all the pumpstations is divided by the total demand of the system as a whole. If the resulting fraction is greater than 1, it is made equal to unity - this is convenient for the bargraph format in which it is displayed.

i.e. FRAC = 100 * TOTPMP/TOTDEM

where FRAC = percentage of system demand pumped from the River Murray
TOTPMP = summation of pumping at all three pumpstations (megalitres)
TOTDEM = total system demand (megalitres)

7.6.2 Operator Performance

(a) Use of natural inflow

Inflow can be either stored in a reservoir or used to satisfy demand. If it is stored, the demand must be supplied from transfers. Thus the net demand to be supplied by the combination of reservoir storage and inflow is the difference between the subsystem demand and incoming transfers. This demand fraction indicates how well inflow is utilized. Thus the fraction of inflow used for demand is given by:

inflow fraction = (DEMAND-TRANSFER)/INFLOW

(b) Use of incoming transfers

Incoming subsystem transfers may be sufficient to supply only subsystem demands, or large enough to augment subsystem storage as well. The fraction of subsystem transfer used to satisfy demand is given by:

transfer fraction = DEMAND/TRANSFER

7.7 "Preview" Mode Predictions

The forms of data used in "ACCEPT" and "PREVIEW" modes have already been pointed out to be different in their relation to the subsystem (Chapter 6, Section 6.7). Of particular importance is the type of inflow data used to check the likely result of subsystem management in "PREVIEW" mode. The inflow data used is that of the 90% probability of exceedence rainfall for the subsystem catchments. This is usually fairly certain to be the minimum probable inflow for any given month. It is the same probability level as that used in the real system management for prediction of future months' inflows.

7.8 Calculation Cycles

From the information given so far it can be appreciated that the model can adequately calculate the changing subsystem storages at each monthly interval. However the effects of management for the current month are not quite sufficient for the model operator. He not only wishes to know that the system management is satisfactory for the immediate short term (current month) but also what critical events (spill or deficit) are likely in the future months of the year.

The model supplies this information in the form of confidence limits on the end-of-year storage for the one unregulated storage in each subsystem. Two sets of calculation are performed, one using inflow based on 10% probability of exceedence and the other using 90% probability of exceedence inflow. This gives the range of storage which may be expected by the end of the year. The data is in the same form as that for "PREVIEW" mode (see Chapter 6, Section 6.7), that is a total subsystem inflow figure, and so the same calculation method is used.

These future predictions use the storage calculated for the end of the current month and cycle through the subsequent months using only their respective probable natural inflows to augment subsystem storage. It is assumed that the existing subsystem management strategy is operative only for the current month in making the predictions. This gives a better indication of how the subsystem is likely to behave in future rather than if the strategy is continued through succeeding months. In the event that a critical state develops in the predictions before June, that is either spill or deficit, the predictive calculation stops and the month and type of extreme event are displayed to the operator (Chapter 8, Section 8.5).

Hence there are three cycles of use for the calculation routines:

1. Current month operation including all elements of the chosen strategy - pumped inflows, transfers, storages.

2. Use end-of-month storage with 10% probability of exceedence inflows only to cycle through future months up to June.

3. As for (2) with 90% probability of exceedence inflows only.

7.9 Control and Communication Elements

Within the suite of programs forming the body of the model there are several arrays and variables which require explanation for a full understanding of the internal control and communication processes. These elements are responsible for adequate system control and the associated transfer of some data among the subroutines. Information is also transferred to and from the satellite control program to keep it up to date with the state of the main system.

7.9.1 Variables

1. IPMP or IPUMP(IPSTN)

Given as IPMP when transferring control to the satellite control program and IPUMP(IPSTN) when calculating the pumped volume for pumpstation IPSTN, this variable contains the pumping strategy of the station under consideration.

When the operator chooses a pumping strategy three decisions must be made:

(i) number of pumps to be used.

(ii) time of day for pumping off peak to special on peak.

(iii) monthly operating period:
intermittent to whole month.

In IPMP these values are associated with hundreds, tens and units respectively and stored as a single three digit number.
For example:

111 = 1 pump off peak intermittently
232 = 2 pumps special on peak for 1 week
325 = 3 pumps on peak for whole month

2. IPRVW

As discussed in Chapter 6 (Section 6.6) four light buttons are provided for the control of the simulation cycle:
CHECK, PREVIEW, ACCEPT, REVERT
IPRVW is used to indicate the mode of operation of the model. It is passed to the host program from the satellite control program after appropriate lightpen interaction.

Its values are as follows:

+1 = PREVIEW mode
e.g. Experiment with a possible subsystem strategy.

0 = ACCEPT mode

e.g. Satisfied with current stragety and ready for next subsystem

-1 = REVERT mode

e.g. Wish to revise original condition of the subsystem and start a new strategy.

+10 = CHECK mode

e.g. Wish to check another subsystem condition before making any further modification to current strategy.

3. ISPPLY and PSPPLY

Due to the dual role of Millbrook reservoir (Chapter 5, Section 5.3.3), additional variables are required to cope with its alternative operating modes.

(a) ISPPLY is used to indicate whether Millbrook is supplying to Anstey Hill Water Treatment plant:

ISPPLY sign + = supply to Anstey Hill
- = no supply to Anstey Hill

The additional problem of bypassing the limited capacity section of the Mannum-Adelaide pipeline when the Anstey Hill demand and Little Para transfer exceed this capacity require a further level of control. That is, in order to pump to the Torrens subsystem for the period of pipeline capacity exceedence and pump out of Millbrook the corresponding amount without prompting the operator (since he has no direct knowledge of pipeline demands) requires ISPPLY to take different numerical values for the times of capacity exceedence and non-exceedence.

ISPPLY = 1 no capacity exceedence
= 10 gravity main capacity exceeded, shunt water through Millbrook reservoir

(b) PSPPLY is closely related to ISPPLY

(i) When no supply from Millbrook reservoir to the pipeline has been requested by the operator, PSPPLY is used to include any Little Para transfer in the overall pipeline demand.

(ii) When Millbrook is already supplying to the pipeline, PSPPLY is the additional pipeline supply to be obtained through Millbrook reservoir which cannot be attributed to the Little Para transfer.

4. ITRN

This is another variable passed from the satellite control program to the host due to the satellite control of all lightpen interaction. It is used to indicate whether the operator has requested a transfer for the current subsystem on the display screen.

ITRN = +1 transfer requested
     = 0 no transfer requested

5. NCYCL

Within the model there are three modes of cycling through storage calculations for each month. NCYCL keeps a record of which cycle is currently operating.

NCYCL = 1 use data for current month
      = 2 using 10% probability of exceedence inflows cycle through monthly storage calculations to the end of the year

= 3 as for NCYCL = 2 but use 90% probability of exceedence inflows

7.9.2 Arrays

1. ICNTRL(ISYS)

During the first cycle of model operation in which the initial subsystem storage predictions are calculated for each subsystem ISYS, predictive calculations to change the current month storage values must be avoided since these have been supplied by the operator.

ICNTRL is simply a flag for each subsystem to indicate whether the initial calculations for it have yet been completed.

ICNTRL(ISYS) = +1 initial subsystem calculations have been performed

= 0 calculations not yet done

2. IRANGE(ISYS,2)

This is a data array containing the reference numbers of the first and last storages in each subsystem ISYS. This supplies the range of storage indices over which subsystem ISYS has control.

IRANGE(ISYS,1) = minimum storage number

IRANGE(ISYS,2) = maximum storage number

The following arrays are double dimensioned in order to conveniently carry with them some important characteristic of the storage element they represent as well as the associated current calculated value.

3. TRANSF(NRES,2)

Since only a small number of storages can accept inflows from pumping stations, these need to be specially identified.

While the first element of the array holds the current value of the pumped transfer to the storage NRES from the appropriate pumpstation, the second element indicates which pumpstation is involved and the supply pipeline capacity:

TRANSFR(NRES,1) = current value of incoming pumped transfer

TRANSF(NRES,2) = (+ or -)A.B

sign + = transfer requested

sign - = transfer not required

integer A = pumpstation number

decimal: B*100000 = limiting capacity of the supply pipeline (megalitres per month)

NOTE: TRANSF(NRES,2) = 0 means no pumped inflow is available to storage NRES.

4. STOR(NRES,2)

This array distinguishes between reservoirs, weirs and service reservoirs. The second element of the array indicates the type of storages NRES is. The first element holds its current storage.

STOR(NRES,1) = current true storage
STOR(NRES,2) = 0 service reservoir
= 1 reservoir
Less than 0 weir

5. S(IMONTH,NRES)

Having established through STOR(NRES,2) that NRES is indeed a service reservoir, this array supplies the twelve fixed storages for each service reservoir, for each month IMONTH. It is also used by Millbrook reservoir to set up its monthly storage based on the previous month's value.

This array may also be used to differenciate between service reservoirs and other storages.

i.e. S(IMONTH,NRES) = 0 then NRES not a service reservoir

7.10 Model Validation

Ideally, the use of historical data in the model followed by a comparison of the computer results with the actual storage results forms the most useful validation procedure for such a simulation as this.

The Engineering and Water Supply Department does maintain records of the system operation for reference. Inflow data (from catchment) is recorded as a single number for each subsystem and not as a figure for each reservoir within the subsystem. This has apparently proven itself to be a convenient method of recording the operation of the whole system. However the computer simulation, when balancing the system, regards each reservoir within a subsystem as an individual storage with associated inflow. Thus a validation involving historical data would require separate inflows for each storage.

When a decomposition of the recorded historical inflow was attempted for both summer and winter months in several years of data, it was found that on an individual reservoir basis the inflows did not balance with the other data. This is apparently due to errors in estimated quantities such as evaporation and inaccuracies within the measuring equipment (which may reach 10%) which are of particular significance during low inflows (mid-summer) and large inflows (mid-winter). Since the inflow recorded is a calculated "balancing figure", over the whole subsystem such discrepancies do not appear on a monthly basis.

The discrepancies on the individual reservoirs are of sufficient significance to require modification of the historical data to remove their effect. Any such calculation and modification would negate the advantage of using historical data and so it was decided to find an alternative validation method.

Simplified inflow and demand profiles for twelve months' simulation were synthesised for each storage and demand zone respectively, using 70% probability of inflow exceedence values for inflow and the deterministic demand file 1980-1981 as guidelines.

Convenient and realistic initial storages were chosen for the storages and the model was run several times through the twelve months' data:

1. No pumping, no transfers
2. No pumping, transfers included
3. Pumping included, no transfer
4. Pumping and transfers included

The results were checked by hand calculation for correct transfers, consistent pumping, total system balance and correct costing.

CHAPTER 8

8.1 Introduction

The key factor in interactive graphic simulation is plainly the requirement of intermittent responses from an operator to a computer program. Using the visual information presented to him by the computer, as well as his own personal experience and intuition, such an operator makes decision which are used to advance the computer program.

This human link in the control system disrupts the tidy, autonomous situation in which the computer has total control of input, calculation and output.

Thus to ensure effective man-machine communication for efficient execution of a chosen task, human factors involvement in the control loop must be considered. The human factors that apply to the functional aspects of the man-computer interface are not all amenable to precise definition, nor are they readily verifiable by experiment. Some of them can be described only as "intuitive" in nature.

However, if there is one belief that is consistently apparent in the writings of researchers in this field, it is that the incorporation of the necessary human factors in a system is much more an art than a science. As a result, the opinions expressed lay emphasis on different aspects of the problem, depending on the research background. Despite the different approaches, the final goal of efficient communication remains. Hence while the rationale for adopting certain attitudes varies, final implementation concepts and much of the methodology is common to all approaches.

This factor does, however, highlight the point that while certain characteristics are desirable in all systems - for example, low response times, ease of learning - each application requires its own individual style of consideration of human factors.

It can therefore be appreciated that clarity and vividness in interactive graphics communication is not an automatic consequence of the use of graphics equipment. Conscious design effort must be applied to provide the desired characteristics in the user's communication with his machine. The aim is to make the communication paths both from user to computer, and vice versa, natural to the user.

8.2 Aspirations of the Graphic Display

The graphic display in this program is the single interface between the human operator and the computer program. As a result it must be highly efficient at conveying information to the operator and allowing an unhindered return flow of instructions to advance the program in its execution.

Ideally, after an initial learning phase, the operator should be able to become virtually unaware of the existence of this interface, so easy should it be to concentrate on and manipulate the problem under consideration.

Many factors influence how closely any interactive graphic program approaches this ideal, the vast majority being concerned with the ideosyncracies of the operator, from psychological factors to visual perception and interpretation (see chapter 4). It is the function of the computer program to comply with the requirements of the user and not vice versa.

Close consultation had taken place with the prospective users of the interactive graphics program discussed in these pages before any final formulation and design were chosen. It was important to establish just how the operations which this program simulates are accomplished, and how much control is available for modifications, so that these functions might be made available on the computer in a simple, clear and unambiguous format.

Inclusion of as many familar concepts as possible within the simulation framework reduces the learning time and allows the user to carry over his understanding of the real system as the conceptual model for the computer program. There is sufficient reorientation required from the operator in learning to use the lightpen and a type-writer-like console without demanding a reshuffling of usual operating techniques - which in any case would reduce the effectiveness of the simulation program as a model of the real system.

To enhance the user's conceptual model, an uncluttered schematic representation of not only the storages but also their interconnections within and outside each subsystem has been included. This is also significant benefit to the new-comer to the system since the model provides a complete picture of the system, requiring only a minimum of background knowledge.

8.3 Graphics Related Interaction

The model is designed to minimise the requirement for typed-in data during the simulation and to maximise use of the lightpen, since the lightpen provides a very rapid, error free input and command language.

This has been possible since there are only a small number of well defined system command operations (a total of four) which lend themselves admirably to lightpen nomination (chapter 6, section 6.6) without recourse to a separate menu page. This in turn means that the operational lightpen elements can be included conveniently on the screen at all times.

In the same manner the pumping combinations available at any pump station have been reduced to a limited number of possible alternative strategies, any of which can be picked by the lightpen.

However, it can be appreciated that numbers are more easily typed in than nominated with a lightpen. Data required at the start of the simulation for starting date, length of simulation and starting storages, as well as transfers desired during the simulation, must be supplied via the keyboard.

When the keyboard is used, there is already an automatic visual feedback to the operator inherent in the graphics terminal design. As the individual numbers are typed on the keyboard, they appear on the screen at the position of the prompt, and when the operator is finished, the "RETURN" key (or "CR" key) must be pressed before the model accepts the new data. The model then clears the data from the screen, providing further reinforcement to the fact that the model has accepted and is using the data.

To faciliate feedback to the operator using the lightpen, some immediate modification of the display is needed to indicate that the operation has been noted and the computer is working on the request. When a system control item is picked (CHECK, PREVIEW, ACCEPT or REVERT), the chosen item disappears from the screen until the whole operation is completed.

Coinciding with this, a message appears under "system communications" indicating the state of the system during the operation.

The choice of a pumping strategy is somewhat simpler, since no calculation is immediately required, and any new element picked in the pumping configuration informs the operator of the new condition by flashing on and off.

In choosing a new subsystem for consideration a third indication is used. Once an item is picked, the title intensifies in brightness for a short time and the screen immediately changes to the format for the chosen subsystem.

8.4 Response Time

After considering some of the comments in chapter 4, it becomes quite clear that a short response time is needed to maintain effective man-machine communication. Two different avenues are used in the model to help realize this aim. Firstly, a satellite control program (chapter 7, section 7.1) has been used to avoid the lengthy host-alone response time, and secondly, calculations have been designed around the short response ideal. This is done by avoiding the protracted system balancing calculations when only experimenting with different operations in "PREVIEW" mode. Of course, a total system balance is required before proceeding from one month to the next, but calculations are only performed on the currently displayed subsystem until all subsystems have been ACCEPT'ed.

The reason for this approach is to enable the operator to consider each month as a block of decisions. Within this block, response is rapid, while at completion of the month's management, a short delay occurs before the next block is to be tackled. This concept is consistent with the psychological principle of closure, or the feeling of having completed a task.

From an operator's point of view, the task to be accomplished is to arrange an acceptable set of operating strategies for the subsystems in the model for the current month. The model should work at the operator's pace and unreasonable delays in task completion avoided. If such considerations are not anticipated and acknowledged, fatigue, boredom or frustration at unnecessary delays may occur.

However, having completed the task, a "breathing space" or pause before tackling the next set of decisions is often useful to the operator. Time can be spent reflecting on the overall system strategies, or simply taking a mental break. The completion of the month's operation represents psychological closure to the operator. The task is finished and there is usually greater tolerance of an extended period of inactivity before the next task requires attention. This also strengthens the principle that the user should not feel pushed or hurried to oblige a constantly demanding computer, otherwise more mistakes will occur, and confusion may set in, due to insufficient time being allowed for thought and consideration of the next decision.

The overall dictum on response time used in the model when the previous points are considered, can be summarised as follows:

A low response time throughout task completion is desirable, while a somewhat longer "inter-task" lag time is tolerable.

The final correct answer to the response time dilemma is naturally dependent on the opinions of the users of the model.

8.5 Screen Layout

The design of the visual display is an important aspect of any graphics-oriented program, especially when most interaction is via a lightpen. The screen is the interface between the operator and the model, through which data and instructions are both entered and received, and it provides the user with a conceptual model of the model's functions. It is therefore important that the various elements in the design are straightforward, easily understood, and positioned logically, to facilitate rather than hinder communication between operator and model.

The subsystem diagram is the focal point of the screen for most of the time and consequently occupies the central part of the viewing area. The other screen elements are placed around its perimeter. Each item has an associated "viewing priority" according to the needs of the operator at any instant in the simulation. As a result of this the elements which receive attention with similar frequency have been grouped together (fig 8.1.):

(1) All lightpen control elements are arranged together at the right of the screen. This grouping is convenient as the operator need not chase all over the screen to find the lightpen items.

(2) All the information-oriented output - region and time, system communication and economic criteria - are positioned to the left of the screen.

   (a) "System Communication" is somewhat out of immediate view when concentrating on the lightpen "menus", however the messages displayed in that area are only secondary feedback after the primary acknowledgement of the requested operation and so do not require immediate attention. While useful to a

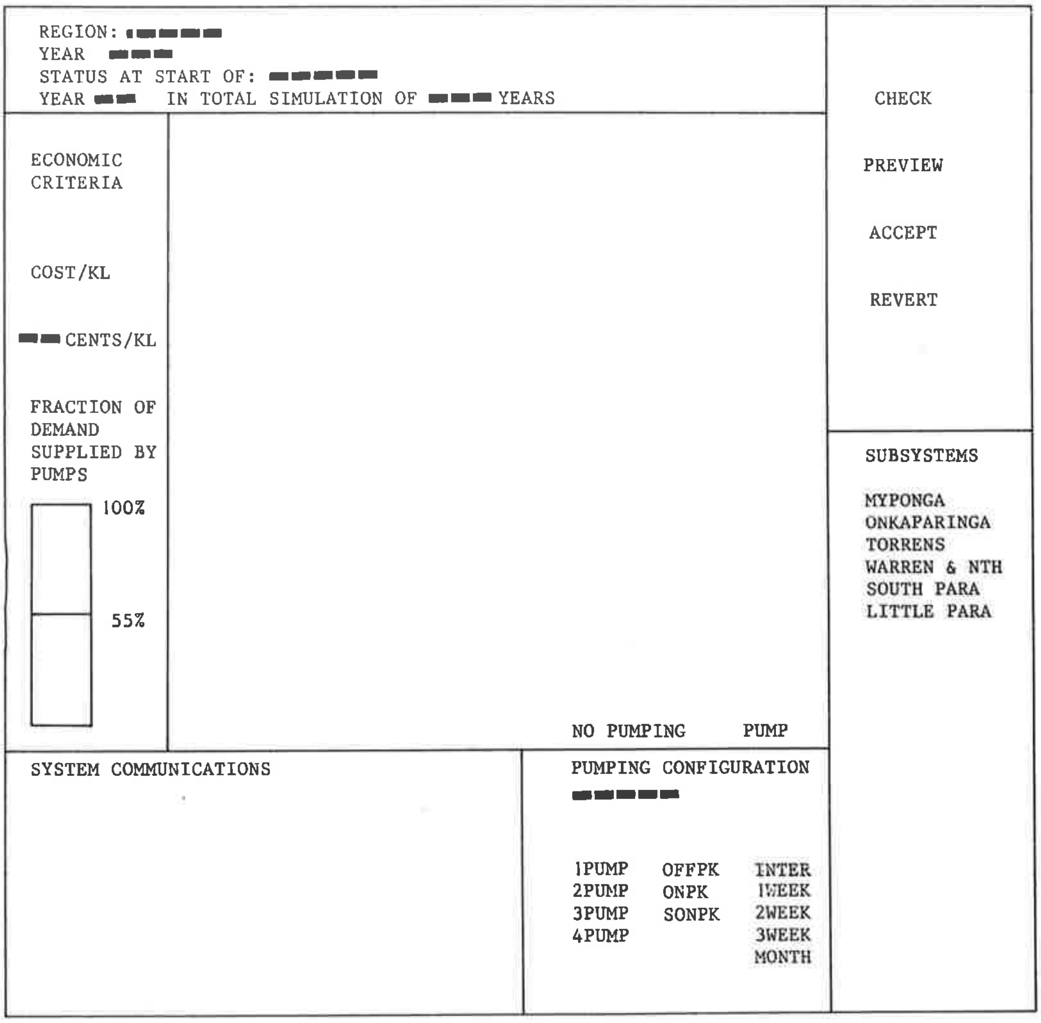


FIGURE 8.1 Screen format for graphics display

novice, the prompts are often anticipated by a regular user who feels more independent (in control).

(b) Similarly "Economic Criteria" does not require full time attention, being most useful as an "at a glance" guide to the cost of the current strategy.

(c) The important, but nevertheless sporadically required data concerning subsystem name, time of year and the simulation progress, is located "out of the way" at the top of the screen for occasional reference.

8.6 Storage Bargraph

The bargraph is a useful form in which to display the volume held in a storage (fig 8.2). At a glance it shows qualitatively just how much water is in the storage as a fraction of the maximum storage, which is numerically displayed at the top left hand side of the bar. Thus the initial impression indicates whether storage is particularly low, high, or within reasonable operating limits. A closer inspection reveals the actual volume in the storage; current volume being displayed next to the left hand side of the bar.

Each bargraph has a title which names the storage represented by it and this completes the standard

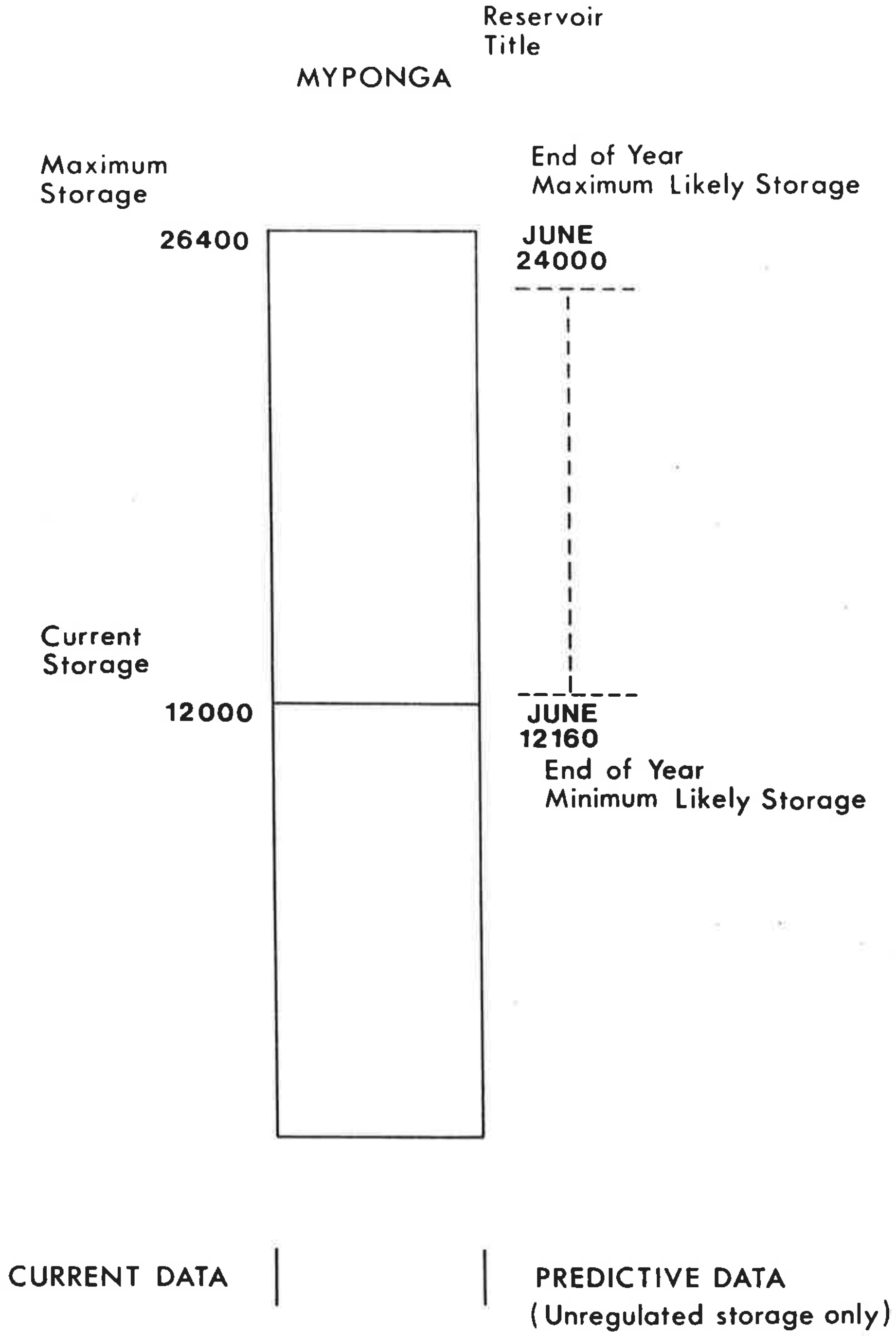


FIG. 8.2 BAR GRAPH REPRESENTATION OF STORAGE

format for the service reservoirs in the subsystems.

The single unregulated storage within each subsystem has two additional indicators on its bargraph at the right hand side. While the operator can see the immediate short term effect of any operating strategy using the "PREVIEW" light button, the two extra storage levels supply a longer term quantitative, and temporal indication of the effects of the strategy (chapter 7, section 7.8).

8.7 Graphic Representation of Pumping

Due to the inevitable limitation of space on the display screen in a graphics program, it is not possible to provide the full 24 hour pumping schedule for each pump station to be lightpen interactive. The three conditions of greatest importance for pumping occur at the changes of tariff rates from off-peak to on-peak, on-peak to special-on-peak and full special-on-peak. These three times, the maximum for each tariff rate, have been used in the model. While this choice is limited, some flexibility is provided in the number of weeks to be used for pumping, so that a fair variety of operation can be obtained.

This limitation does not exist in the event that the model itself must deside the pump operation. Internally the full pumping data set for each pump station is available to the model.

8.8 Pumping Configuration

The name of a pumping station, the quantity pumped at the station and a tabulated form of the possible operating modes appears in the "PUMPING CONFIGURATION" section of the screen display for each subsystem capable of accepting water pumped from the Murray River (fig 8.3).

Current operating strategy is indicated by the continual flashing of any three elements of the table, one in each column. The operation may be changed by pointing at other elements in the table with the lightpen which will cause the new choices to flash instead. This action does not automatically change the screen storages; "PREVIEW" must be used again before the effects of the new pumping configuration are seen.

In addition to controlling the pump operation, the user must indicate whether or not the pumped water is required by the currently shown subsystem by pointing to either the "PUMP" or "NO PUMP" elements associated with the PUMPING CONFIGURATION table. Such a double handshake of confirmation is required since there are two cases of a single pumping station potentially supplying two different subsystems. Either or both subsystems can demand some pumping to be transferred and to indicate which, if any, require the extra water these extra controls are required. Any modification to the pumping configuration, when no

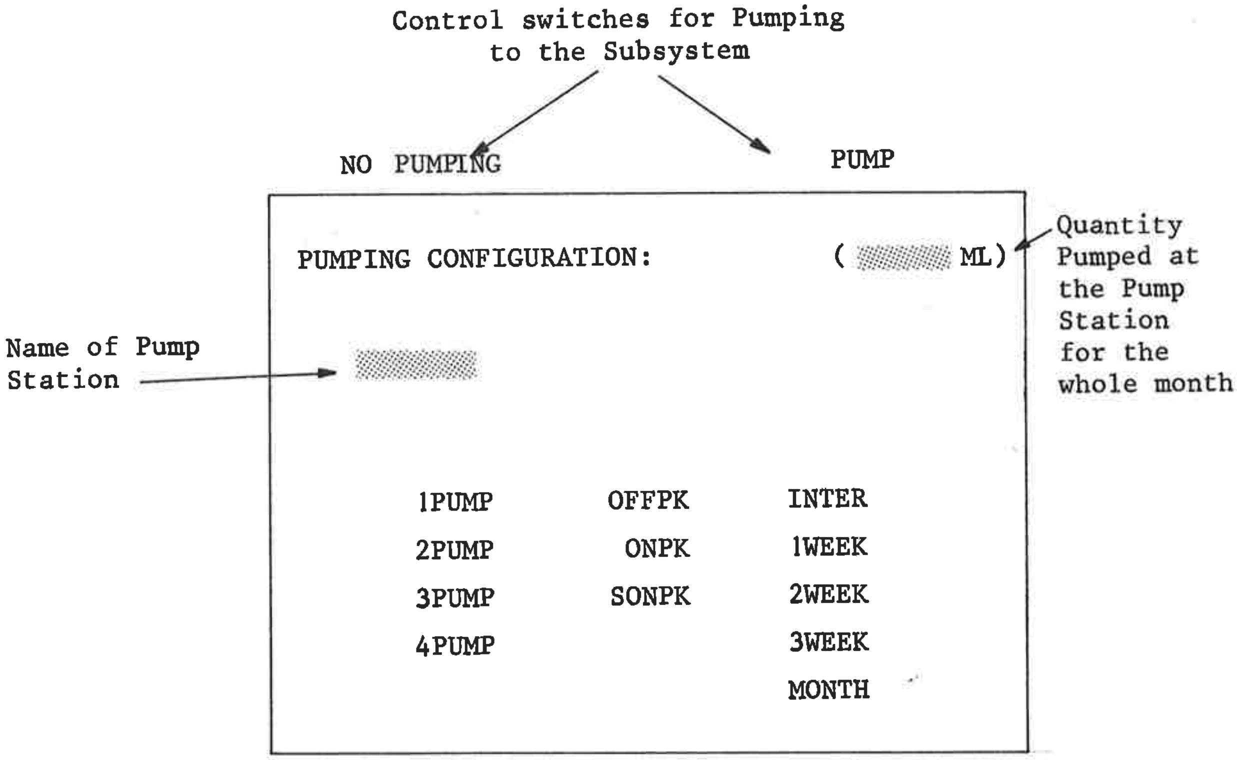


FIGURE 8.3 PUMPING CONFIGURATION GRAPHICS DETAIL

pumping is desired by any associated subsystem, is ignored in calculation and direct pipeline offtakes alone are considered. The model then changes the pumping operation to an appropriate level of supply. The actual amount pumped by the pump station as a result of the strategy is given also.

8.9 Subsystems and Subpictures

The graphics display features associated with the model have been created using the Digital Equipment Corporation's graphics language Dec-Graphic 11 (ref 2). Within the framework of this language individual picture elements may be grouped together into a unit called a subpicture. Conceptually a subpicture has a similar function to the Fortran subroutine. The subpicture can be called at different points in a program, the convenience being that there is no need to redefine the picture each time it is used or changed. Subpictures are identified by a user-supplied index number in the same way as a subroutine is given a name. They may also be nested within each other allowing selected parts of a screen picture to be modified.

The model uses subpictures throughout its structure both for ease of programming and for ease of reference, since the lightpen must be able to interact with many of them on the screen. Each subsystem has a subpicture associated with it in the form of its schematic screen display diagram. Within this subpicture all the operating storage bargraphs are subpictures also. Each subsystem which can supply or receive a transfer has a small cross in the appropriate position which appears or disappears depending on the transfer strategy - this also is a subpicture.

It can be appreciated that subpictures both large and almost trivial are used wherever a particular feature must be highlighted or changed. No two subpictures can have the same index number, so each subsystem has its own set of subpictures to define its complete graphics display. The screen layout itself is a subpicture with the control elements (CHECK, PREVIEW etc), pumping configuration, system communication messages etc, all being subpictures nested within it.

In order to create graphics pictures, elements are programmed for the screen according to X-Y co-ordinates. The screen is divided into a grid 1024 units by 1024 units with the point (0,0) at the bottom left hand corner. The elements used in the model are vectors (lines) and text, with modifications including change of line, character type and flash mode to differenciate between the screen elements.

Numbering of subpictures is given in table 8.1. The wide spacing of the numbering system is deliberate to allow for easy expansion of the graphic sector in future applications.

APPLICATION	SUBPICTURE NUMBER
Subsystem light buttons (MYPONGA, ONKAPARINGA, etc)	1-7
Control elements (CHECK, PREVIEW, etc)	21-24
System communication	50(+)
Permanent screen format	100
Pumping configuration (including PUMP, NO PUMP)	101-114
Subsystem layout diagrams:	
Myponga	1000(+)
Onkaparinga	2000(+)
Torrens	3000(+)
Warren	4000(+)
South Para	5000(+)
Little Para	6000(+)

Table 8.1 System elements and the associated subpictures.

CHAPTER 9

9. Program Structure and Subroutine Description

This chapter provides the detail of the general program approach and implementation requirements. It also outlines the highlights of the routines used in the model and as a result should be read in conjunction with the computer listings of the program code, to be found in Appendix C.

9.1 General Structure

The model is centred around a main controlling program which guides the simulation procedures from start to finish and communicates with the satellite computer. From this routine are called the other two major routines, each in charge of one of the two aspects of the model - graphics or calculation.

These second level, more problem specific routines are autonomous within themselves to perform the operations for completion of their particular assignments. Thus they are responsible for calling most of the third level subroutines, each of which is designed for a single task or group of related procedures.

A simple schematic of this system is shown in figure 9.1.

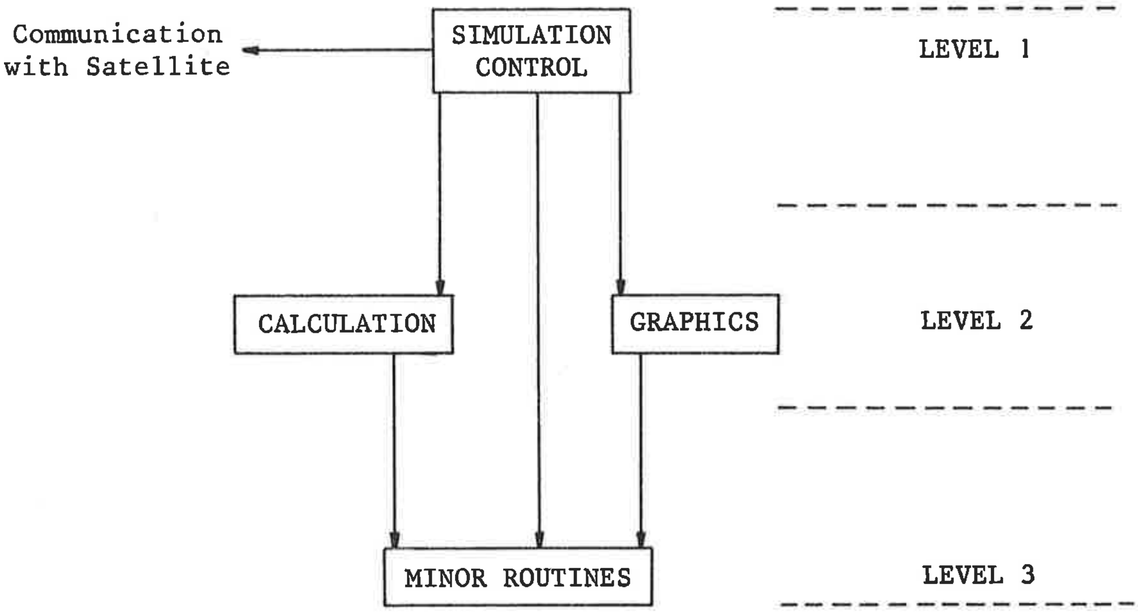


FIGURE 9.1 Levels of control within the computer programs.

The three routines that are responsible for these main processes are CORE, CALCST and BARGR. Their specific functions are as follows:-

1. CORE retains overall control of the system from program initialisation to completion. It calls the other main routines when required and passes information to and receives it from the satellite processor.

2. CALCST is responsible for calculation of all storages for both predictive and current month data.

3. BARGR uses the data generated in CALCST to draw up and calibrate the storage graphs of each subsystem. It also modifies the bar graph levels after they have been drawn.

9.2 Division of Control

Each of the routines used to build the model may be put into a category according to its major function within the program structure.

These categories may be defined as:

1. System Control
2. Calculation
3. Read Data
4. Store Output/Write Output
5. Graphics

Although some routines fit into more than one group, this list may be considered as definitive. Table 9.1 indicates the actual grouping of routines. In order to obtain a clearer picture of how these categories divide the work load, figure 9.2 shows a simple flow chart of the control program CORE, with the procedures numbered to show their operation categories.

9.3 Overlay Structure

Due to the limit of 32 K of memory which may be accessed by a single program on the computer used for the research, an overlay structure was necessary to allow the model to function. Thus instead of having all the routines spaced sequentially through memory, they are packed down into parallel branches, any one of which is shorter than the serial chain of routines.

In the example given in figure 9.3 the reduction in memory requirement is obvious. It should be noted, however, that only one branch of an overlay can be in memory at any one time. Thus if the root segment PROG calls either subroutine SUB1 or subroutines SUB2 and SUB3 no conflict arises. On the other hand, if SUB1 calls SUB2 or SUB3 the overlay will not work since both branches (i.e. SUB1 and SUB2-SUB3) are needed in memory, which cannot occur.

Duty	Subroutine
1. SYSTEM CONTROL	CORE
	SATPRG
	MNTH
	STINIT
	SUPPLY
	TIMSET
	TORRNS
2. CALCULATION	CALCST
	EVAPOR
	PMP
	WEIR
3. GRAPHICS	BARGR
	BAR
	CROSS
	SCREEN
4. READ DATA	CALDAT
	REDATR
5. STORE OUTPUT, WRITE OUTPUT	HRDCOP
	OUTDAT
	SKILL

TABLE 9.1 Main subroutine functions

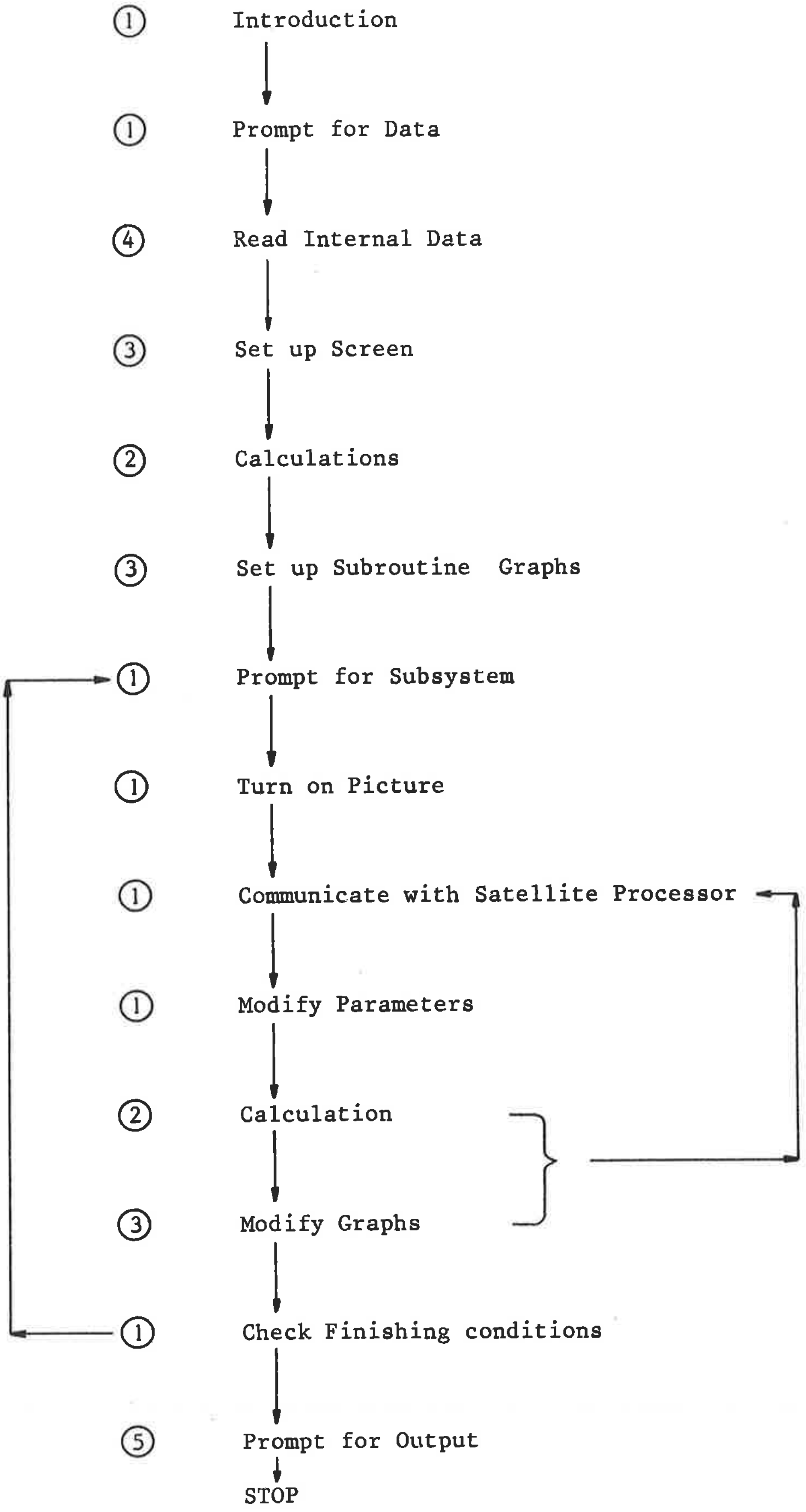
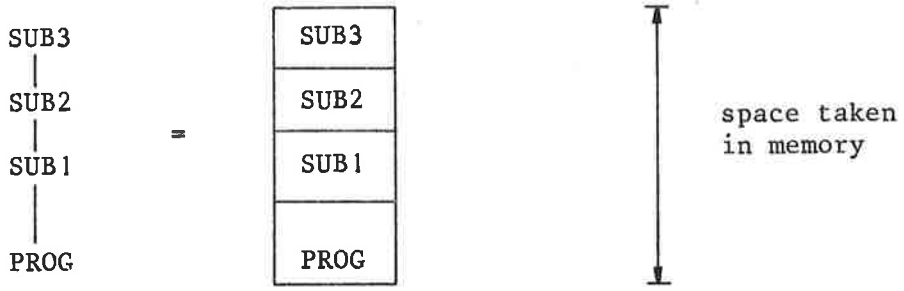
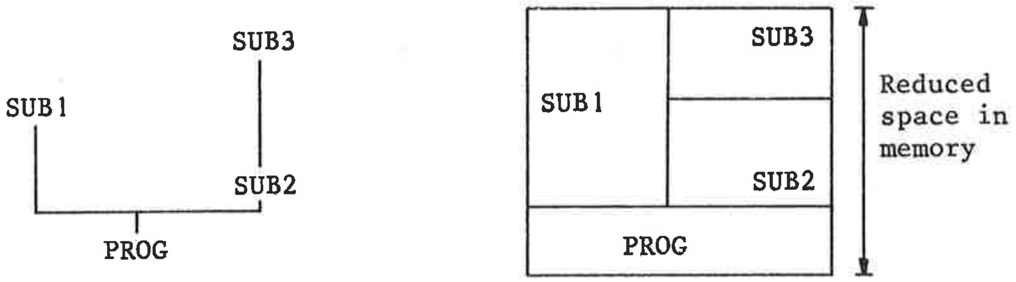


FIGURE 9.2 CORE flowchart showing categories of operations



(a) Program not overlaid



(b) Overlaid Program

FIGURE 9.3 Storage differences for overlaid and non-overlaid tasks.

A similar non-conflicting branching structure was required for the model and its schematic form is shown in figure 9.4. Each of the major routines (CALCST and BARGR) is on a different branch since they are never both needed for operations simultaneously (i.e. one does not call the other). The graphics routines are force loaded into the root segment of the overlay which always stays in core memory, since they are used in several branches and do not need redeclaration at each usage when so positioned.

9.4 Subroutines

Now that the general procedures associated with the subroutines have been defined, the mechanisms for executing those procedures may be discussed.

In order that the program configuration may be better understood in the context of the following comments, figure 9.5 shows the subroutine interconnections at each level of the program.

9.4.1 System Control

The system control routines are responsible for organising each step of the simulation, without actually becoming involved with the detail of the model. Where alternative paths are available for the simulation to follow the operator may be prompted for his choice of the next sequence, as

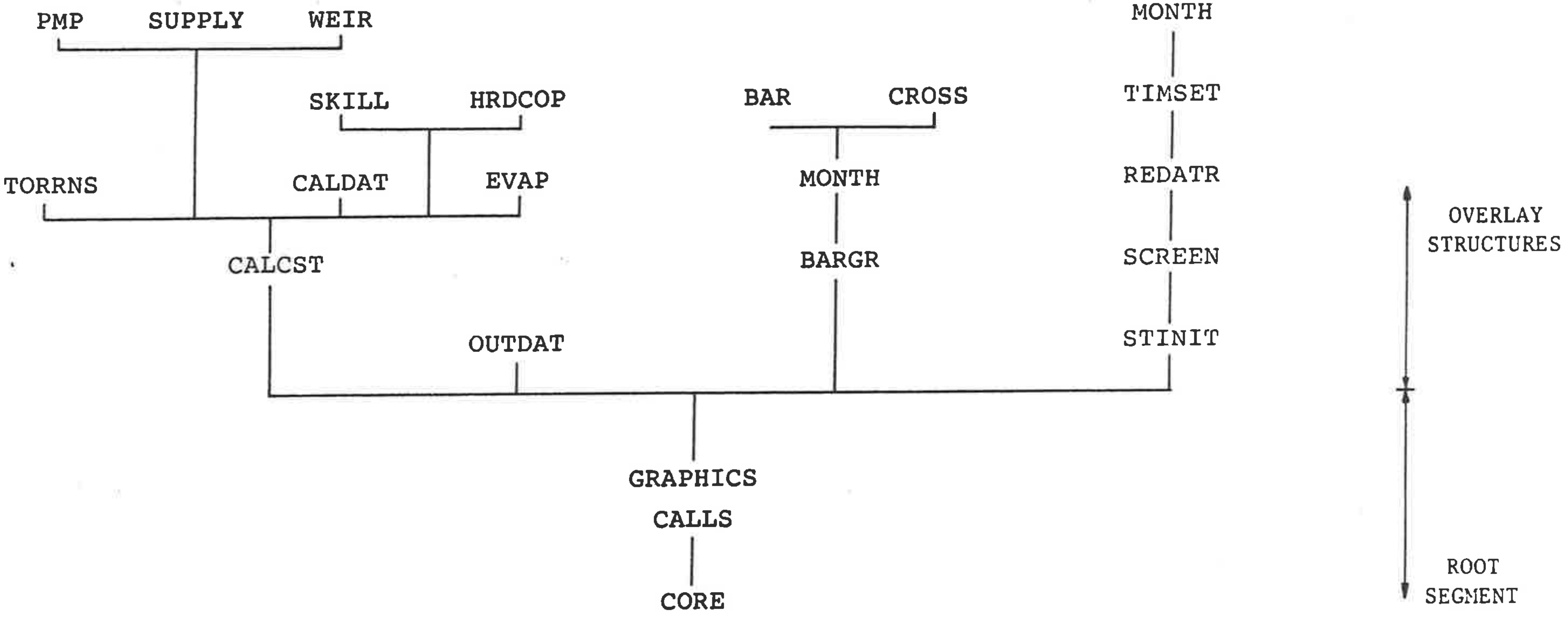


FIGURE 9.4 Final branching overlay structure for the model.

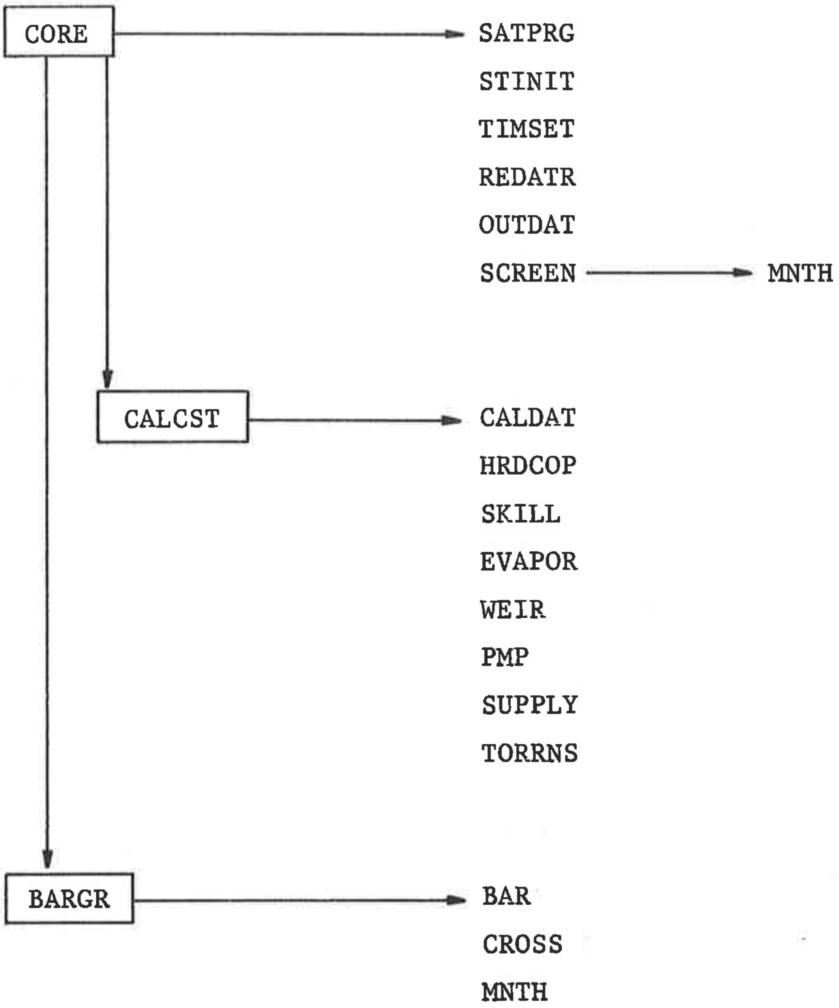


FIGURE 9.5 Subroutines called by each main program segment.

in the control of subsystem transfers. In general however the mechanics of program operation are governed within the model.

(a) CORE

This program forms the highest level of control in the model. Due to its key role it forms the root segment of the overlaid task (fig. 9.4) and as a result is always in central memory while the program is being used.

It controls data input from the operator for defining the starting point of the simulation and also reads into memory the permanent data for the simulation (chapter 10, section 10.2.1).

There are two sections to the program. The first involves setting up the simulation from data input to screen definition and including starting calculations and graphics calls. This part is used only once on the first loop through the program. The second involves repeating a section of code in which CORE passes data to the satellite control program and receives data about the operator's decisions in return, which it uses to determine the next sequence of operations. The cycle through this code continues until the operator is finally prompted for a hardcopy output at the end of the simulation.

(b) SATPRG

This is the program which is in charge of the graphics interaction in the satellite computer. As soon as program CORE issues the "TOSAT" command, to transfer control to the satellite processor, SATPRG is brought into action.

The transfer of data to this routine is performed in a single byte form and each element of information is stored in the LOGICAL*1 array B. Thus to transfer a variable to the satellite such as IPMP, which is an integer using two bytes, two successive elements of array B are used. These two elements must be concatenated in the satellite processor to again yield IPMP and this is achieved with the INTEGR function. The other two values transferred, ISYS and ISAT, are only one byte in length and so present no problem for decoding in the satellite. The first element of array B is used as a flag to indicate that it is the program SATPRG and not a standard graphics element which is required. Similarly the integer I is a value of unity only when the host processor specifically transfers to the satellite. This holds the two processors, host and satellite, in syncronism.

The body of the satellite program is designed around controlling the lightpen and simple screen modifications, such as turning elements on or off. The first section of code decodes the data from the host and checks that the correct pumping station is displayed. The remaining section involves a loop which polls the lightpen. When a lightpen attention of sufficient duration occurs (IHIT greater than 5) the number of the lightbutton chosen (IT) indicates the subsequent procedure to be followed. Data array IPIC is used as a reference for all the lightpen sensitive screen elements. These are the subsystem names, control words, pumping elements and valve controls in the Myponga screen display. Finally the new graphics state of the currently displayed subsystem is returned to the host to implement the changes.

(c) SUPPLY

This subroutine is one of those which fit more than one category. In its graphics operation it is responsible for prompting the operator for either Little Para or South Para subsystem's transfer. In its system-control sense it checks whether the proposed transfer is greater than the summer or winter pipeline capacity and if greater a reduction in the transfer volume occurs. It is of particular importance with respect to Little Para subsystem since it also checks the Mannum-Adelaide pipeline capacity in respect of the proposed transfer, and prompts for a reduction in volume if the capacity is exceeded.

(d) TORRNS

This subroutine was required specifically for the complexity of the Torrens subsystem. Millbrook reservoir has a prompt for its operator-specified storage, and the choice of supply to Anstey Hill is also made through this subroutine.

The additional degree of complexity arises with the transfer of water through Millbrook to avoid the low capacity section of main. To accomplish this, the transferring variables take on special values (ISPPLY = +10 or -10) and the transferring indicator for the Torrens subystem (TRNSF2) must be modified. This detailed modification is only possible in "ACCEPT" mode (IPRVW = 0) when Millbrook's individual inflow can be used.

(e) STINIT

The subroutine is called in the opening stages of program CORE to obtain the starting storages for each of the main reservoirs in the system. Storage values are prompted for the operator in the order of subsystem calculation (Myponga first, Little Para last) and from upstream to downstream. A check is made to ensure that no storage has more than its full supply volume.

(f) TIMSET

The month and year titles on the screen format are the responsibility of TIMSET. In each month of simulation the time headings are updated and a count of the number of years simulated so far is displayed. It is called from program CORE.

(g) MNTH

MNTH is a simple routine used both in setting the screen titles (in TIMSET) and on the reservoir bar graphs (in BARGR). It contains a data array A of the abbreviated names of the twelve months of the year and, given the current month index, loops through the array until the correct abbreviation is found.

9.4.2 Calculation

Under this heading come all the operations involved in determining the monthly storages for each subsystem. No reference is made to the system control routines for the order of calculation, since that is organised within subroutine CALCST. The transfer of control is complete, until calculatioin stops.

(a) CALCST

Subroutine CALCST is called from program CORE and is in complete control of the order and method of all simulation calculations. Each subsystem loops through the calculations in CALCST at least three times for each month. The first loop (NCYCL = 1) calculates the storage for the current month using either deterministic (IPRVW = 1) or stochastic (IPRVW = 0) data. The second time around (NCYCL = 2), the routine cycles through calculations for the months remaining until the end of the financial year using large inflow values (10% probability of exceedence). Finally, the same monthly calculations are performed using low inflows (90% probability of exceedence). No transfers are supplied during the second and third loops. Thus the one segment of code is potentially used many times for each subsystem. This is possible due to the simplicity of the calculations involved.

Each subsystem is considered as a single unit and only after the overall subsystem requirements are met do the individual storage characteristics become important.

Since this is the key calculating routine, it is reasonable that it should be responsible for the recording of subsystem data throughout the simulation. This it does through subroutines HRDCOP and SKILL. it is also responsible for organising each year's set of renewable data for demands and inflows which it performs through subroutine CALDAT.

(b) PMP

While subroutine CALCST is in overall charge of calculation for each subsystem, routine PMP is responsible for the complete evaluation of the pumped supplies and their associated costs. The usefulness of PMP hinges on its two main operations. Firstly, it decomposes the elements of array IPUMP to give the actual pumping strategy and converts this to a pumped volume and cost. Secondly, PMP is able to set an economic pumping operation independently of the operator when required. These functions are considered in chapter 7, sections 7.5 and 7.6.

In addition, the section of code dealing with the special nature of Millbrook reservoir, as a bypass to the low capacity gravity main, is basically designed to allow the Mannum pumping station to supply more than the limited capacity without the subroutine automatically curtailing its pumping operation when that pipeline capacity is exceeded.

(c) WEIR

Subroutine WEIR is the first of two simple linear interpolation routines. In array WIRTRF are stored the co-ordinates of the weir transfer functions at which the characteristics change from complete transfer of inflow, to part transfer and finally to the limiting hydraulic transfer capacity of the supply route. From the stochastic inflow assigned in CALCST, this routine interpolates the amount transferred to the appropriate storage.

(d) EVAPOR

This is the second interpolation routine. Data array EVAPN contains all the storage vs evaporation curves for each reservoir in the system, prefixed by the reservoir index as a negative number. The subroutine searches the first elements of each record in the array until the appropriate negative value is found. It is then a simple matter, given the current storage in the reservoir, to interpolate between two storage curves for the appropriate month to find the evaporation loss. See chapter 10 for the data format.

9.4.3 Graphics

The routines involved with the graphics features of the model are simply drawing programs. They use the results of calculation and system control routines to create and modify the screen display. No values are generated in the graphics subroutines which are of importance to any other model segment besides graphics display and control.

(a) BARGR

All storage bargraphs and the associated subsystem displays (subpictures) are drawn under the control of BARGR. Using X-Y co-ordinates as discussed in chapter 8, section 8.8, BARGR sets up the positioning of each graph in the screen display area. Subroutine BAR is then used to fill in the details of the graph. Finally, all the appropriate titles, values and storage interconnections are added by BARGR. This part of the subroutine is only used once for each subsystem since after they are drawn the subpictures remain in memory and do not need redrawing each time they are displayed.

By skipping the code responsible for the previous operations, the remainder of BARGR modifies the levels for each graph, at monthly intervals, using the calculated data from CALCST.

(b) BAR

This subroutine is called by BARGR to draw up each storage's bargraph at the start of the simulation. It uses the X and Y co-ordinates calculated in BARGR to draw the bar to the correct scale in the required position on the screen. Blank titles are positioned on the diagram to be filled in later by BARGR. If the storage is neither a service reservoir nor a weir, the additional set of predictive indicators for maximum and minimum storages is also supplied.

(c) CROSS

This subroutine simply draws a diagonal cross on the screen to indicate a valve in a pipeline. It must be called in the subpicture at the position where the cross (valve) is to be located.

(d) SCREEN

Subroutine SCREEN is responsible for the overall division of the display screen into the different compartments required by the model. It also creates all the headings for the screen and positions the main interactive light button elements. It is used only once, at the start of the model operation.

9.4.4 Read Data

Apart from the system initialisation data to be supplied by the operator, there are two other data sets to be included in the simulation - permanent and renewable data (see chapter 10). These data sets are read in separately at different points in the program.

(a) REDATR

This subroutine is called by program CORE once only at the start of simulation. It reads from unit 7 (magnetic disc) the data for inflow (10% and 90% probability of exceedence), pump characteristics for the pump stations used, and evaporation data for each reservoir. These values do not change throughout the simulation.

(b) CALDAT

All the monthly varying calculation data are read and stored in routine CALDAT. These data are read during the simulation at the start of each year by a call from routine CALCST. As a result, any effect of this routine on response time needs to be minimised. Thus instead of reading one file at a time, each with its associated opening and closing requirements, three different logical unit numbers (7,8 and 9) are used to enable all files to be opened, read and closed simultaneously, resulting in a faster overall subroutine execution.

It is in this subroutine that the demands for each subsystem are combined from the twelve individual demand zones.

9.4.5 Store and Write Output

The storing and writing of system operation to output is an important facet of the program. Not only is the operator able to test his skill on the simulator over several years, but afterwards his performance may be inspected and analysed for a measure of his ability to manage the system.

(a) HRDCOP

Subroutine HRDCOP is called by routine CALCST at the end of each month of simulation to store each subsystem's characteristics. Storage characteristics are stored in array SYSSTR and pumping operations in array SYSPMP. At the end of each twelve month period these arrays are emptied into files OUTPUT.DAT and OUTPMP.DAT respectively and subsequent months' data start to fill the arrays once more.

(b) SKILL

This is the subroutine used to store the pertinent data on system operation with which to determine the operator performance. Data is written to file each month to avoid increasing the program requirements too much. This has not adversely affected response time. Data is stored on the basis of the individual subsystem and the system as a whole, using files SUBFORM.DAT and TOTFORM.DAT respectively, on logical units 7 and 8. The data is calculated for monthly, yearly and whole simulation time periods to indicate the progressive effects of averaging. Data are taken from the arrays in subroutine HRDCOP, SYSSTR and SYSPMP, and are manipulated in array PERFRM before being written to file.

(c) OUTDAT

OUTDAT is a formatting routine that sets up the tables for and prints, the stored data from the simulation in legible form. It employs the number of input data records used as its index for the amount of output data to be written i.e. it works from the first record MINREC to the last record MAXREC. It is responsible for printing all the output data, both the system characteristics and the operator performance.

CHAPTER 10

10. MODEL DATA

Within the framework of the simulation model there are three separate data sets required for its operation. The first is the operator supplied initialisation data for the desired model starting conditions, which is used by the model to extract the correct values from the second data set of inflow, demand and the like. The final data files are written by the model as output, not only to record the system operation, but also to supply information concerning the efficiency of operation.

Each of these areas will be discussed separately in this chapter.

It is worth noting that the files which are referenced more than once are labelled "DIRECT ACCESS". This allows immediate reference to the last record read or written and saves laboriously sorting through the file which results in a lessened impact on response time.

10.1 Initialisation data

The information required of the operator tells the model:

1. which zone of the system is to be simulated

2. in what year and month to start (at or after 1976)
3. the duration of simulation
4. reservoir starting storages

This type of data is basic to the operation of any reservoir simulation model, however, the starting year of simulation requires further explanation.

The data sets used in the model for inflow and demand consist of 30 years of monthly values for each storage and demand zone. This period was developed to coincide with the interval from January of 1976 to December of 2005 (ref. 1, section 8.1). In order to reference the required segment of data for simulation an offset to the first value from the start of the file must be calculated at the initialisation of the simulation. Future data references are all made according to this offset which is in terms of monthly records from the start of the file.

10.2 Input Data

In this category there is a total of six data files which are required by the model. Their characteristics may be further divided into permanent and renewed data.

10.2.1 Permanent Data

The permanent data is read into the model once only for the entire simulation and is never changed. It deals with system characteristics of pumping, reservoir evaporation and average or deterministic inflow.

(a) Pumping : PUMP.DAT.

The pumping data file contains the full 24 hour pumping schedule for each pumpstation. Pumping rates in megalitres and costs in $ per megalitre are given for hourly time increments. The data refers to a single week's operation. (Table 10.1 a, b and c).

(b) Evaporation : EVAP.DAT.

For each reservoir in each subsystem there is a series of tabulated storage vs evaporation curves for monthly evaporations throughout the year, spanning the range of storage volumes from zero to full capacity.

The number of curves for each reservoir is variable depending on the maximum storage volume. As a result of this a simple indexing arrangement is used to divide this single file appropriately. Immediately prior to each block of curves is the negative value of the reservoir index number. It is then a simple matter to scan through the data until the appropriate negative index is found after which the data may be read

MURRAY BRIDGE ONKAPARINGA PIPELINE

OUTPUT IN MEGALITRES AND COST OF ELECTRICITY IN CENTS PER KILOLITRE FOR VARIOUS PUMPING COMBINATIONS AND PUMPING HOURS

As from 1.8.80

NO. OF PUMPS			1				2				3			
OUTPUT Litres/Sec.			2 350 ≡ 203 ML/D				4 380 ≡ 378 ML/D				5 760 ≡ 497 ML/D			
KWH/Kilolitre			1.39				1.50				1.65			
PUMPING HOURS			OUTPUT - ML			CENTS PER KILO LITRE	OUTPUT - ML			CENTS PER KILO LITRE	OUTPUT - ML			CENTS PER KILO LITRE
WEEK DAY	W.E. DAY	WEEK	WEEK DAY	W.E. DAY	WEEK		WEEK DAY	W.E. DAY	WEEK		WEEK DAY	W.E. DAY	WEEK	
8¼	22	85¼	70	184	718	2.13	130	334	1 318	2.30	171	428	1 711	2.52
9	22	89	76	184	748	2.16	142	335	1 378	2.33	187	428	1 791	2.57
10	22	94	85	184	793	2.21	158	334	1 458	2.38	207	428	1 891	2.62
11	22	99	93	184	833	2.24	173	334	1 533	2.42	228	428	1 996	2.66
12	22	104	102	184	878	2.28	189	334	1 613	2.46	249	428	2 101	2.71
13	22	109	110	184	918	2.31	205	334	1 693	2.49	270	428	2 206	2.74
14	22	114	119	184	963	2.34	221	334	1 773	2.53	290	428	2 306	2.78
15	22	119	127	184	1 003	2.37	237	334	1 853	2.55	311	428	2 411	2.81
16	22	124	136	184	1 048	2.39	252	334	1 928	2.58	332	428	2 516	2.84
17	22	129	144	184	1 088	2.41	268	334	2 008	2.61	353	428	2 621	2.87
18	22	134	153	184	1 133	2.44	284	334	2 088	2.63	373	428	2 721	2.89
19	22	139	161	184	1 178	2.45	300	334	2 168	2.65	394	428	2 826	2.91
20	22	144	170	184	1 218	2.47	315	334	2 243	2.67	415	428	2 931	2.94
21	22	149	178	184	1 258	2.49	331	334	2 323	2.69	428	428	2 996	2.96
22	22	154	184	184	1 288	2.50	334	334	2 338	2.70	428	428	2 996	2.97
24	24	168	204	204	1 428	2.64	378	378	2 646	2.85	498	498	3 486	3.13

TABLE 10.1 (a) Murray Bridge

MANNUM ADELAIDE PIPELINE

OUTPUT IN MEGALITURES AND COST OF ELECTRICITY IN CENTS PER KILOLITRE FOR VARIOUS PUMPING COMBINATIONS AND PUMPING HOURS

As from 1.8.80

NO. OF PUMPS			1				2				3				4			
OUTPUT Litres/Sec.			1 290 ≡ 111 ML/D				2 410 ≡ 208 ML/D				3 450 ≡ 298 ML/D				4 320 ≡ 373 ML/D			
KWH/Kilolitre			1.63				1.69				1.74				1.83			
PUMPING HOURS			OUTPUT - ML			CENTS PER KILO LITRE	OUTPUT - ML			CENTS PER KILO LITRE	OUTPUT - ML			CENTS PER KILO LITRE	OUTPUT - ML			CENTS PER KILO LITRE
WEEK DAY	W.E. DAY	WEEK	WEEK DAY	W.E. DAY	WEEK		WEEK DAY	W.E.	WEEK		WEEK	W.E.	WEEK		WEEK	W.E.	WEEK	
8¼	22	85¼	38	100	390	2.49	72	183	726	2.59	102	256	1 022	2.66	128	313	1 266	2.80
9		89	42		410	2.54	78		756	2.63	112		1 072	2.71	140		1 326	2.85
10		94	46		430	2.59	87		801	2.68	124		1 132	2.76	156		1 406	2.90
11		99	51		455	2.63	95		841	2.73	137		1 197	2.81	171		1 481	2.96
12		104	56		480	2.67	104		886	2.77	149		1 257	2.85	187		1 561	3.00
13		109	60		500	2.71	113		931	2.81	161		1 317	2.89	202		1 636	3.04
14		114	65		525	2.74	121		971	2.85	174		1 382	2.93	218		1 716	3.08
15		119	70		550	2.78	130		1 016	2.88	186		1 442	2.96	233		1 791	3.12
16		124	74		570	2.81	139		1 061	2.91	199		1 507	2.99	249		1 871	3.15
17		129	79		525	2.83	147		1 101	2.94	211		1 567	3.02	264		1 946	3.18
18		134	84		620	2.86	156		1 146	2.96	224		1 632	3.05	280		2 026	3.21
19		139	88		640	2.88	165		1 191	2.98	236		1 692	3.07	295		2 101	3.23
20		144	93		665	2.90	174		1 236	3.01	248		1 752	3.10	311		2 181	3.26
21		149	98		690	2.92	182		1 276	3.03	256		1 792	3.12	313		2 191	3.28
22		154	100		700	2.94	183		1 281	3.05	256		1 792	3.14	313		2 191	3.30
24	24	168	111	111	777	3.10	208	208	1 456	3.21	298	298	2 086	3.30	373	373	2 611	3.48

Table 10.1 (b) Mannum

SWAN REACH PUMPSTATION
TABULATED WEEKLY VOLUME AND COST

TIME		1 PUMP OUTPUT			2 PUMPS OUTPUT			3 PUMPS OUTPUT		
WEEK DAY	W.E. DAY	ML/WEEK	kwH/MNT	$ COST/ML	ML/WEEK	KwH/MNTH	$ COST/ML	ML/WEEK	KwH/MNTH	$ COST/ML
11¼	24	110	699 889	43.51	212	1 416 213	41.58	304	2 115 776	40.00
12	24	114	725 038	43.81	219	1 467 102	42.03	315	2 191 802	40.58
13	24	119	758 570	44.18	230	1 534 954	42.59	330	2 293 171	41.30
14	24	124	792 102	44.52	240	1 602 806	43.10	345	2 394 539	41.96
15	24	129	825 635	44.83	250	1 670 658	43.57	359	2 495 908	42.56
16	24	135	859 167	45.12	260	1 738 510	44.01	374	2 597 276	43.11
17	24	140	892 699	45.39	270	1 806 361	44.41	388	2 698 645	43.63
18	24	145	926 231	45.63	280	1 874 214	44.78	403	2 800 013	44.11
19	24	150	959 763	45.86	290	1 942 065	45.12	418	2 901 382	44.55
20	24	156	993 296	46.07	300	2 009 917	45.45	432	3 002 750	44.96
21	24	161	1 026 828	46.27	311	2 077 769	45.75	447	3 104 119	45.35
22	24	166	1 060 360	46.46	321	2 145 621	46.03	461	3 205 487	45.71
23	24	171	1 093 892	46.64	331	2 213 473	46.29	476	3 306 856	46.05
24	24	177	1 127 425	46.80	341	2 281 325	46.54	490	3 408 224	46.37

TABLE 10.1 (c) Swan Reach

according to Table 10.2.

The possibility of correlating evaporation to rainfall has been investigated for this reservoir system (ref. 1, section 4.3.4) but the results achieved were no better than those of average evaporation data. Hence average data has been used in this model.

(c) Deterministic inflow : DETINFL.DAT.

The file contains the inflow values used in "PREVIEW" mode and for future predictions (chapter 7, section 7.7, 7.8). Each record of the file contains the twelve, monthly inflows to a subsystem. The records are sorted according to the order of subsystem calculation (Myponga first, Little Para last) and the data for each subsystem is grouped - the 90% probability of exceedence data followed by that for the 10% probability of exceedence. These values are based on probability of exceedence curves for each subsystem catchment (fig. 10.1).

10.2.2 Renewed Data

Under this heading are inflow and demand files that are used once only. Each one of these files contains 30 years of monthly data as discussed in section 10.1. The files are read by the model at the start of each annual cycle rather than at

Reservoir Number
i.e. 4 = Happy Valley

Monthly Evaporation
values - July to June

STORAGE

INCREMENTS

4.												
3000.	45.	60.	73.	107.	129.	166.	184.	160.	132.	92.	52.	43.
3500.	46.	64.	77.	114.	138.	176.	196.	170.	141.	98.	55.	46.
4000.	48.	68.	82.	121.	146.	187.	208.	181.	149.	104.	59.	48.
4500.	51.	72.	86.	127.	153.	196.	218.	189.	156.	109.	62.	51.
5000.	53.	75.	90.	133.	161.	206.	230.	200.	165.	115.	65.	53.
5500.	56.	79.	94.	139.	168.	215.	240.	208.	172.	120.	68.	56.
6000.	58.	82.	98.	145.	175.	224.	249.	217.	179.	125.	71.	58.
6500.	60.	85.	102.	151.	182.	233.	259.	225.	186.	130.	73.	60.
7000.	63.	88.	106.	156.	189.	242.	269.	234.	193.	135.	76.	63.
7500.	64.	91.	109.	161.	195.	249.	277.	241.	199.	139.	78.	64.
8000.	67.	95.	113.	168.	203.	260.	289.	251.	207.	145.	82.	67.
8500.	69.	97.	116.	171.	207.	265.	295.	256.	212.	148.	83.	69.
9000.	71.	101.	121.	178.	215.	276.	307.	267.	220.	153.	87.	71.
9500.	73.	103.	124.	183.	221.	283.	315.	273.	226.	157.	89.	73.
10000.	75.	106.	127.	187.	227.	290.	323.	280.	231.	161.	91.	75.
10500.	77.	109.	130.	192.	232.	297.	331.	287.	237.	165.	94.	77.
11000.	79.	112.	134.	198.	239.	306.	341.	296.	244.	170.	96.	79.
11500.	81.	114.	137.	202.	245.	313.	348.	303.	250.	174.	99.	81.
12000.	83.	118.	141.	208.	252.	322.	358.	311.	257.	179.	101.	83.
12500.	85.	120.	144.	213.	257.	329.	366.	318.	263.	183.	104.	85.
12750.	86.	122.	146.	215.	260.	333.	370.	322.	266.	185.	105.	86.

TABLE 10.2 Typical set of evaporation data for a reservoir as stored in evaporation data file.

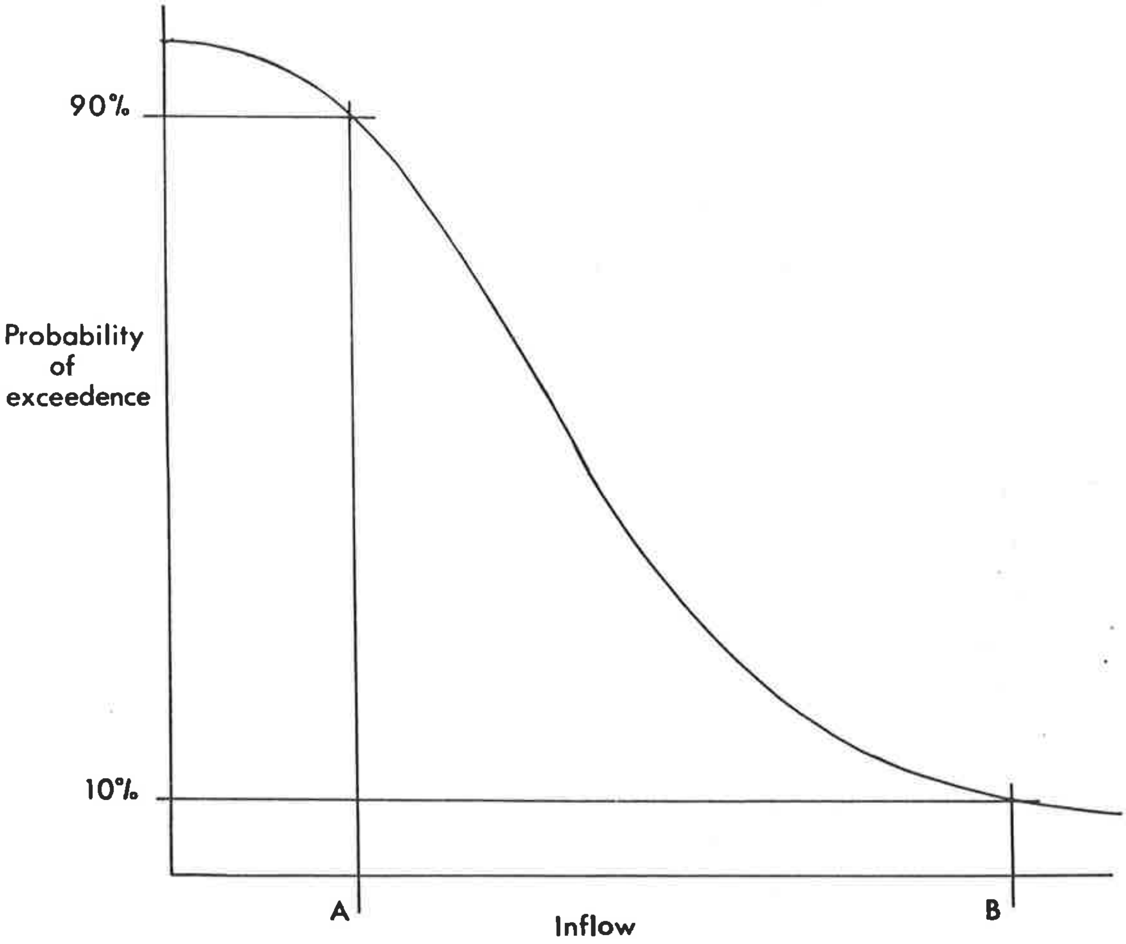


FIGURE 10.1 Typical probability of exceedence curve from which confidence limit inflows are taken for a catchment.

shorter intervals which would affect model response time.

(a) Deterministic (average) demand, DETDEM.DAT:

Deterministic monthly demands for the twelve separate demand zones which are supplied by the combined pumping and reservoir system are found in this file. Within the model these separate values are combined into totals representing the overall demands supplied by individual subsystems and pumpstations. These collective demands are used in the "PREVIEW" mode and for future month predictions with the previously discussed inflow values. The demands in the various zones increase over the 30 years according to predicted demographic changes in that time (ref. 1, chapter 6).

(b) Stochastic (generated) inflow, STOINF.DAT:

The inflow values were generated using the "Key station - satellite station" technique as discussed in the water resources study (ref. 1, chapter 5). The results are a set of monthly inflow volumes for each storage in the metropolitan system including the two weirs being modelled. No values were generated for the service reservoirs (chapter 5, section 5.4) since they receive no inflow.

(c) Stochastic (generated) demand, STOCDEM.DAT:

This demand file follows the same format as the deterministic demand file, however an important point to note is that these demands, while based on the deterministic values, are correlated with the stochastic inflow.

10.3 Output Data

There are four files generated by the simulation which are used to provide the information for the final model output at the end of the session. They are concerned with storage operation, pump operation and performance of the user on a subsystem and total system basis.

10.3.1 Storage Operation, OUTPUT.DAT:

Data which are stored in this file consist of monthly starting storages, inflows, demands, spill, deficit, transfers in and out, and the associated pumping costs. For each subsystem therefore the monthly management is recorded for future reference. The costs recorded are those incurred only by the particular subsystem in obtaining pumped transfers. If it is possible to transfer out of a subsystem as well as into it, as in the cases of Warren and Torrens subsystems, then each subsystem is billed only for the pumped transfer that remains in its storage and any transfers out take their associated costs to the receiving subsystem. Thus a transfer to Warren reservoir from the Mannum-Adelaide pipeline of 425 megalitres may cost nothing to Warren subsystem since it in turn is transferring to South Para subsystem a volume greater than the 425 megalitres, and South Para therefore stands the cost. Transfers out are signified by a minus sign (-) while transfers in are positive.

Demand values for each month include not only the total subsystem demands but also the monthly evaporation.

10.3.2 Pump Operation, OUTPMP.DAT:

The pumping operation data records the actual pumping strategy at each pumpstation. The pumping configuration is stored as:

Number of pumps, Daily duration, Number of weeks

where the daily duration is given as offpeak (=1), onpeak (=2), special on peak (=3). To indicate how much water is available to the metropolitan system, the total pumping at the station, pipeline demands and the net available pumping are stored. The supply from Millbrook reservoir to the Mannum-Adelaide pipeline is also included, as is its pumping bill in the total costs if it supplies to Anstey Hill water treatment plant rather than Little Para subsystem.

10.3.3 Performance of the Operator, SUBFORM.DAT, TOTFORM.DAT:

Data is stored on monthly, yearly and whole simulation averages to enable a comparison of system operation over and above the subsystem management. Values are written to the files each month to avoid excessive internal storage of data. Further detail is given in chapter 11.

CHAPTER 11

11. EXPERIMENTAL RESULTS AND ANALYSIS

11.1 Introduction

This chapter discusses the experiments performed using the system model and the analysis of results so obtained. The model performed its role as a simulator quite adequately, with no major grievances being voiced by any of the operators who used it. However, a section outlining improvements suggested by the operators is included in this chapter.

Difficulties were experienced at times with the graphics aspects of the model, there being occasions on which communications failures between host and satellite processors caused automatic program abort. In such cases there was no alternative other than to resimulate the appropriate period. This may be seen as supplying the potential for an operator to obtain "prior knowledge" of the inflow and demand sequences, thus affecting his subsequent performance in the resimulated period. Immediate repetition of a time sequence after computer failure was avoided where possible, there remaining usually two other sequences to complete before being compelled to use the same data set again. In addition, due to the considerable time lapse between experiments (one to three weeks), there was sufficient opportunity for an almost total loss of recall on any initial data memorisation. The computer communication problem, while not solved, was circumvented by simulating in one year intervals for each two year sequence. Thus there was only ever one year which required resimulation.

Final storage data from the first year became the initial storage data for the second year's simulation.

The choice of a two year set as the basic unit of the experiments was governed by the speed of the operators in completing a simulation run. The time taken for a two year set ranged from 1½ to 2 hours.

Two hours is quite an extended period of time for concentration to be maintained at an adequate level for the productive use of the model. It should also be noted in this context that the model offers a severely reduced time scale for management decisions which would normally be considered over days rather than minutes. Thus to avoid operator fatigue and errors of judgement due to loss of concentration, the two hour limit and hence the two year unit was used in the experiments.

An alternative approach to the problem would have been to use a longer period of time (say, six years) and split it into three successive simulations of two years each. The limiting factor in this case was the limited availability of the operators who gave their time to be a part of the experimentation. Splitting up the simulation over the previously mentioned time span of weeks would have caused a significant loss of continuity for each experiment as a whole, effectively reducing them to individual experiments. It was also desired to see variation of operation over wet, dry and normal years on an individual basis and the two year sequence was adequate for this.

As a result of the previous considerations, three different data sets, each of two years duration, were chosen from the total of 30 years' data available. Their characteristics gave an adequate but not extreme spread of system inflows and demands to test system management throughout the system. In terms of the 30 year data set (starting in January 1976) the three series were from July to June in the following years:

1. 1977 to 1979 (dry to dry)
2. 1987 to 1989 (wet to wet)
3. 1990 to 1992 (wet to dry)

11.2 Experimentation

For the comparison of simulated performance between operators to have any true validity, individuals were required who at least had some operational experience with the real system. Without this background, concepts such as off-peak or on-peak pumping, high and low storages and large and small transfers would have to be learned until they became second nature, so that finally, any incompetent operation of the model could not be put down to ignorance of the system.

In addition, those who have had time to develop an "operations feel" for the system should also have developed an individual philosophy on system operation which they can apply to the model and thus show their individuality.

Three officers of the Engineering and Water Supply Department were made available to operate the model. All three had experience and responsibility of full time management of the system ranging from six months to several years in official capacities as either the Pumping Engineer or his assistant. This experience was considered adequate background.

Before commencing the experimental simulations, each operator was allowed to familiarise himself with the model through several short trial simulations until he felt confident of his ability to operate the model. Thereafter the operators were individually put in control of the model for the three separate two year simulation periods. Each experimental trial was considered as a separate sequence and the starting storages for the subsystems in each trial were the same for all the operators.

The set of starting storages used in the experiments are the "target" storages for each subsystem. These values are used in the real system as the minimum reference points to be obtained at the end of each financial year. They have been developed over the life of the system as the finishing/starting storages which give minimum acceptable security when combined with pumping in the event of drought, and adequate unused buffer storage in the event of excessive inflow.

At the end of each simulation, the variation between the final storages obtained and the target storages were used to help determine operational performance.

11.3 Method of Evaluation

Early in this thesis study the question was posed of how different operators would manage the system model. To this end, a means had to be found that the computer might conveniently implement to monitor the methods used and their efficiency of operation. From data obtained in the simulation, performance parameters needed to be calculated which could indicate the operational bias of the system user.

The two basic variables on which the operation of any reservoir system depends are the rainfall (natural inflow) and the demand conditions. Maximum use of natural inflow reduces the requirement for extra pumped supplies which would increase costs and reduce efficiency. At some stage, however, demand will exceed inflow considerably, requiring some pumping to replenish storages. Just how much pumping is used depends on the operator's preparedness to gamble on obtaining more rain for natural inflow.

This argument indicates that parameters involving the inflow, demand and pumped transfer characteristics of the simulation may produce a reasonable picture of the operator's philosophy. The volume held in each reservoir is another potential variable, but storage is perhaps more of an "action-triggering" mechanism, since a high storage at the end of winter and low storage at the end of summer are common management practice, while the opposite conditions are certainly unacceptable. It would appear rather that the time of occurrence of any given storage is the important factor which controls what remedial action, if any, is to be taken. Hence a temporal distribution of any parameters from July to June should enhance the definition of human performance. This is also important for inflow and demand considerations since these are highly time dependent (seasonal).

11.3.1 Choice of parameters

Two parameters were chosen to attempt to quantify explicitly the efficiency of system operation. They used the inflow, demand and pumping elements mentioned previously.

(a) Fraction of inflow used to supply demand:

$$(D-T)/INF$$

where D = subsystem demand

T = transfer into the subsystem from external sources

INF = natural inflow to the subsystem

This indicates how efficiently the inflow is being used. Any pumping transfers to the subsystem reduce the amount of inflow required to supply the subsystem demands and hence leave a greater volume available to boost the reservoir storage. A low or negative value for this parameter should indicate a conservative approach, since excessive transfers are being used to keep storages high.

(b) Fraction of pumped water used to supply demand:

D/T

where D = subsystem demand
T = transfer into the subsystem from external sources

This indicates how much of the extra water supplied to the subsystem is being used to directly satisfy the immediate demand, and how much is being put into the reservoirs to make sure that there is sufficient to meet future demands in case the rainfall proves to be sporadic.

A low value should indicate that large transfers are being supplied to boost reservoir storages, implying a conservative approach.

(c) Results of use:

These two parameters were included in the model and calculated monthly for each operator. Two unforeseen problems occurred with them, being the relative magnitude of the different elements and their variability.

Due to the size of the demand zones supplied by individual subsystems, summer demands are often very large, effectively swamping the effects of transfers into or out of the subsystem. Similarly, inflows during winter from large natural catchments are much larger than the relatively modest transfers into subsystems. As a result, parameter values seesaw between very large values in summer and small fractions in winter which are not much affected by the relatively small variations in transfers between the different operators' management policies. These effects make the parameters of little use in their current state.

11.3.2 Other Alternatives

Although a single, explicit and quantitative measure of system efficiency does not seem feasible, other avenues exist for the comparison of different methods of system operation. The most important of these is the pumping costs which accrue during each year of operation. These highly variable costs indicate indirectly the amount of water pumped, and more importantly enable an assessment of the relative economic efficiency of different operations. In some respects pumping costs are a better form of operator assessment than at first appears. As has been explained in chapter 5 (section 5.5) there are three electricity tariffs, used throughout the financial year, of different unit costs. The aim of the system operator is thus twofold - not only to minimise pumping, but also to ensure that any pumping required is performed at the lowest cost rate possible. As a result, a conservative operator will have a higher pumping budget result than a "gambler" who uses less pumping but risks empty reservoirs instead. This implies that the cost of pumping in the system may be used as an index of the degree of operator conservatism.

This in itself would provide the basis for an adequate operator comparison if all the operators, having started on the same minimum target storages, finished on exactly the same volumes. Of course this never happens in practice and so some economic allowance must be made for the excess or deficit between the operators' finishing storages and the target values.

In general if the reservoirs in the real system at the finish of a year are above the minimum targets then no attempt is made to draw them down to the exact target values. The excess water is considered either as a bonus if occurring as the result of unforeseen natural inflow, or as a costly mistake of judgement if due to excessive pumping. On the other hand any deficit below the minimum targets is viewed with concern, since it means that extra pumping will need to be done in the next financial year to regain the margin of security given by the targets.

It is this approach to storage variation which has been used to bring the results of the different operators to a comparable form. If there is any excess storage above target at the end of the two year simulation it is ignored. If the excess is in fact due to excessive pumping, the operator has already penalized himself by having a larger pumping cost than required.

However, volumes spilled, deficits in supply and discrepancies between targets and lower finishing storages are given an economic cost according to the average cost of supplying water over the two years

i.e.

cost

$$= (\text{deficit}+\text{spill}+\text{discrepancy}) * \frac{\text{TOTAL DEMAND}}{\text{TOTAL PUMPING COST}}$$

This results in a total cost for the operation:

$$\text{TOTAL COST} = \left(\begin{array}{c}\text{TOTAL PUMPING}\\ \text{COST}\end{array}\right) + \left(\begin{array}{c}\text{TOTAL ECONOMIC}\\ \text{COST OF STORAGE}\end{array}\right)$$

Hence the different operators may be compared according to their total cost of two years operation to find which is the most conservative and which is the least conservative.

11.3.3 Little Para Subsystem

At the time of creating the model, the operational split of demand between the South Para and Little Para subsystems was still uncertain and under review. As a result, the original proposed operating rule for Little Para Subsystem was included in the model. Subsequent operation of the model showed that demands on the subsystem were insufficient to affect its seasonal storage to such an extent that concentrated operation of Little Para storage was required. This resulted in the frustrating situation of South Para subsystem being drawn down by summer demands and so requiring Swan Reach pumping while Little Para gained quite substantial storage which could not be used to relieve South Para due to the obsolete operating rule. As a result, the operators left Little Para untouched in the experiments, resulting in Little Para having no influence on the overall simulation. For this reason the Little Para subsystem was not included in the analysis.

11.4 The Operator's Viewpoint

It would be fallacious to consider the results of an interactive model such as this without including some of the feedback and comments from the operators concerning the ease or difficulty of model use and their suggestions for improvements.

The following paragraphs discuss aspects of the model from the operator's point of view.

11.4.1 Model Usage

(a) Response time was acceptable as a general rule. The system balancing calculations at the end of each month (30 to 50 seconds), while slower than individual subsystem previews, did not take an excessive amount of time. This view is probably due to the operators' appreciation of the amount of calculation being performed.

A shorter delay would however be an improvement. Lightpen response time was unnoticed and no one felt they were under pressure from a constantly demanding model.

(b) The predictive storage levels on the right hand side of one reservoir in each subsystem proved useful in "tight" situations. Under normal operating conditions when the storage is high and the predictions are not near empty or full, they are ignored. However when the storage is approaching either extreme condition, the values taken by the predictions become more important and are considered when framing a monthly strategy.

(c) The economic prediction elements - cost per kilolitre supplied and the fraction of demand supplied by pumping - are less useful than had been hoped. Being updated on the basis of individual monthly demand data, the parameter values change with changing demand even though the same pumping strategy is in operation. An improvement would be to give an averaged value up to the current position in the financial year so the operator might see his position relative to the past months' strategies.

11.4.2 Model Improvements

(a) At present the use of a monthly time interval requires a commitment each month to a single strategy of transfers and/or pumping. While this is adequate for system operation when spill or deficit are unlikely, a more realistic operation would be to allow the optional use of a shorter time interval, for example one week, to step through critical periods of spill or empty storages. This would allow a closer tailoring of management to system requirements.

(b) Since the implementation of the model, the operating rule of Little Para reservoir has been modified to accept more demand from the Barossa trunk main than originally programmed. The facility to change the fraction of shared demand taken by South Para and Little Para subsystems would be a necessary improvement to allow for different operating rules on the Little Para subsystem.

(c) While the fixed operating rules for the service reservoirs in the system give adequate minimum holding storages, greater realism would be obtained by allowing these reservoirs to accept more than the minimum.

At present the set storage values prevent any excess inflow from being taken, thus causing spill of potentially usable water.

(d) In a similar manner, rather than setting the actual storage in Millbrook reservoir, the model could set the minimum acceptable storage, so that if any excess inflow were received, it would stay in Millbrook and not be passed down to Kangaroo Creek reservoir.

11.5 Results: Comparison of results

In addition to the three officers of the Engineering and Water Supply Department, the author included himself as a fourth operator for the three simulations. It was realized that he had an intimate knowledge of the system - model relationship and was far more familiar with the details of the model functions than the other three individuals. In this sense he had priveleged knowledge of the system. Nevertheless, he was not in the position of knowing the detail of the inflow and demand files until after he had performed the three sessions of simulation himself and so was in the same state as the other three operators in attempting to plan system strategies around unknown weather conditions.

A table showing the results of each of the operators in the three experiments is given in table 11.1 It can be seen that, despite a similar basic training there is a significant economic variation in the different operators' management results.

To illustrate the ranges of system operation which were exhibited in the experiments, the least and greatest cost operations for the period 1987-89 have been chosen for detailed discussion, i.e. the methods used by the author and operator 3. It is this particular simulation which shows the greatest difference between the operator cost values. Details of these two operations in terms of individual subsystems can be found in appendix A.

11.5.1 Comparison of Operation

Table 11.2 shows a summary of the calculations used to arrive at the final costs for the two operations. It is worth noting at this point

YEAR SEQUENCE	OPERATOR COSTS: $			
	AUTHOR	1	2	3
1977 - 79	8 119 960	8 375 884	7 841 819	8 597 334
1987 - 89	5 692 121	6 422 055	6 808 596	7 658 256
1990 - 92	6 664 861	7 014 642	7 312 368	7 529 217

TABLE 11.1 Summary of Total cost of two years' operation for each operator.

OPERATOR	TOTAL PUMPING COST ($)	TOTAL SYSTEM DEMAND megalitres	COST PER MEGALITRE SUPPLIED	LOST STORAGE (ML)					TOTAL COST OF LOST STORAGE	TOTAL COST
				MYPONGA	ONKAPARINGA	TORRENS	WARREN	SOUTH PARA		
AUTHOR	4 774 202	465 721	$10.2/ML	1 312	47 047	43 672	-	-	$ 947 19	$5 692 121
OPERATOR 3	6 150 750		$13.2/ML	-	62 638	51 407	160	-	$1 507 506	$7 658 256

TABLE 11.2 Comparison of least and greatest cost operation in 1987 - 89.

that the large values of lost storage for the Onkaparinga and Torrens subsystems are due in part to excessive inflows at Clarendon Weir and Deep Creek which could not be transferred into the system storages and were therefore spilled to waste.

What becomes immediately apparent from the table is the large difference in total pumping costs, of the order of $1.4 million. This indicates that operator 3 pumped greater amounts from the Murray River to augment storage than did the author. The differences in lost storage among the subsystems also show that, due to the larger pumping, a greater amount of spill occurred under the management of operator 3.

These two factors are responsible for the final difference in total management costs of nearly $2.0 million.

To see in more detail how this difference occurred, the plots of subsystem operation in appendix A are used. Three general points are immediately obvious from an examination of the graphs:

1. The quantity of pumping into the subsystems by the author is lower, and is also left later in the year than by operator 3.

This naturally causes pumping costs to be lower, but there is a corresponding heavier reliance on natural inflow to help replenish the storage.

This has its associated higher risk of insufficient inflow which would require heavy pumping (with great expense) to avoid the storage registering a deficit.

2. Due to this avoidance of early pumping, the author uses much more of the storage in the Onkaparinga and Torrens subsystems. This leaves less of a safety margin against failure of winter rains.

3. Transfers from Myponga to Onkaparinga and from Millbrook to Anstey Hill by the author may be smaller but are more frequent during heavy summer pumping than those of operator 3. Such a method allows a lower pumping tariff to be used because the load on the pump stations is reduced - hence pumping costs are lower.

   Such transfers during summer cause a higher risk of reservoir non-replenishment by winter inflow, perhaps resulting in an inability to satisfy demands in future years.

Such results taken in isolation could be construed as simply a chance occurrence of one operator working more economically than another. However, table 11.1 shows that this trend is consistent for all three experiments. Of course the sample involved in this research is too small, and the range of experiments too limited, to be able to use this as the foundation on which any statistically significant conclusions may be formed - but some interesting implications are apparent with regard to conservative, as opposed to non-conservative operation - particularly when it is realised that the author is the least operationally experienced model user of the group, while operator 3 is by far the most experienced, with several years of system management background to call on.

In fact the group was chosen to obtain a range of experience in the experiments, ranging from insignificant for the author, to approximately six months for operator 1, eighteen months for operator 2 and finally six years for operator 3.

To give a picture of the variation of operating procedure across the four members of the group, individual operation of the Torrens subsystem, the most complex subsystem, is given for the same period in graphical form in appendix B. With the inclusion of the remaining two operators, some of the space between the economies of the author's operations technique and that of operator 3 is filled in. Operator 1 pumps more and transfers less than the author and operator 2 pumps still more and transfers even less again. Thus operator 1 is less conservative and operator 2 more conservative in this case. The distinction including these two additional operators is less well indicated by the experiments overall since operator 2 is more economical than both operator 1 and the author in the 1977-79 period (table 11.1).

11.6 Conclusions

This research has not been able to explicitly quantify operator performance in anything other than a comparative manner. A further interesting avenue of research would be to compare the operator controlled result of a simulation with that of a stand-alone computer model using one of the direct optimisation techniques available and gauge performance by investigating just how close to the mathematical optimum solution the operator can reach.

On the other hand, it has been possible to investigate and quantify an economic measure of each operator's performance in the two year periods. Two years is an extemely short time-span in the management of a reservoir system and it would be erroneous to isolate anything more than indications of operator tendencies. The experimental results may be considered as three sets of snapshots of the range of system management which may be expected from different operators. Taking the 1987-89 period of operation as an indication of the management approaches of the four individuals, it can be seen that a less conservative attitude towards system operation suggests significant economic savings. It was acknowledged in an earlier chapter that a non-extreme data set was chosen to provide approximately normal conditions for the model. Thus while conservatism has not proven its worth in these experiments, many more simulations over a wider variety of seasonal conditions would be needed to determine whether the economies of higher risk do in fact pay off even for severe drought and flood conditions. The political consequences of restrictions or floods would also have to be considered.

This, however, is not the main result of the exercise. Neither is the indication over only three simulations that one operator is more economical than another. The main implication to be drawn from the results is that despite a common knowledge of the water supply system and its operation, four individuals do in fact operate it differently with sufficient difference to be economically significant. It is suggested that this variation, while tempered by experience is inherently due to the personal approaches to the trade-off of security of supply for economic bonuses, in other words the personal "gambling" tendency. With the range of results showing cost ranges from $0.75 million to $2.0 million over just two years operation, albeit under controlled conditions, the potential appears to exist for the saving of many times a system manager's salary if his capacity for risk assessment can be effectively matched to the system requirements. Massive scope exists for the investigation of this relatively unexplored field and the benefits in terms of system operation and economics would definitely prove to be an advantage to the community served by a system so managed.

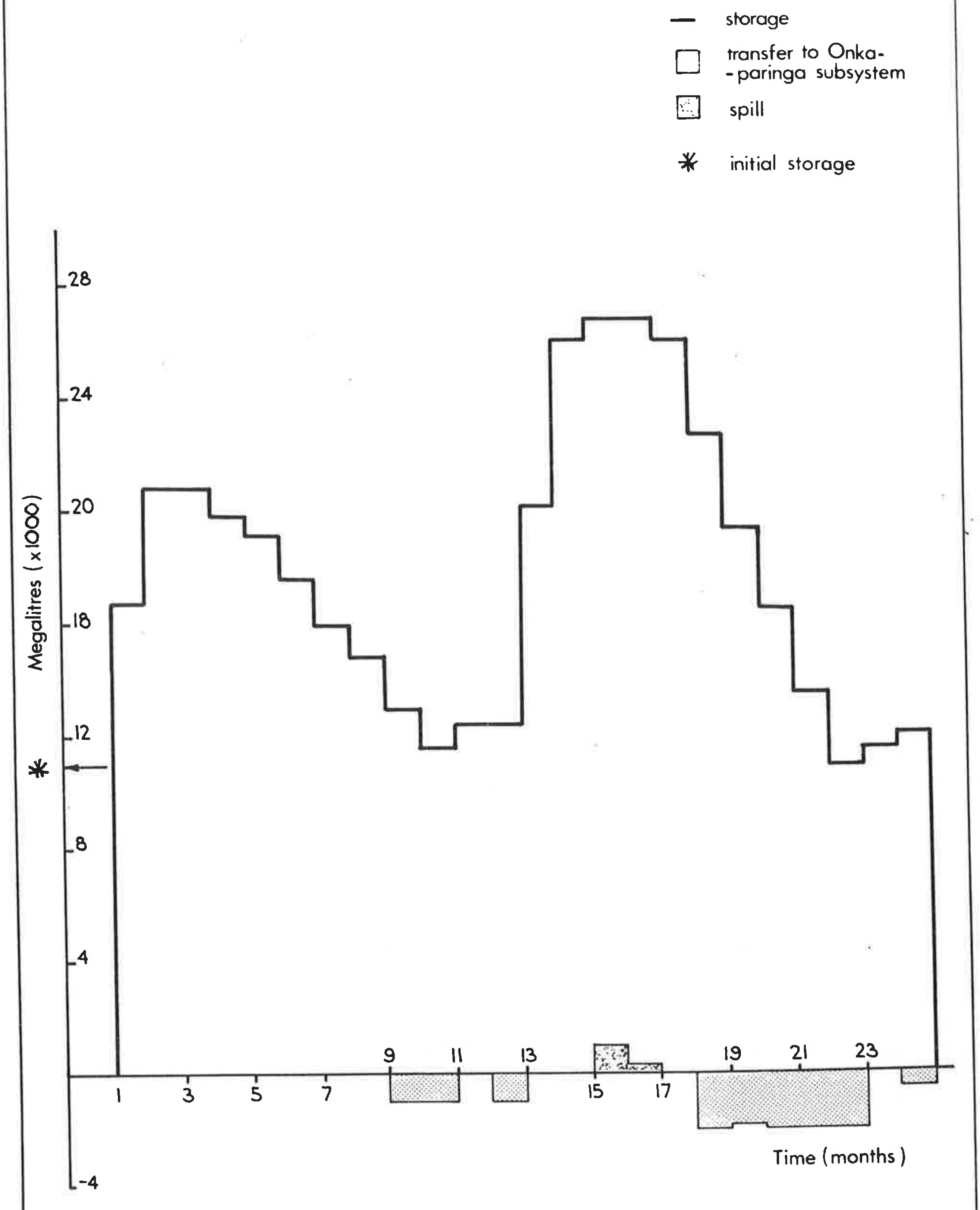
The second implication of this research concerns the gaining of experience.

That inexperienced individuals - operator 1 and the author - who have had limited experience of real system management, can perform well on the simulator, after an initial period of familiarization with the system management techniques, indicates that the use of such a simulator in the learning phase of system operation can prove very beneficial to a manager's overall view of the system, resulting in a system operator better able to cope with system vagaries and more capable of improvements in system operation than an equivalent novice manager without such prior background.

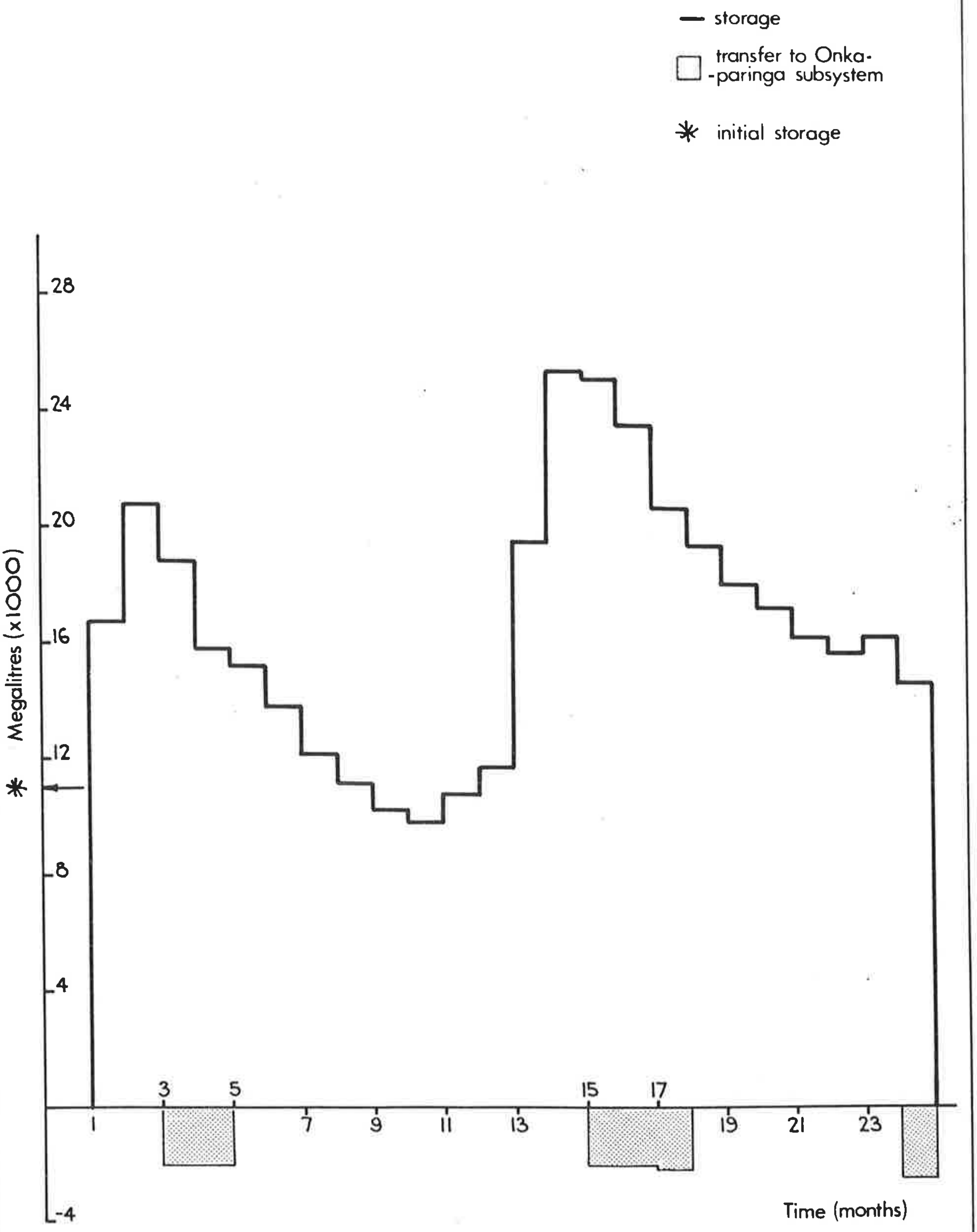
APPENDIX A

MYPONGA SUBSYSTEM
1987-89

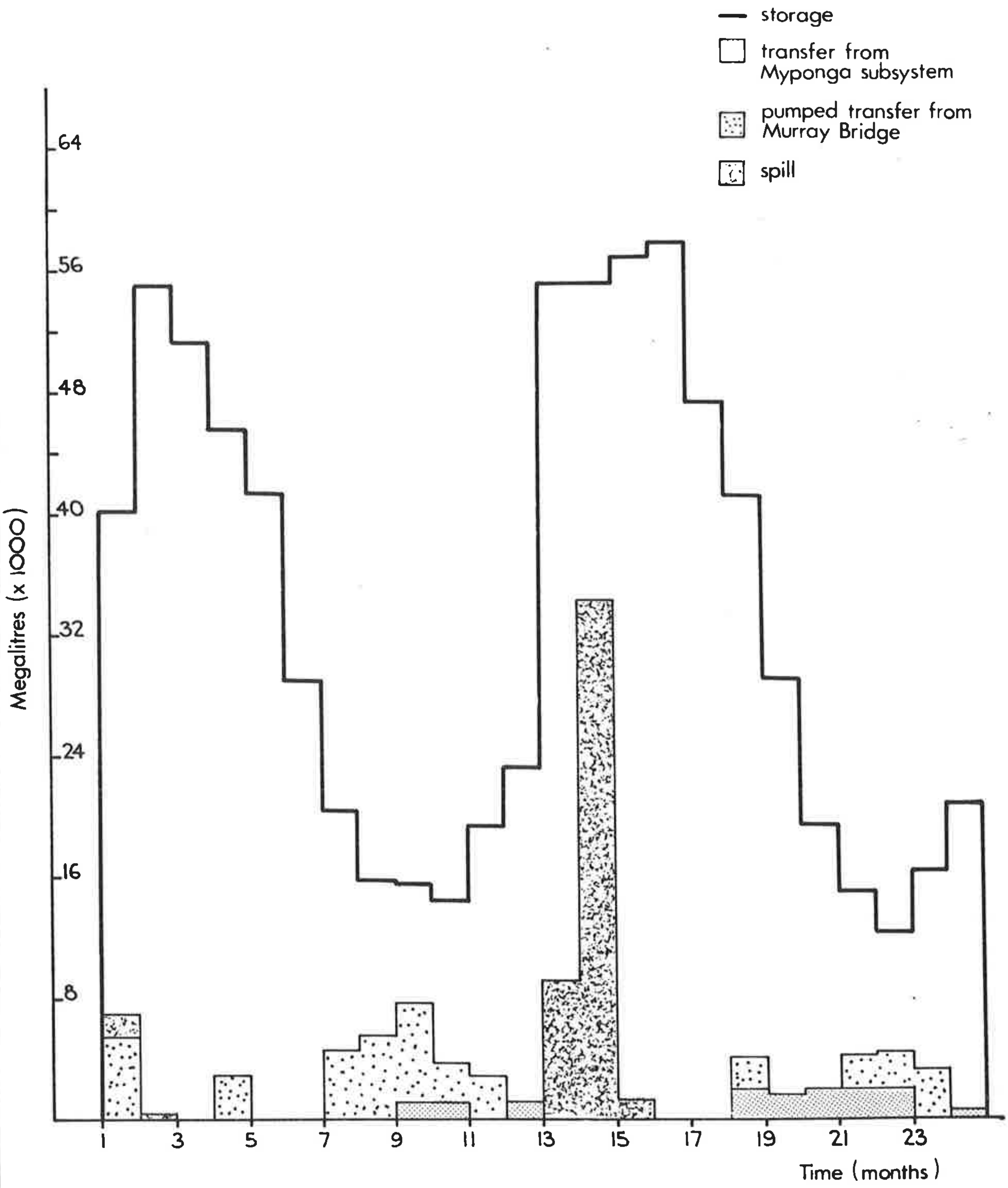
AUTHOR



MYPONGA SUBSYSTEM
1987–89
OPERATOR 3

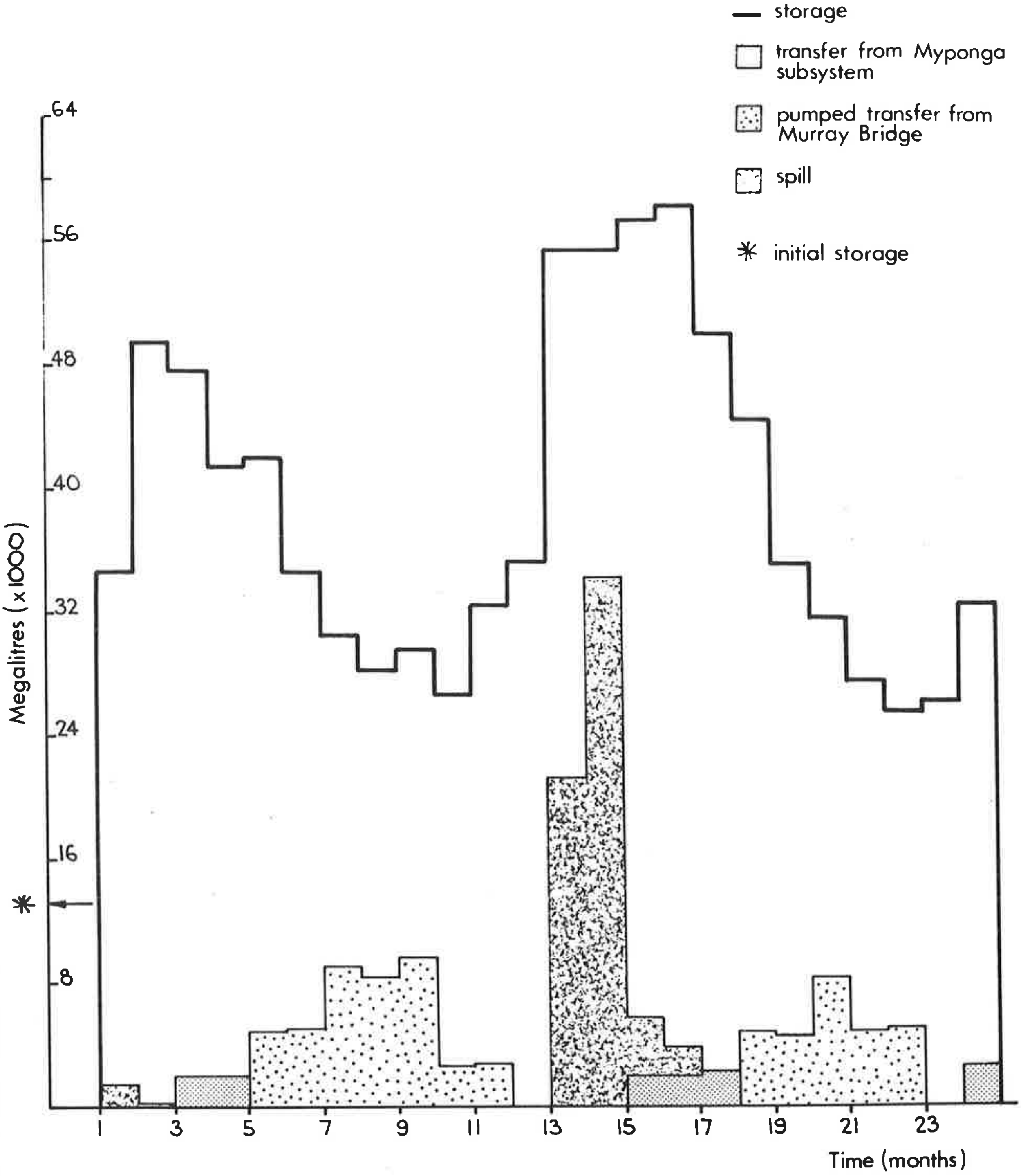


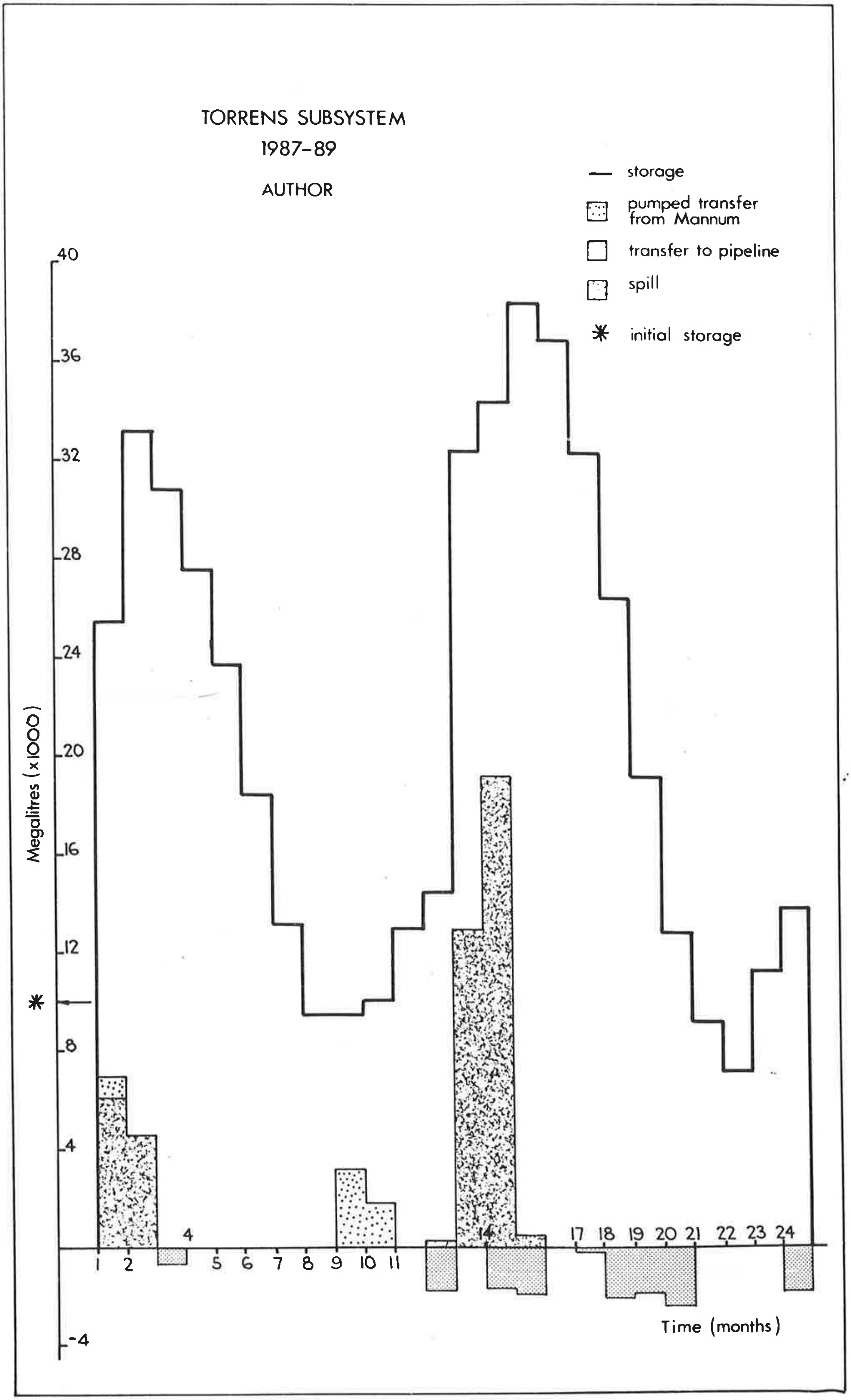
ONKAPARINGA SUBSYSTEM
1987–89
AUTHOR

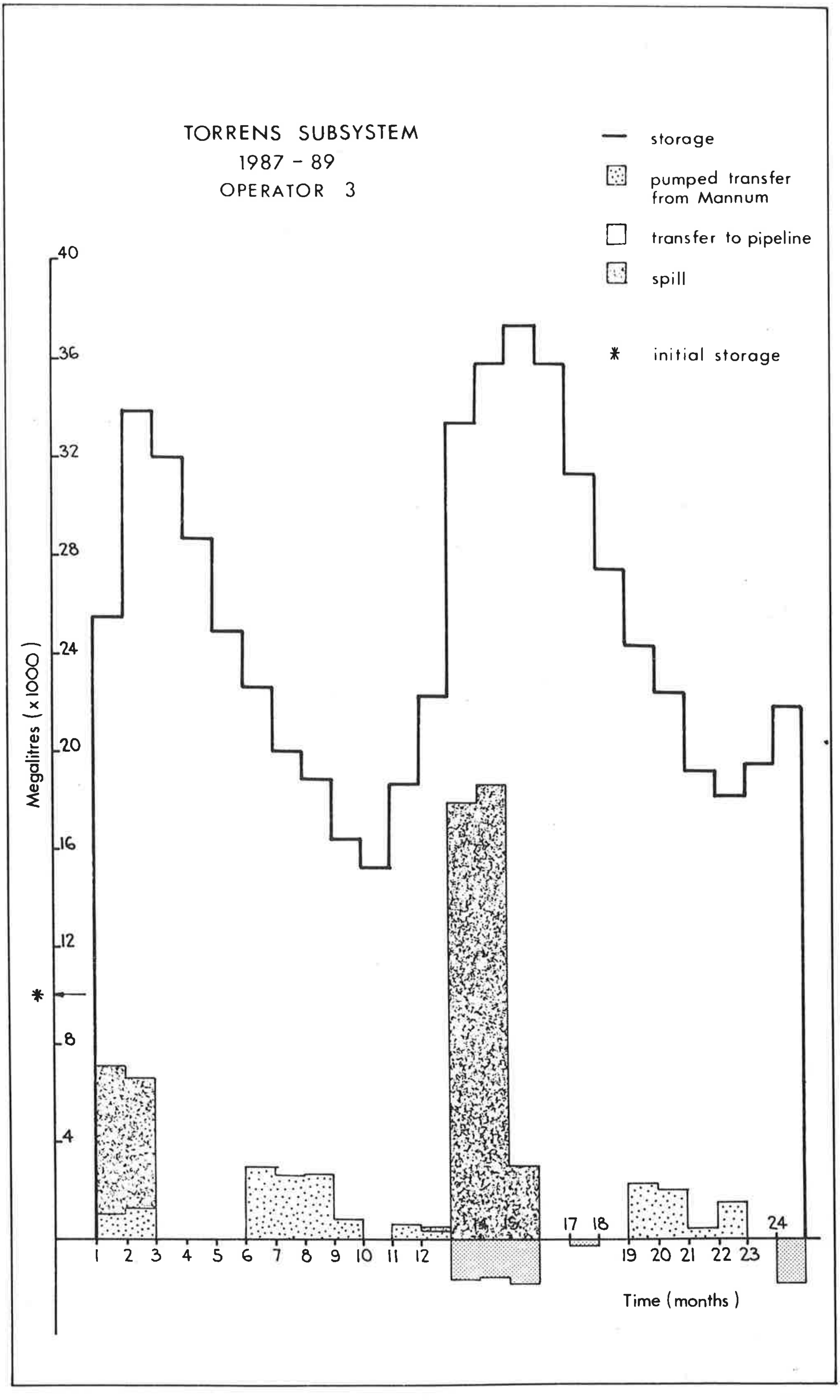


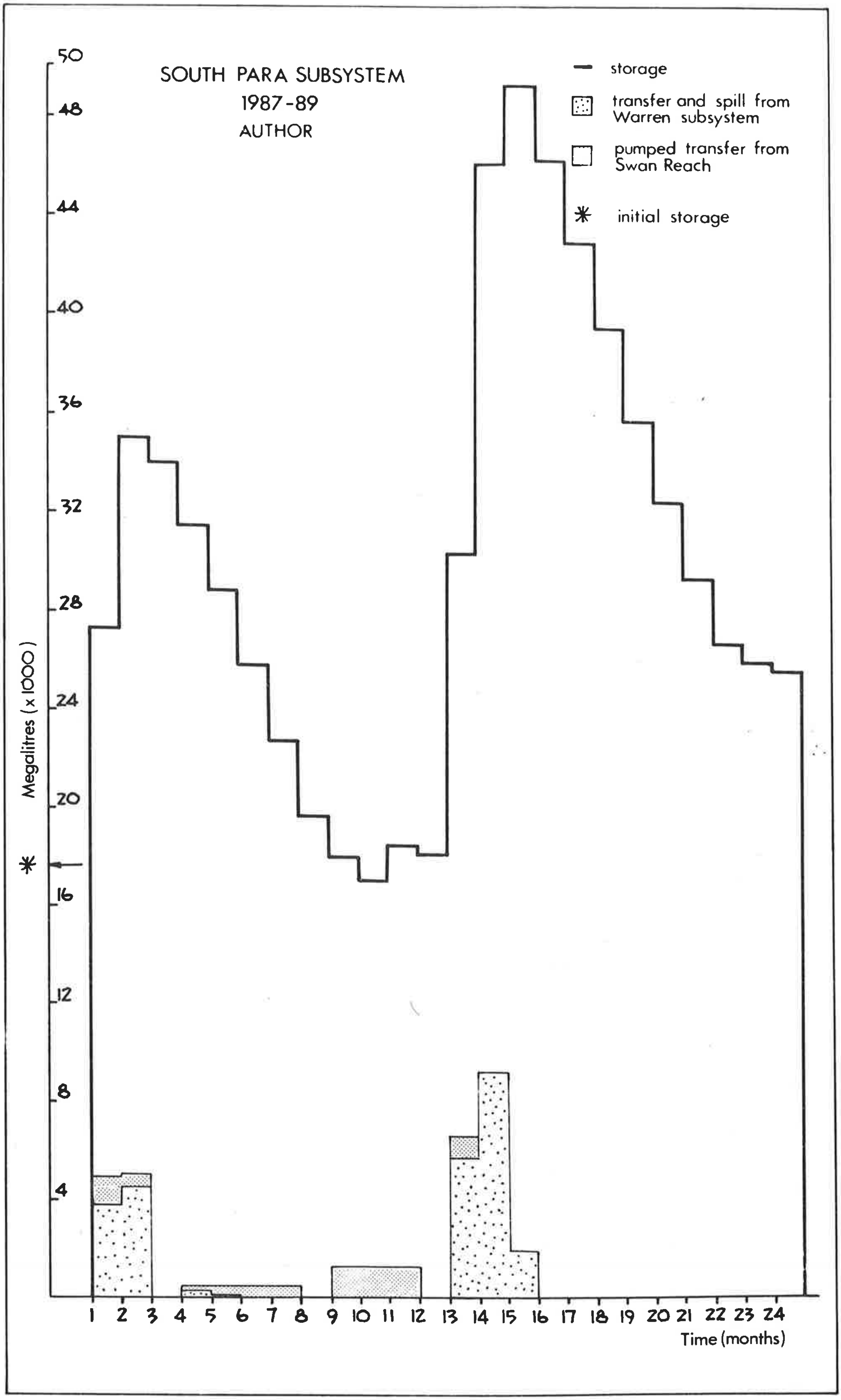
ONKAPARINGA SUBSYSTEM
1987-89

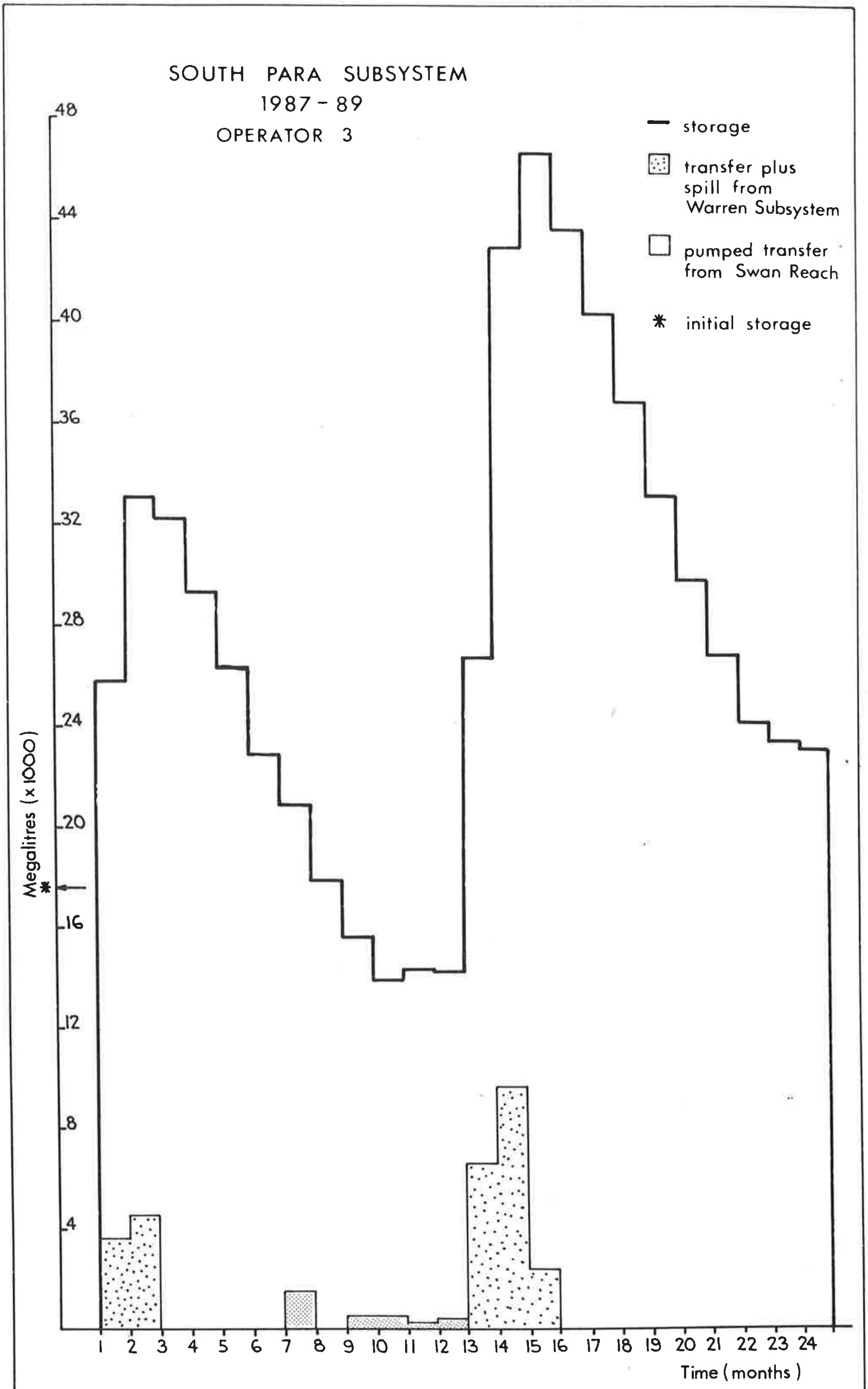
OPERATOR 3



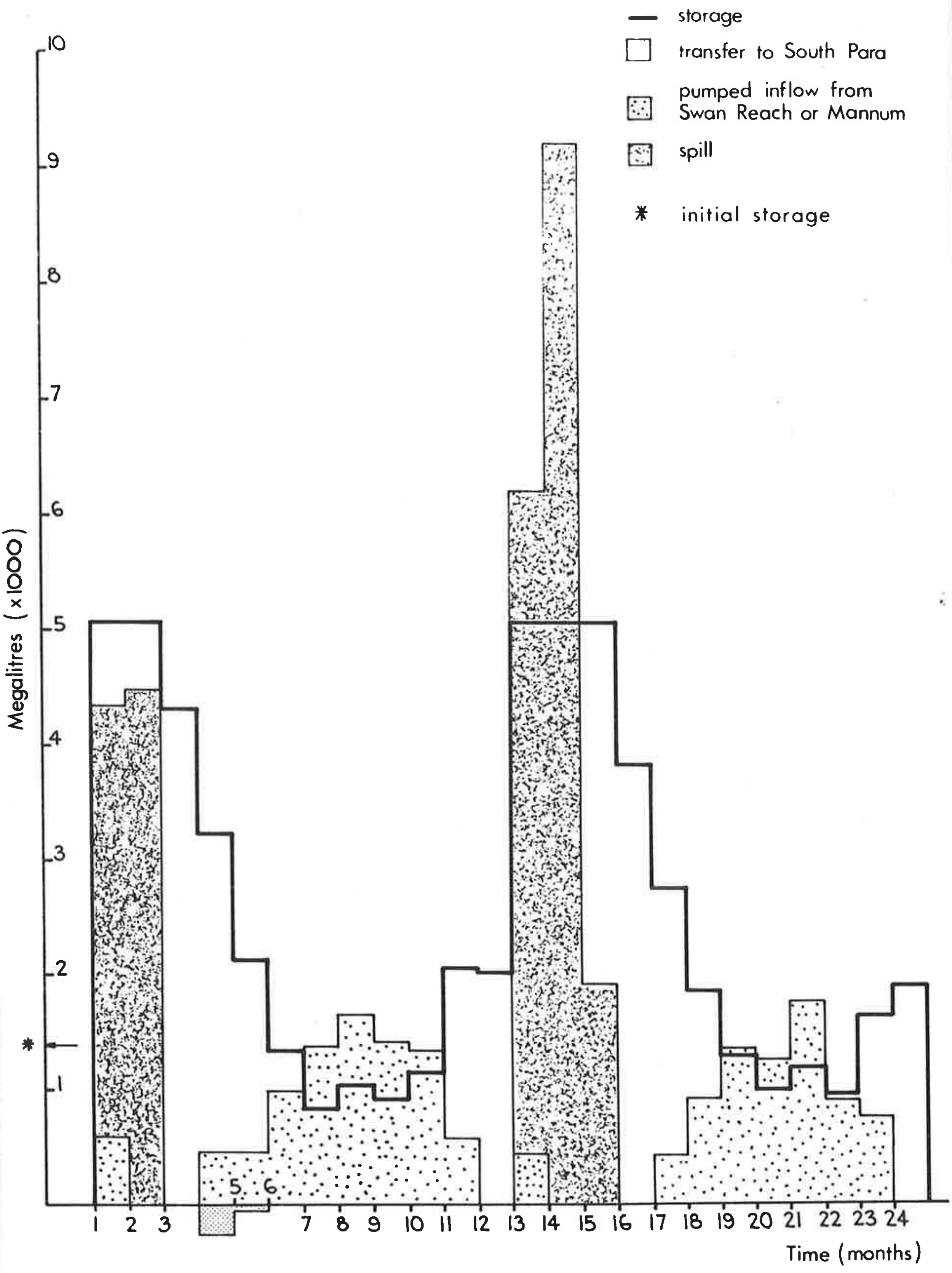

TORRENS SUBSYSTEM
1987-89
AUTHOR
— storage
pumped transfer from Mannum
transfer to pipeline
spill
* initial storage
Megalitres (x1000)
40
36
32
28
24
20
16
12
8
4
-4
*
1
2
4
5
6
7
8
9
10
11
14
17
18
19
20
21
22
23
24
Time (months)

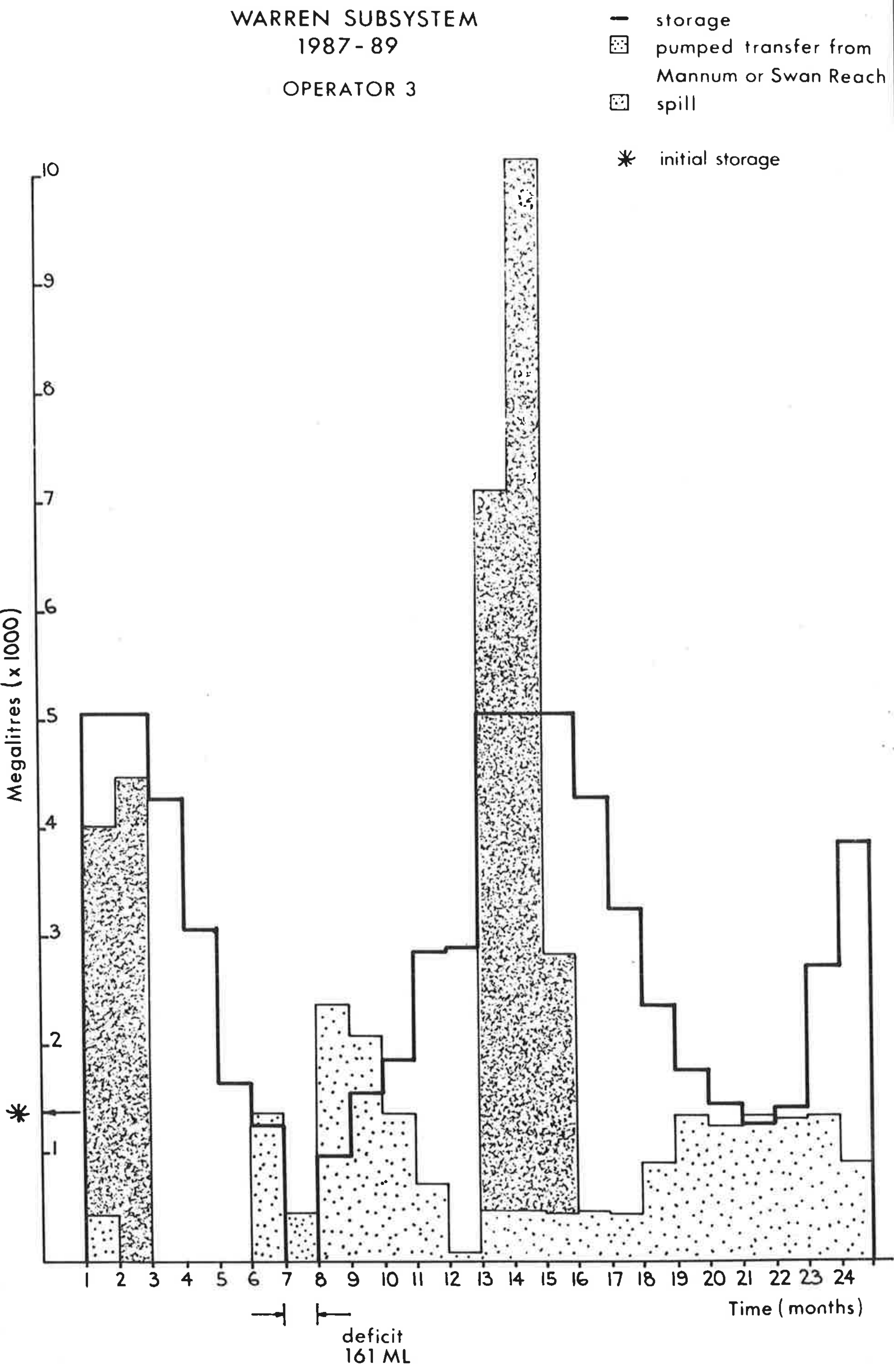

TORRENS SUBSYSTEM
1987 - 89
OPERATOR 3
storage
pumped transfer from Mannum
transfer to pipeline
spill
* initial storage
Megalitres (x1000)
40
36
32
28
24
20
16
12
8
4
*
1 2 3 4 5 6 7 8 9 10 11 12 14 15 17 18 19 20 21 22 23 24
Time (months)


SOUTH PARA SUBSYSTEM
1987-89
AUTHOR
storage
transfer and spill from Warren subsystem
pumped transfer from Swan Reach
initial storage
Megalitres (x 1000)
50
48
44
40
36
32
28
24
20
16
12
8
4
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Time (months)


SOUTH PARA SUBSYSTEM
1987 - 89
OPERATOR 3
storage
transfer plus spill from Warren Subsystem
pumped transfer from Swan Reach
✱ initial storage
Megalitres (x 1000)
48
44
40
36
32
28
24
20
16
12
8
4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (months)

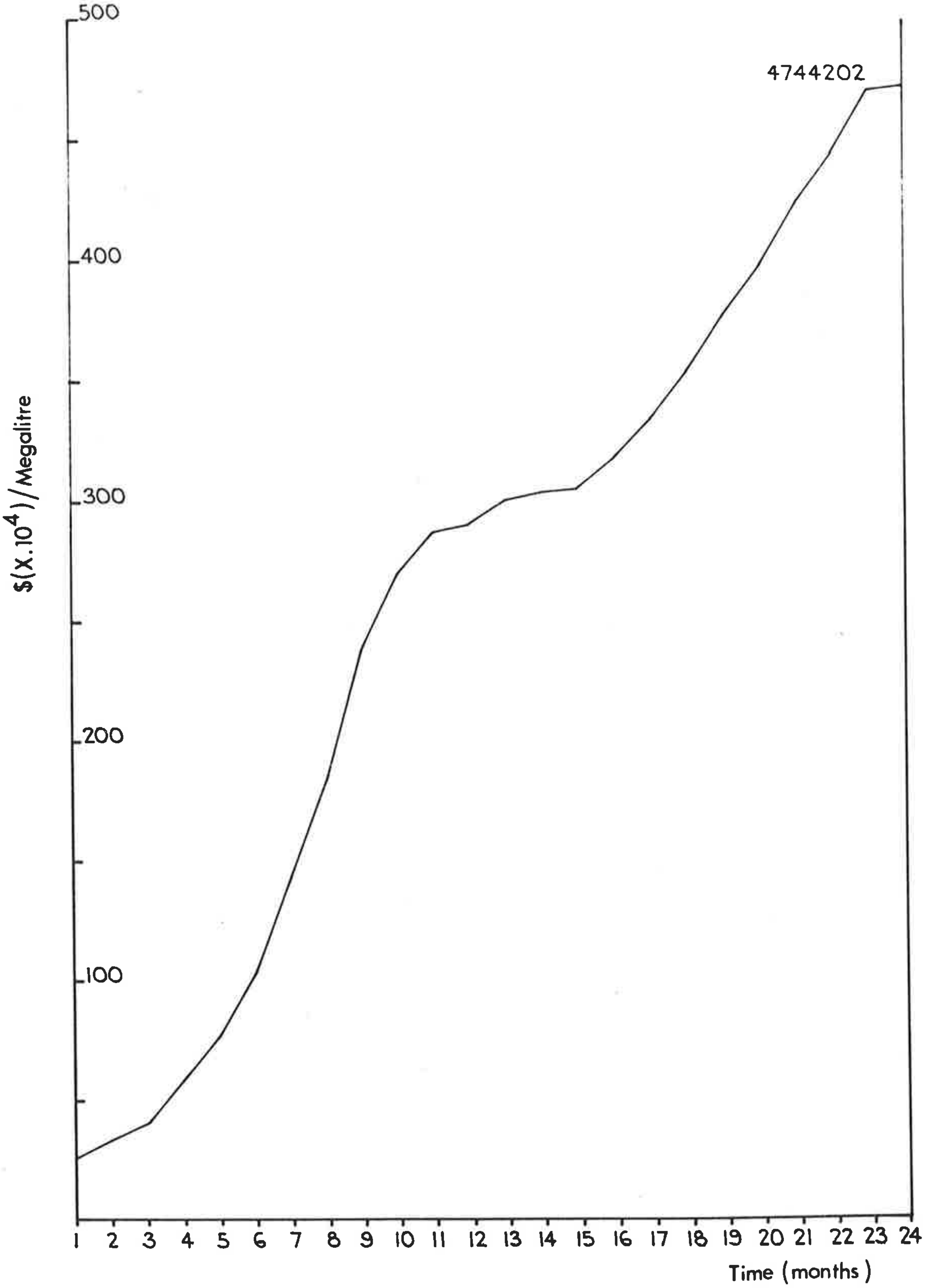
WARREN SUBSYSTEM
1987-89
AUTHOR

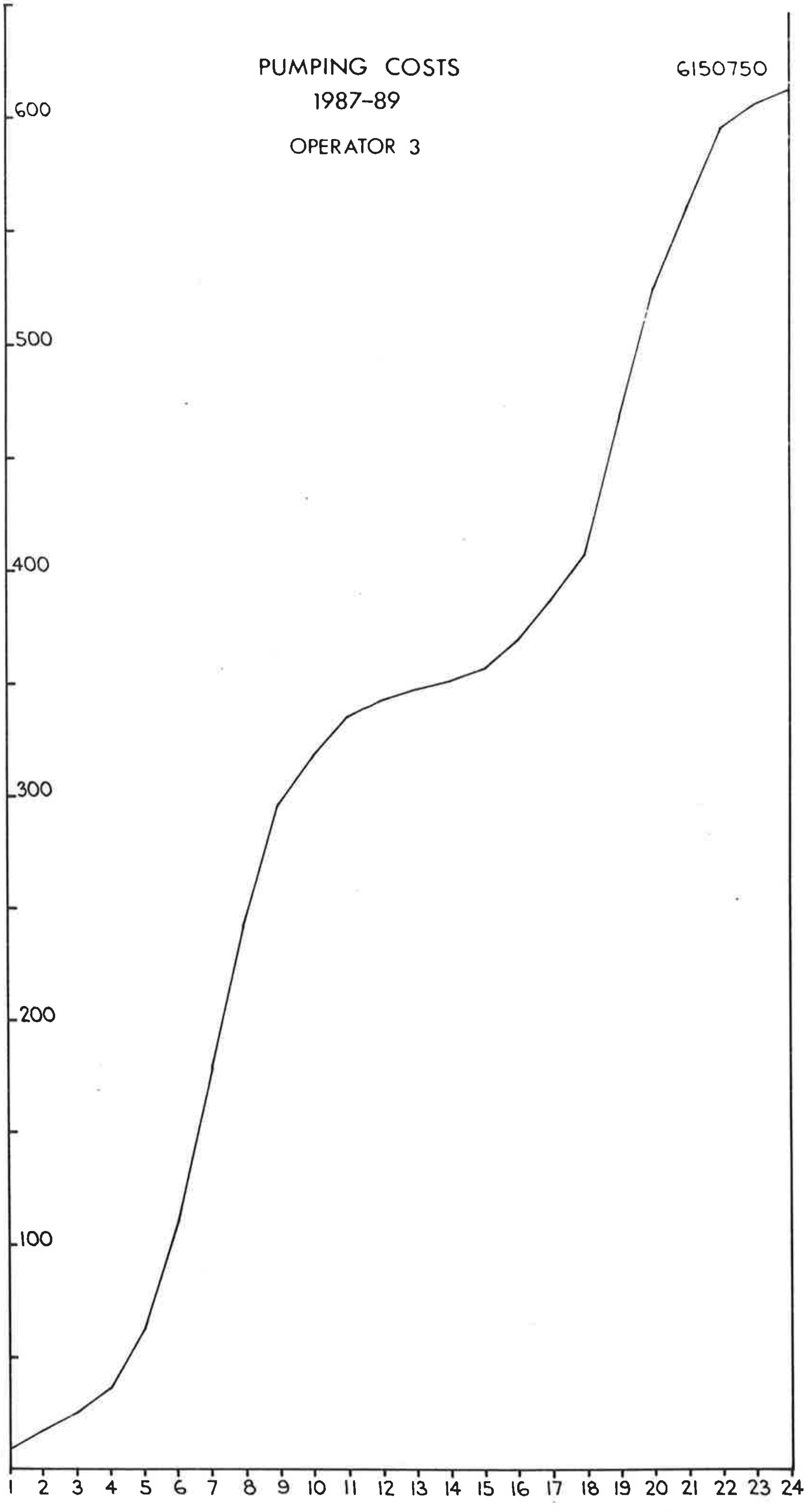



WARREN SUBSYSTEM
1987-89
OPERATOR 3
— storage
▨ pumped transfer from Mannum or Swan Reach
▨ spill
* initial storage
Megalitres (x 1000)
10
9
8
7
6
5
4
3
2
1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (months)
deficit
161 ML

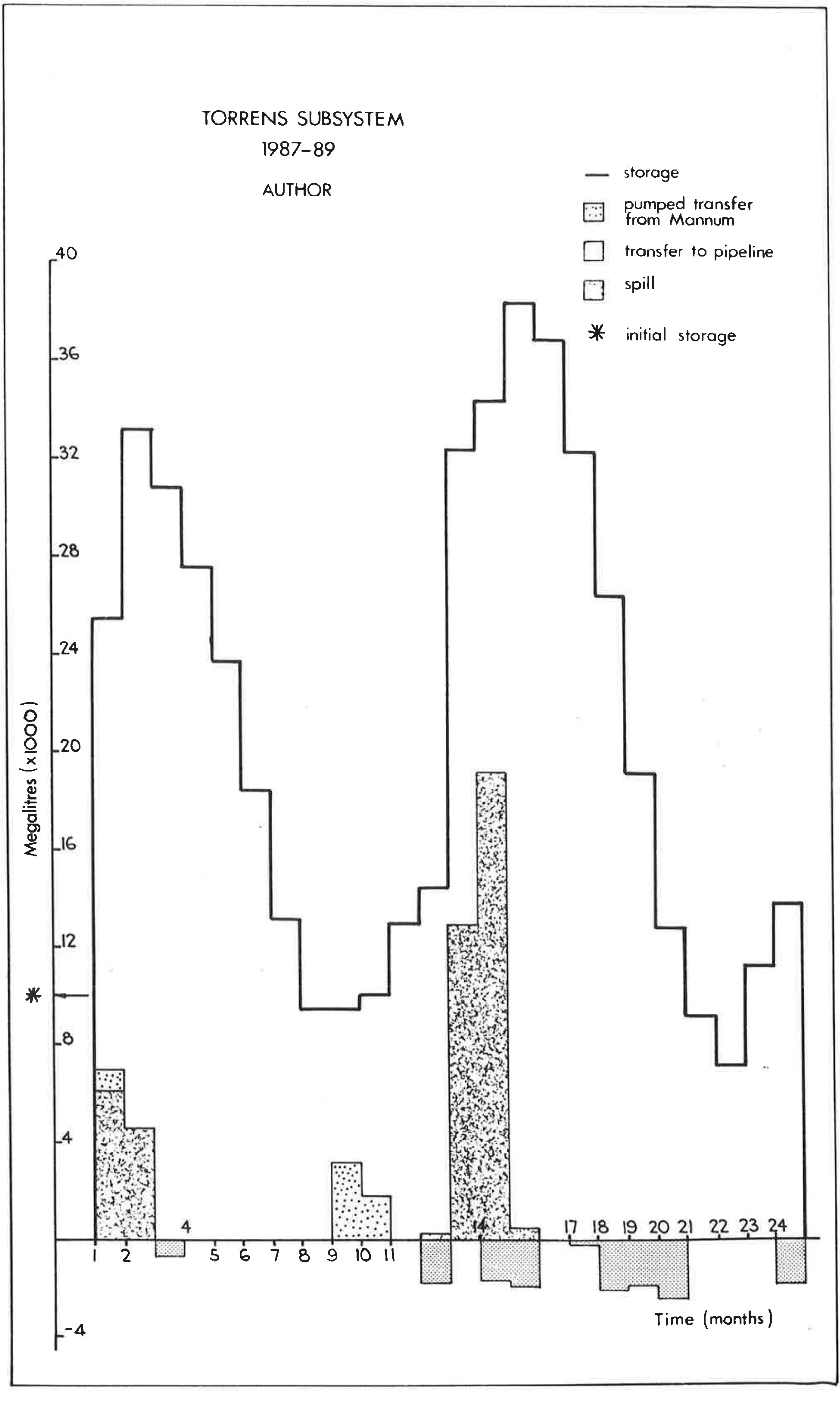
PUMPING COSTS
1987-89

AUTHOR

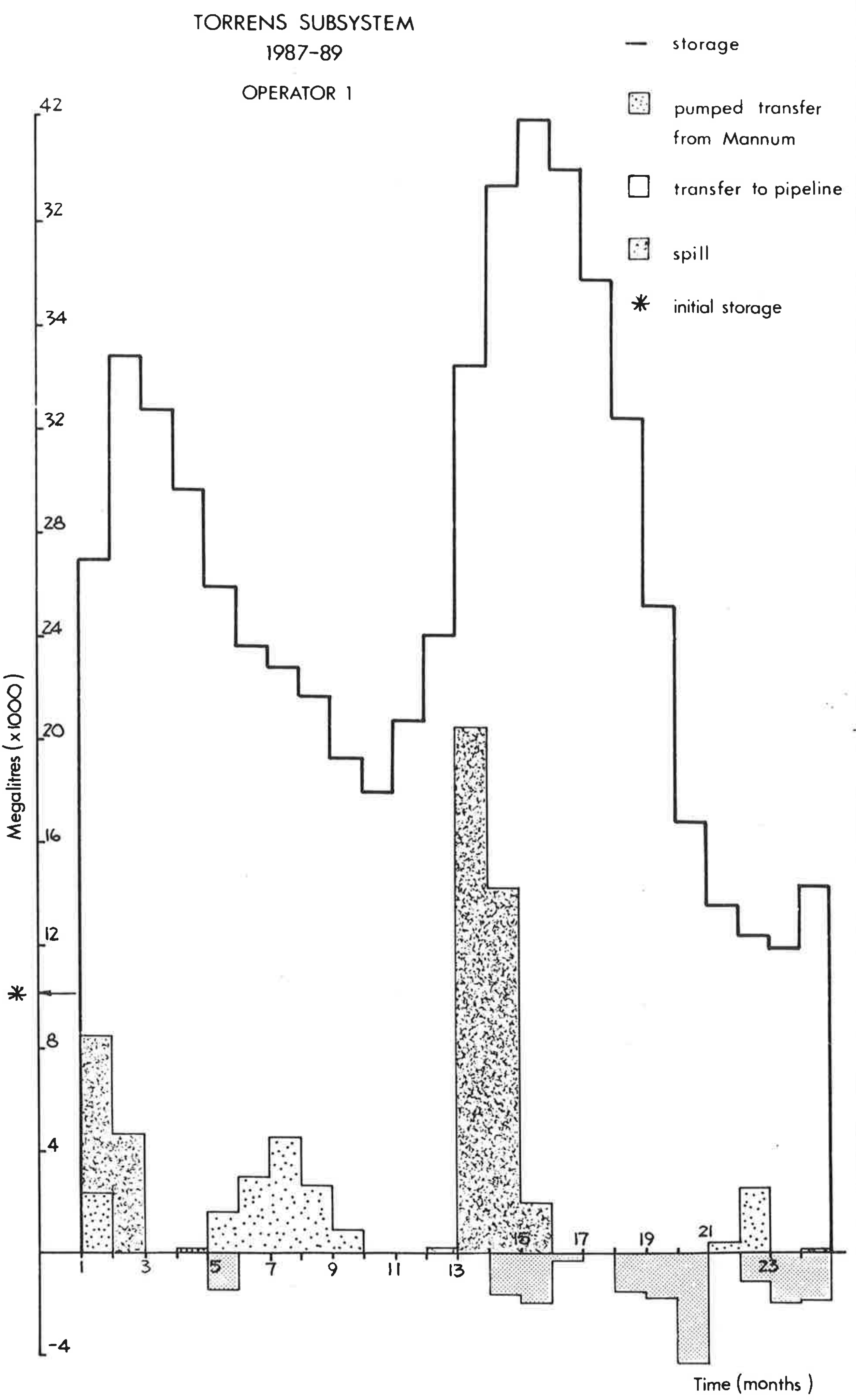


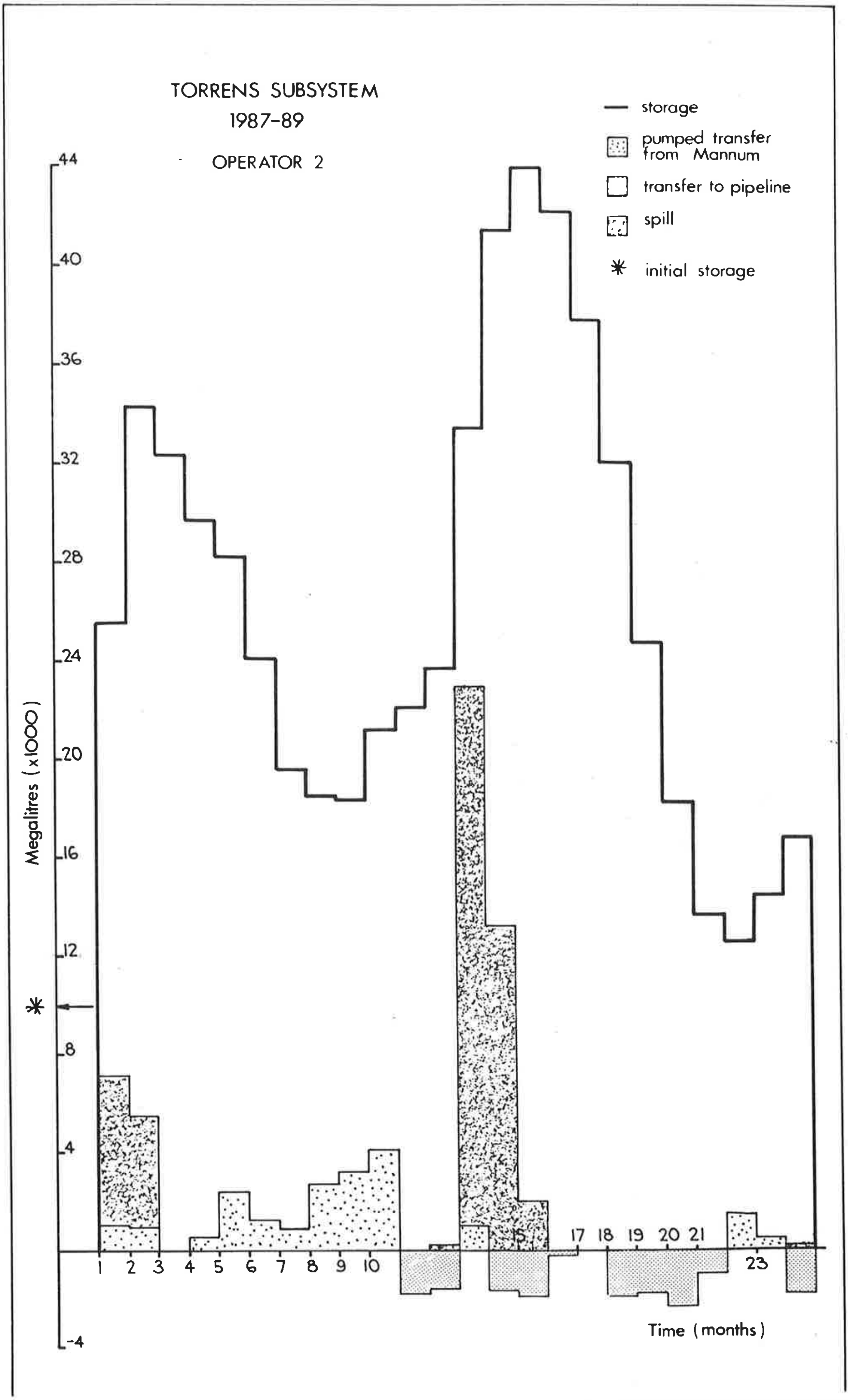

PUMPING COSTS
1987-89
OPERATOR 3
6150750
$(X.10^4)/Megalitre
600
500
400
300
200
100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Time (months)

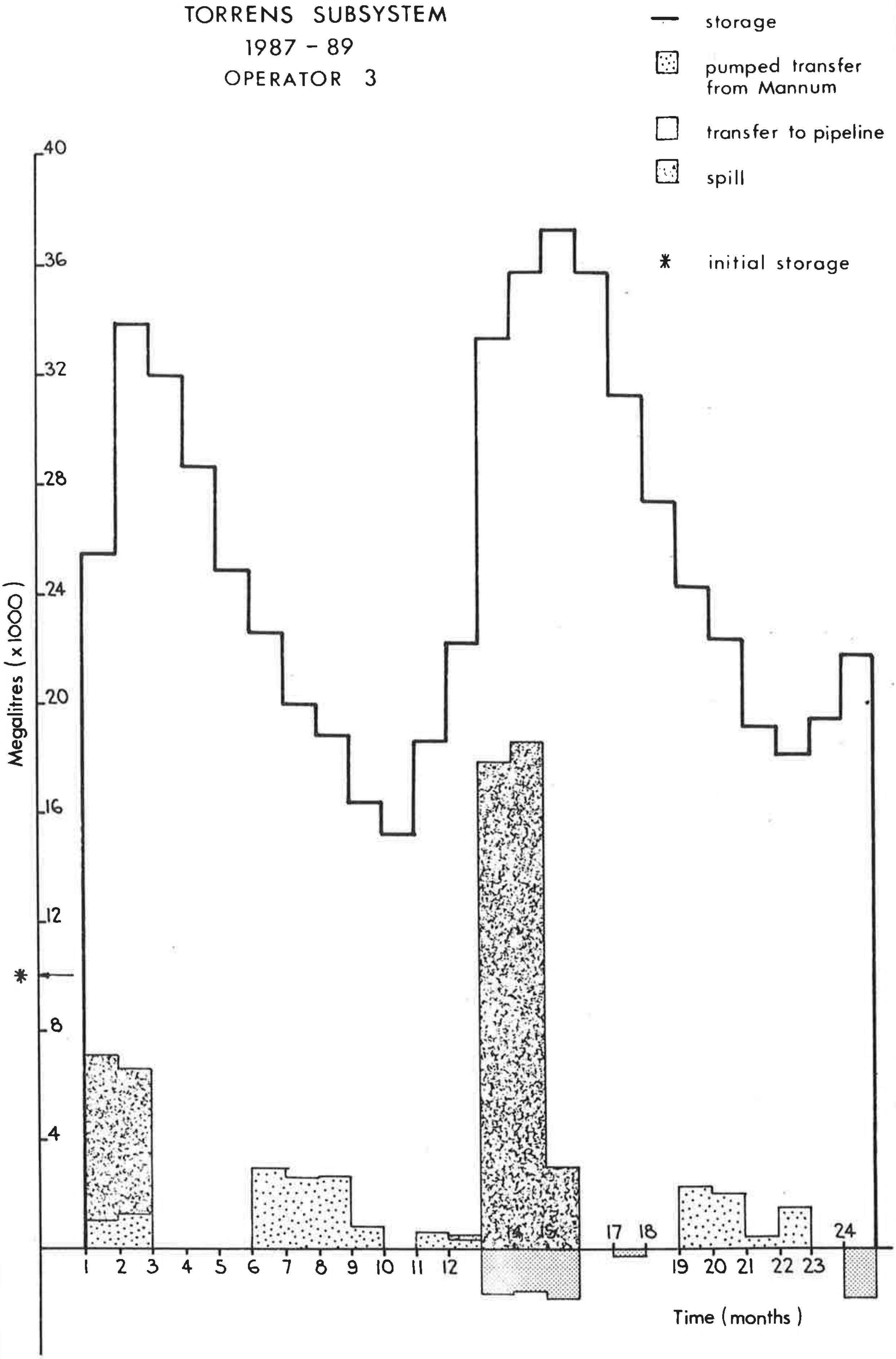
APPENDIX B



TORRENS SUBSYSTEM
1987–89
AUTHOR


TORRENS SUBSYSTEM
1987-89
OPERATOR 1
— storage
pumped transfer from Mannum
transfer to pipeline
spill
* initial storage
Megalitres (x1000)
42
32
34
32
28
24
20
16
12
*
8
4
-4
1
3
5
7
9
11
13
15
17
19
21
23
Time (months)


TORRENS SUBSYSTEM
1987-89
OPERATOR 2
storage
pumped transfer from Mannum
transfer to pipeline
spill
initial storage
Megalitres (x1000)
44
40
36
32
28
24
20
16
12
8
4
-4
1
2
3
4
5
6
7
8
9
10
15
17
18
19
20
21
23
Time (months)


TORRENS SUBSYSTEM
1987 - 89
OPERATOR 3
storage
pumped transfer from Mannum
transfer to pipeline
spill
initial storage
Megalitres (x 1000)
40
36
32
28
24
20
16
12
8
4
*
1
2
3
4
5
6
7
8
9
10
11
12
14
15
17
18
19
20
21
22
23
24
Time (months)

APPENDIX C

PROGRAM LISTING

```
*               COMPUTER SIMULATION OF THE METROPOLITAN ADELAIDE
*
*                         WATER SUPPLY SYSTEM - 1980.
*
*                                   0000000
*
*               THE MODEL SIMULATES THE RESERVOIR SYSTEM RESPONSIBLE
*               FOR THE SUPPLY OF WATER TO METROPOLITAN ADELAIDE
*               AS CONFIGURED IN THE YEAR 1980.
*               LIGHTPEN AND KEYBOARD ARE USED FOR OPERATOR
*               INTERACTION.
*
*                                   0000000
*
*               WRITTEN BY:
*                                 P.M.MACDONALD
*               IN:
*                                 1980
*
*               FOR:
*                       MASTER OF ENGINEERING SCIENCE DEGREE
*                       ADELAIDE UNIVERSITY
*                       CIVIL ENGINEERING DEPARTMENT
*                       1980
*
*               -----------------------------------------------------
*               0000000000000000000000000000000000000000000000000000
*               -----------------------------------------------------
*
*
*               VARIABLES -
                ---------
*

                AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

*
*

        A(59) - LOGICAL*1 ARRAY CONTAINING ABBREVIATED MONTH NAMES
        ADJST3 - EXCESS INFLOW TO HOPE VALLEY RESERVOIR WHICH IT CANNOT
                STORE DUE TO ITS OPERATING RULE.THIS INFLOW IS THEREFORE
                REMOVED AS SPILL.
        ADCST - COST TO BE ADDED TO SUBSYSTEM ACCOUNT ARISING FROM
                EXTERNAL WATER TRANSFERS.
        ASTOR - STORAGE IN TORRENS SUBSYSTEM FOR COMPARISON WITH STORAGE
                AFTER DETERMINISTIC INFLOW IS ADDED,WHEN TRANSFERS OUT OF
                THE SYSTEM ARE REQUIRED.
        AVAIL - VOLUME AVAILABLE FOR TRANSFER OUT OF THE TORRENS SUBSYSTEM.
        AMIN(NRES) - HEIGHT OF MINIMUM PREDICTED STORAGE BAR.
        AMAX(NRES) - HEIGHT OF MAXIMUM PREDICTED STORAGE BAR.

*
*
                CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
*
*

        COST(IPSTN) - COST OF ALL AVAILABLE PUMPING IN CURRENT MONTH FROM
                PUMP STATION 'IPSTN'.
        CSTMIL - COST ($/MEGALITRE) OF PUMPING FROM MILLBROOK RESERVOIR
                INTO THE MANNUM-ADELAIDE PIPELINE.
        CSTPRT - FRACTION OF TOTAL PUMP STATION COSTS TO BE TAKEN BY ANY
                SUBSYSTEM.
        CAPSUM - CAPACITY OF THE MANNUM-ADELAIDE PIPELINE FROM SUMMIT
                STORAGE TO MILLBROOK TANKS.
        CAPANS - CAPACITY OF THE MANNUM-ADELAIDE PIPELINE IMMEDIATELY
                UPSTREAM OF THE ANSTEY HILL FILTRATION PLANT.
        CAPW3 - CRITICAL WINTER CAPACITY OF MANNUM-ADELAIDE PIPELINE.
```

CAPS3 - CRITICAL SUMMER CAPACITY OF MANNUM-ADELAIDE PIPELINE.
CAPBAR - CAPACITY OF BAROSSA TRUNK MAIN.
CAP5S - SUMMER CAPACITY OF BAROSSA TRUNK MAIN
CAP5W - WINTER CAPACITY OF BAROSSA TRUNK MAIN
CAPCTY - CAPACITY OF THE PIPELINE OFFTAKE ASSOCIATED WITH THE STORAGE 'NRES' UNDER CONSIDERATION
CAPMYP - CAPACITY OF MYPONGA TRUNK MAIN TO THE ONKAPARINGA SUBSYSTEM
CAPMYS - SUMMER CAPACITY OF MYPONGA TRUNK MAIN
CAPMYW - WINTER CAPACITY OF MYPONGA TRUNK MAIN
COSTKL - VALUE OF COST OF WATER PER KILOLITRE PASSED TO SUBROUTINE 'BARGR'
COSTKL1 - COST OF WATER PER KILOLITRE LOCAL TO SUBROUTINE 'CALCST'

*
*

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

*
*

DETINF(ISYS,J,MON) - DETERMINISTIC INFLOW DATA IN EACH MONTH 'MON' FOR EACH SUBSYSTEM 'ISYS'
J=1 90% PROB INFLOW
J=2 10% PROB INFLOW
DEFCIT(JSYS) - ARRAY WHICH RECORDS ANY DEFICIT IN STORAGE FOR SUBSYSTEM 'JSYS'
DEMAND - TOTAL DEMAND ON THE SUBSYSTEM INCLUDING CONSUMPTION AND EVAPORATION
DEMMIL - TRANSFER OUT OF MILLBROOK RESERVOIR INTO THE MANNUM-ADELAIDE PIPELINE
DEMMYP(J,IMON) - DEMANDS ON MYPONGA RESERVOIR FROM MYPONGA WATER DISTRICT
J=1 DETERMINISTIC
J=2 STOCHASTIC
DTDEM(ISYS,IMON) - TOTAL DETERMINISTIC DEMAND FOR THE SUBSYSTEM 'ISYS' IN MONTH 'IMON'
DETDEM(IDISTR,MON) - DETERMINISTIC DEMAND FOR EACH OF TWELVE DISTRICTS 'IDISTR' IN EACH MONTH 'MON' OF THE YEAR.
DPCENT - PERCENTAGE OF DETERMINISTIC DEMAND ON BAROSSA TRUNK MAIN THAT CAN BE WITHDRAWN FROM SOUTH PARA SUBSYSTEM

*
*

EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE

*
*

EV - EVAPORATION FROM STORAGE AT CURRENT SUPPLY LEVEL
EXSMIL - CHANGE OF STORAGE IN MILLBROOK RESERVOIR FROM ONE MONTH TO THE NEXT WHICH MAY BE USED TO SUPPLY A TRANSFER
EXTRAN - VOLUME OF TRANSFER FROM ONE SUBSYSTEM TO ANOTHER
EVAPN(154,13) - ARRAY OF STORAGE VS EVAPORATION CURVES FOR ALL RESERVOIRS FOR ALL MONTHS IN THE YEAR

*
*

FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF

*
*

FRAC - VALUE OF FRACTION OF DEMAND SUPPLIED BY PUMPS , LOCAL TO CALCST
FRACTN - FINAL VALUE OF 'FRAC' USED TO MODIFY SCREEN DISPLAY IN SUBROUTINE 'BARGR'

*
*

HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH

*
*

HAPVLY - VOLUME OF WATER TRANSFERRED FROM MYPONGA RESERVOIR

```
                TO THE ONKAPARINGA SYSTEM
*
*
                IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
*
*
        I - MONTH IN FINANCIAL YEAR
        ICOUNT - COUNTER OF THE NUMBER OF YEARS SIMULATED
        IMONTH - MONTH OF FINANCIAL YEAR CORRESPONDING TO CALENDAR MONTH
        IYEAR - YEAR IN WHICH SIMULATION STARTS
        IYEARS - DURATION OF SIMULATION IN YEARS
        IBAR(ISYS) - FLAG INDICATING WHETHER THE FIRST TIME THROUGH THE
                SUBROUTINE FOR THE SUBSYSTEM 'ISYS'.THIS SAVES REDEFINING
                SCREEN ELEMENTS ALREADY DRAWN
        ISYS - NUMBER OF SUBSYSTEM
        IPIC - SUBPICTURE NUMBER ASSOCIATED WITH EACH STORAGE
        IPRVW - INDICATES THE MODE IN WHICH THE SYSTEM IS BEING OPERATED
                AND SO GOVERNS THE TYPE OF DATA TO BE USED FOR MODIFYING
                THE GRAPHS.             PREVIEW=1
                                        ACCEPT =0
                                        REVERT =-1
                                        CHECK  =10
        ISUBP - OVERALL SUBPICTURE TITLE FOR THE GROUP OF BARGRAPHS IN
                SUBSYSTEM 'ISYS'
        IRANGE(ISYS) - MINIMUM AND MAXIMUM STORAGE NUMBERS ASSOCIATED
                WITH EACH SUBSYSTEM 'ISYS'
        ISAT - INDICATES WHETHER THE SYSTEM PROMPTS HAVE YET BEEN
                SET UP (+1)
        ISYSTM - NEW SUBSYSTEM NUMBER CHOSEN IN THE SATELLITE PROGRAM
        ITRN - PASSED FROM SATELLITE TO INDICATE WHETHER PUMPING OR
                TRANSFERS TO THE SUBSYSTEM HAVE BEEN REQUESTED (+1=YES)
        IZONE - REGION TO BE SIMULATED
                        1=SOUTHERN SYSTEM
                        2=NORTHERN SYSTEM
                        3=WHOLE METRO REGION
        ICALC(ISYS) - INTERNAL FLAG TO DETERMINE IF SUBSYSTEM 'ISYS' HAS
                CYCLED THROUGH THE SUBROUTINE YET (+1=YES)
        ISPPLY - FLAG INDICATING WHETHER A TRANSFER OUT OF MILLBROOK
                RESERVOIR HAS BEEN SPECIFIED
        ISTRT - FLAG INDICATING WHETHER THE SUBROUTINE HAS BEEN PREVIOUSLY
                USED AND HENCE WHETHER DATA NEED BE READ IN FOR PROGRAM
                INITIALLISATION
        ISWTCH - FLAG INDICATING IF PREDICTED CALCULATION FOR A STORAGE
                MAY BE STOPPED DUE TO SPILL OR DEFICIT CONDITIONS
        ISTOR - INPUT VARIABLE FOR PROMPTED STORAGE VALUE
        ISYSMN - )         MINIMUM AND MAXIMUM SUBSYSTEM NUMBERS ASSOCIATED
        ISYSMX - )         WITH THE CHOSEN REGION OF SIMULATION
        IMON - CURRENT MONTH INDEX
        IPSTN - NUMBER OF PUMP STATION WITHIN THE SYSTEM
                        1=MURRAY BRIDGE
                        2=MANNUM
                        3=SWAN REACH
        IPUMP(IPSTN) - KEY NUMBER FOR THE PUMPSTATION 'IPSTN' WHICH,WHEN
                DECOMPOSED INTO HUNDREDS,TENS AND UNITS YIELDS THE
                PUMPING CONFIGURATION
        ISTN - PUMPSTATION NUMBER
        ISTMAX - )         HIGHEST AND LOWEST PUMPSTATION
        ISTMIN - )         NUMBERS USED
        IWKS - DURATION OF PUMPING IN WEEKS AS OBTAINED FROM ARRAY
                'IPUMP(IPSTN)'.NOTE 'IWKS=0' MEANS INTERMITTENT PUMPING
        ICNTRL(JSYS) - FLAG INDICATING WHEN FINAL STRATEGY FOR SUBSYSTEM
                'ISYS' HAS BEEN 'ACCEPTED'
        IPMP - CODED FORM OF PUMPING STRATEGY PASSED TO AND FROM SATELLITE
                PROCESSOR
        IXS - FLAG INDICATING THAT GRAPHICS PROMPT FOR LITTLE PARA TRANSFER
                REDUCTION HAS ALREADY BEEN CREATED (+1=YES)
```

```
*
*
               JJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJ
*
*

      JMON - CALENDAR MONTH CORRESPONDING TO 'I'
      JMONTH - CALENDAR MONTH OF SIMULATION
      JRES - COUNTER FOR THE NUMBER OF STORAGES IN A SUBSYSTEM
      JTIME - SPECIFIES POSITION IN THE PUMPING AND COST ARRAYS FOR THE
              APPROPRIATE 'OFFPEAK','ON PEAK' OR 'SPECIAL ON PEAK' VALUES

*
*
               KKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKK
*
*

      KMON - CALENDAR MONTH

*
*
               LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
*
*

      LSTMON - MONTH BEFORE CURRENT MONTH UASED TO DEFINE MILLBROOK'S
              STORAGE
      LPARA - FLAG INDICATING LITTLE PARA GRAPHICS PROMPT HAS ALREADY
              BEEN CREATED (+1=YES)

*
*
               MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
*
*

      MINREC - STARTING RECORD IN DATA FILE
      MON - LOCAL MONTH NUMBER
      MONTH - COUNTER FOR NUMBER OF MONTHS WHICH HAVE BEEN SIMULATED
      MAX - MAXIMUM NUMBER OF PUMPS AT CURRENT STATION
      MAXPMP(IPSTN) - MAX NUMBER OF PUMPS AT EACH PUMPSTATION 'IPSTN'
      MAXREC - FINISHING RECORD IN DATA FILE
      MAXRES - MAX STORAGE NUMBER ASSOCIATED WITH A SUBSYSTEM
      MINRES - MIN STORAGE NUMBER ASSOCIATED WITH A SUBSYSTEM
      MYPTRN - INDICATES WHETHER MYPONGA SUBSYSTEM IS TRANSFERRING TO
              THE ONKAPARINGA SUBSYSTEM
      MAXFIN(NRES) - MONTH NUMBER ASSOCIATED WITH THE 10% PROBABILITY
              INFLOW CALCULATIONS FOR THE UNSPECIFIED STORAGE 'NRES'
      MINFIN(NRES) - MONTH NUMBER ASSOCIATED WITH THE 90% PROBABILITY
              INFLOW CALCULATIONS FOR THE UNSPECIFIED STORAGE 'NRES'
      MYP - LOCAL FLAG USED TO AVOID REDEFINITION OF MYPONGA PROMPT
      MIN - STARTING RECORD IN INFLOW FILE
      MLLBRK - FLAG INDICATING THAT GRAPHICS PROMPT FOR TORRENS
              SUBSYSTEM HAS BEEN CREATED

*
*
               NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
*
*

      NRES - NUMBER OF STORAGES UNDER CONSIDERATION
      NOWPMP(IPSTN) - INTERNAL PUMPING VARIABLE OF TOTAL VOLUME
              PUMPED FROM PUMPSTATION 'IPSTN'
      NPUMPS - NUMBER OF PUMPS TO BE USED IN THE CURRENT CONFIGURATION
      NTIME(N,IPSTN) - DATA ARRAY USED IN CONJUNCTION WITH 'JTIME'.IT
              GIVES THE NUMBERS OF THE MAXIMUM 'OFFPEAK','PEAK' AND
              'SPECIAL ON PEAK' DATA VALUES IN THE PUMPING ARRAYS
      NCYCL - SUBROUTINE FLAG INDICATING WHICH MODE OF CALCULATION
              IS TO BE USED            1=CURRENT VALUE
                                       2=PREDICT MAX
                                       3=PREDICT MIN
      NOTRAN - LOCAL FLAG USED TO AVOID REDEFINING THE 'NO TRANSFER
              AVAILABLE' PROMPT FOR THE MYPONGA SUBSYSTEM
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          NXTMON - NUMBER OF THE MONTH WHICH IS THE NEXT MONTH ON FROM THE
                  CURRENT MONTH
          NPMPS - NUMBER OF PUMPS USED
*
*
                  PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
*
*
          PIPOFT(IPSTN,2,IMON) - AMOUNT OF WATER REMOVED BY SUNDRY OFFTAKES
                  ALONG THE PIPELINE BEFORE IT REACHES METRO AREA.DATA IS
                  STOCHASTIC OR DETERMINISTIC DEPENDING ON THE MODE OF
                  SUBROUTINE 'CALCST' OPERATION
          PMPCST(IPSTN,JTIME,NPUMPS) - PUMPING COSTS PER MEGALITRE IN $/ML
                  FOR THE RANGE OF OPERATION TIMES AND THE NUMBER OF PUMPS
                  AT THE PUMPSTATION
          PMPQNT(IPSTN,JTIME,NPUMPS) - PUMPING QUANTITIES FOR THE RANGE OF
                  OPERATING TIMES AND THE NUMBER OF PUMPS AT THE PUMPSTATION
          PUMP(IPSTN) - QUANTITY OF PUMPED WATER AVAILABLE IN METRO SYSTEM
                  AFTER OFFTAKES ARE REMOVED
          PRSTOR(NRES) - STORAGE FOR 'NRES' CALCULATRED USING DATA FOR
                  CURRENT MONTH IN SUBROUTINE 'CALCST'
          PSPPLY - SUPPLY OF WATER PUMPED FROM MILLBROOK RESERVOIR INTO
                  MANNUM-ADELAIDE PIPELINE
          PART - PUMPED TRANSFER TAKEN BY SUBSYSTEM
          PERFRM(J,9,K) - PERFORMANCE DATA
          PMPANS - VOLUME OF WATER TO BE SUPPLIED THROUGH THE CRITICAL
                  SECTION OF THE MANNUM-ADELAIDE PIPELINE
*
*
                  SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
*
*
          STRNG(10) - LOGICAL*1 ARRAY USED FOR MONTH NAME
          SMAX(ISYS) - THE LARGEST STORAGE (FROM 'STRMAX') IN THE
                  SUBSYSTEM 'ISYS'
          S(IMONTH,NRES) - FIXED OPERATING STORAGE VALUE ASSOCIATED WITH
                  STORAGE 'NRES' FOR MONTH 'IMONTH'
          STOR(NRES,2) - FIRST ELEMENT HOLDS STORAGE FOR 'NRES'.
                  SECOND INDICATES WHETHER 'NRES' IS A WEIR (<0),
                  SERVICE RESERVOIR (=0) OR VARIABLE STORAGE (>0)
          SUMCAP - NUMBER OF OFFTAKES CURRENTLY USING WATER FROM THE
                  PUMPSTATION
          SPILL(ISYS) - SPILL OUT OF SUBSYSTEM 'ISYS'
          ST(NRES) - ARRAY FOR MANIPULATING STORAGES
          STDEM(ISYS,IMON) - TOTAL STOCHASTIC DEMAND FOR SUBSYSTEM 'ISYS'
                  IN MONTH 'IMON'
          STMAX(NRES) - UPPER AND LOWER CONFIDENCE LIMITS
          STMIN(NRES) - FOR THE STORAGE IN RESERVOIR 'NRES' BASED ON
                  10% AND 90% PROBABILITY INFLOWS
          STOINF(NRES,IMON) - STOCHASTIC INFLOW FOR EACH RESERVOIR 'NRES'
                  IN EACH MONTH 'IMON'
          STRMAX(JRES) - FULL STORAGE VOLUME IN STORAGE 'JRES'
          SUMSTR - SUM OF ALL USEABLE STORAGE WITHIN A SUBSYSTEM
          SYSPMP(IPSTN,IMON,14) - PUMPING DATA FOR EACH PUMPSTATION 'IPSTN'
                  FOR EACH OF 12 MONTHS 'IMON'
          SYSATR(ISYS,IMON,J) - STORAGE DATA FOR EACH SUBSYSTEM 'ISYS'
                  FOR EACH 12 MONTHS 'IMON'
          SPCENT - PERCENTAGE OF STOCHASTIC DEMAND ON BAROSSA TRUNK MAIN
                  THAT CAN BE WITHDRAWN FROM SOUTH PARA SUBSYSTEM
          STODEM(IDISTR,MON) - STOCHASTIC DEMAND FOR EACH DISTRICT 'IDISTR'
                  IN EACH MONTH 'MON'
          S2 - NEW STORAGE FOR MILLBROOK RESERVOIR
          SPARA - FLAG INDICATING SOUTH PARA GRAPHICS PROMPT HAS ALREADY
                  BEEN CREATED (+1=YES)
*
*
```

```
            TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT
*
*
    TOTPMP(IPSTN) - TOTAL VOLUME PUMPED AT STATION 'IPSTN'
    TRAN(ISYS) - TOTAL TRANSFER AVAILABLE TO 'NRES' IN SUBSYSTEM
            'ISYS' UNDER CONDITIONS OF PUMPING WHICH ARE OPERATING
    TRANSF(NRES,2) - WHEN DECOMPOSED INTO DECIMAL FRACTION AND
            INTEGER,IT GIVES THE PUMP STATION TO BE CONSIDERED
            (IPSTN) AND THE MAX CAPACITY OF THE OFFTAKE PIPELINE
            ASSOCIATED WITH STORAGE 'NRES'
    TOTCST - SUM OF THE COST OF POWER FOR ALL PUMPSTATIONS IN USE
    TOTDEM - SUM OF ALL CURRENT DEMANDS,BOTH ON RESERVOIRS AND
            PIPELINES
    TOTTRN - TOTAL OF PUMPED WATER FROM THE THREE PUMPSTATIONS
            AND MILLBROOK RESERVOIR PUMPSTATIONS
    TRANS - VALUE OF TRANSFER FROM PUMPSTATION TO RESERVOIR,OR
            FROM WEIR TO RESERVOIR
    TRANSFR - LOCAL VARIABLE FOR ASSIGNING THE TRANSFER INTO A
            SUBSYSTEM TO THE CORRECT STORAGE WITHIN THAT SUBSYSTEM
    TRNSF1 - TRANSFER INTO TORRENS SUBSYSTEM BY PUMPING
*
*
            WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
*
*
    WARTRN - TRANSFER FROM MANNUM-ADELAIDE PIPELINE TO WARREN
            RESERVOIR
    WARSPL - SPILL FROM WARREN RESERVOIR.THIS BECOMES AN INPUT
            TO SOUTH PARA RESERVOIR
    WEEKS - NUMBER OF WEEKS OUT OF THE MONTH DURING WHICH PUMPS
            WERE OPERATING
    WIRTRF(2,4) - COORDINATES FOR THE TRANSFER FUNCTION OF EACH OF
            THE TWO WEIRS INCLUDED IN THE MODEL
*
*
            XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
*
*
    XMIN(NRES) - STARTING X-COORDINATE FOR GRAPH OF 'NRES'
    XSDEM - VOLUME OF SUPPLY IN EXCESS OF CAPACITY OF MANNUM-
            ADELAIDE PIPELINE
*
*
            YYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYY
*
*
    YMIN(NRES) - STARTING Y-COORDINATE FOR GRAPH OF 'NRES'
    YGR(NRES) - HEIGHT OF GRAPH REPRESENTING CURRENT STORAGE IN 'NRES'
    YMAX(NRES) - MAX HEIGHT FOR GRAPH OF STORAGE 'NRES'
*
*
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            0000000000000000000000000000000000000000000000000000
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C     PROGRAM CORE:CALLER OF THE MAJOR SUBROUTINES.THIS PROGRAM CONTROLS
C     THE PROGRESS OF THE SIMULATION AND COMMUNICATES WITH THE SATELLITE
C     PROCESSOR TO ENABLE LIGHTPEN INTERACTION ON THE SCREEN.
C                         _000_
      PROGRAM CORE
C
      COMMON /CORDAT/ISYS,MINRES,MAXRES,IPRVW
     * /CORPMP/PMPQNT(3,16,4),PMPCST(3,16,4),IRANGE(6,2),IPUMP(3),
     * ISYSMN,ISYSMX,SUMCAP(3),PUMP(3),ICOP,ICPY,
     * IHDCPY,ICONSD
     * /CORCAL/DETINF(6,2,12),MYPTRN,TRANSF(12,2),STOR(12,2),S(12,12),
     * IMONTH,MONTH,MINREC
      COMMON /EVAPDAT/EVAPN(154,13)
     * /STORDAT/PRSTOR(12),STRMAX(12),STMAX(12),STMIN(12),MAXFIN(12),
     * MINFIN(12),FRAC,CSTKL1,FRACTN,COSTKL
     * /PMPCPY/IPSTN,TOTPMP(3),COST(3),TRAN(6),CAPCTY
     * /CALPMP/PIPOFT(4,2,12),IMON,ISTMIN,ISTMAX,DEMMIL,WARTRN,
     * MAXPMP(3),EXSMIL
      COMMON /SETUP/IBAR,ICALC,SMAX(6),XMIN(12),YMIN(12),YMAX(12),
     * ICOUNT,ISTRT,MYP,NOTRAN,MLLBRK,LPARA,SPARA,IXS
     * /CALHLD/DTDEM(6,12),STDEM(6,12),STOINF(13,12),DEMMYP(2,12),
     * WARSPL,HAPVLY,IDTDEM,ISTDEM,ISTINF,PSPPLY,ISPPLY
     * /RESULT/PERFRM(7,9,3),SYSSTR(6,12,14),SYSPMP(3,12,8),ISUB,ITOT
C
      LOGICAL*1 ISTART(6),STRNG(6),ICNTRL(6),ISAT,
     * IBAR(6),ICALC(6),ISTRT,MYP,NOTRAN,MLLBRK,IHDCPY,ICONSD(6),
     * LPARA,SPARA,IXS
C
C
C               SET PRESCRIBED ERROR CONDITIONING-
C               I.E. FOOL PROOF THE DATA INPUT DURING SIMULATION.
C
      CALL ERRSET(64,1,0,1,0,)
C
C               INTRODUCTION AND PROMT FOR DATA:
C               DETERMINE THE REGION TO BE SIMULATED.
C
      CALL CLR
      CALL INIT
      TYPE1
1     FORMAT(2X,'DO YOU WISH TO CONSIDER:'//
     * 6X,'1.SOUTHERN SYSTEM ONLY?'/
     * 6X,'2.NORTHERN SYSTEM ONLY?'/
     * 6X,'3.WHOLE METROPOLITAN REGION?'//
     * 4X,'TYPE THE REQUIRED INDEX NUMBER AND PRESS "CR"'/
     * 6X,'INDEX NUMBER='$)
      ACCEPT2,IZONE
2     FORMAT(I2)
C
C               DEFINE THE MINIMUM AND MAXIMUM SUBSYSTEM NUMBERS:
C               ISYSMN,ISYSMX
C
      GOTO(3,4,3),IZONE
3     ISYSMN=1
      IF(IZONE.EQ.3)GOTO5
      ISYSMX=2
      GOTO6
4     ISYSMN=3
5     ISYSMX=6
6     CONTINUE
C
C               PROMPT FOR YEAR,MONTH,AND DURATION OF SIMULATION.
C
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        TYPE7
7       FORMAT(//2X,'PLEASE SPECIFY THE YEAR AND MONTH IN WHICH'/
     *  2X,'THE SIMULATION IS TO BEGIN'/2X,'NOTE:DATA FILES START',
     *  ' IN JANUARY 1976'/6X,'STARTING YEAR='$)
        ACCEPT8,IYEAR
8       FORMAT(I4)
        TYPE9
9       FORMAT(6X,'STARTING MONTH(1=JANUARY,12=DECEMBER)='$)
        ACCEPT2,JMONTH
        TYPE10
10      FORMAT(//2X,'FOR HOW MANY YEARS IS THE SIMULATION TO RUN?'/
     *  6X,'DURATION='$)
        ACCEPT2,IYEARS
C
C               CALCULATE INITIAL VALUES OF VARIABLES AND STARTING
C               POINTS IN THE DATA FILES.
C               NOTE:DATA FILES START IN JANUARY 1976.
C
C               DETERMINE THE FISCAL MONTH FROM THE CALENDAR MONTH.
C
        K=(JMONTH-1)/6
        IMONTH=JMONTH+(((-1)**K)*6)
C
C               DETERMINE THE STARTING AND FINISHING POSITIONS IN THE
C               DATA FILES.
C
        MINREC=(IYEAR-1976)*12+JMONTH
        MAXREC=MINREC+(12-IMONTH)+(IYEARS-1)*12
        MONTH=MINREC
        ISPPLY=-1
C
C               PROMPT FOR STARTING STORAGES IN RESERVOIRS.
C
        CALL STINIT(ISYSMN,ISYSMX,IRANGE,STOR,IMONTH,S,STRMAX)
C
C               SET UP MILLBROOK'S STARTING STORAGE IN THE SERVICE
C               RESERVOIR ARRAY.
C
        IF(ISYSMX.EQ.6)S(IMONTH,6)=STOR(6,1)
C
C               NOW SET UP THE SCREEN FORMAT
C
        CALL SCREEN
C
C               ALLOW ONLY THE SELECTED SUBSYSTEMS TO BE CHOSEN BY MAKING
C               THE OTHER SUBSYSTEM MENU ITEMS INVISIBLE TO THE LIGHTPEN.
C
        DO 11 JSYS=1,6
        IF(JSYS.GE.ISYSMN.AND.JSYS.LE.ISYSMX)GOTO11
        CALL OFF(JSYS)
11      CONTINUE
C
C               OPEN FILES AND READ DATA
C               THIS IS THE DATA WHICH REMAINS CONNSTANT THROUGHOUT THE
C               SIMULATION.IT IS NEVER UPDATED.
C
        CALL REDATR(ISYSMN,ISYSMX,DETINF,MAXPMP,PMPQNT,PMPCST,
     *  EVAPN)
C
C               SET UP THE SUBPICTURES FOR ALL THE SUBSYSTEMS UNDER
C               CONSIDERATION.
C
        DO 12 ISYS=ISYSMN,ISYSMX
        MINRES=IRANGE(ISYS,1)
        MAXRES=IRANGE(ISYS,2)
C
```

```
C                  CALCULATE STORAGES ON THE BASIS OF THE INITIAL DATA.
C
12        CALL CALCST
C
C                  IN THIS CASE 'BARGR' IS USED TO DEFINE AND DRAW THE
C                  SUBSYSTEM PICTURES.
C
          DO 13 ISYS=ISYSMN,ISYSMX
          MINRES=IRANGE(ISYS,1)
          MAXRES=IRANGE(ISYS,2)
13        CALL BARGR(STOR,S,IMONTH)
C
C                  INITIALLIZE 'ISYS' FOR CONVENIENCE WHEN CALLING THE
C                  FIRST SUBSYSTEM OF THE SIMULATION.
C
          ISYS=0
C
C                  DEFINE THE PROMPT FOR A SUBSYSTEM.
C
          CALL SUBP(50)
          CALL OFF(50)
          CALL APNT(0.,160.,,-3,-1)
          CALL TEXT(-2,' CHOOSE A SUBSYSTEM WITH THE',
     *    1,-2,' LIGHTPEN FROM THE MENU LIST AT THE',
     *    1,-2,' RIGHT OF THE SCREEN')
          CALL ESUB(50)
C
C                  NOW THE PROGRAM ENTERS THE MAIN CONTROL LOOP
C
C                  INCLUDE THE YEAR,MONTH,AND DURATION OF SIMULATION IN
C                  THE SCREEN LAYOUT.
C
14        CALL TIMSET(JMONTH,MONTH,MINREC,IYEAR,IMONTH,IYEARS)
          GOTO16
C
C                  IF IN 'CHECK' MODE,RESET IPRVW.
C
15        IPRVW=1
C
C                  TURN ON SCREEN AND SUBSYSTEM PROMPT.
C
16        CALL ON(100)
          CALL ON(50)
          CALL CLR
C
C                  TRANSFER TO SATELLITE TO RECEIVE LIGHTPEN NOMINATED
C                  SUBSYSTEM.
C                  NOTE:USE OF SATELLITE IS FOR RAPID RESPONSE TIME.
C
          CALL TOSAT(100,1,1,1)
          CALL FRSAT(1,1,ISYSTM)
          CALL OFF(50)
C
C                  DEFINE THE LIMITING RESERVOIR NUMBERS FOR THE SUBSYSTEM.
C
          MINRES=IRANGE(ISYSTM,1)
          MAXRES=IRANGE(ISYSTM,2)
          IF(ISYS.EQ.0)GOTO19
C
C                  IF NOT FIRST TIME THROUGH,BRIGHTEN ALL SUBSYSTEM TITLES
C                  WHICH HAVE ALREADY BEEN ACCEPTED.
C
          DO 18 JSYS=ISYSMN,ISYSMX
          CALL POINTR(1,JSYS,2)
          IF(ICNTRL(JSYS).EQ.1)GOTO17
          CALL INTENS(1,4)
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      GOTO18
17    CALL INTENS(1,8)
C
C              TURN OFF OLD SUBSYSTEM PICTURE AND TURN ON THE NEW.
C
18    CALL OFF(JSYS*1000)
19    CALL ON(ISYSTM*1000)
C
C              NEW SUBSYSTEM BECOMES THE CURRENT ONE
C
      ISYS=ISYSTM
C
C              IF IN PREVIEW MODE,TURN ON A SYSTEM PROMPT
C
      IF(IPRVW.EQ.1)CALL ON(52)
C
C              ADJUST THE SCREEN TITLE.
C
      CALL POINTR(1,100,4)
      GOTO(20,21,22,23,24,25),ISYS
20    CALL CHANGT(1,'MYPONGA')
      GOTO26
21    CALL CHANGT(1,'ONKAPARINGA')
      GOTO26
22    CALL CHANGT(1,'TORRENS')
      GOTO26
23    CALL CHANGT(1,'WARREN+NTH')
      GOTO26
24    CALL CHANGT(1,'SOUTH PARA')
      GOTO26
25    CALL CHANGT(1,'LITTLE PARA')
26    CONTINUE
C
C              ADJUST THE PUMPING CONFIGURATION TITLE TO SHOW PUMP-
C              STATION AND VOLUME PUMPED.
C
      DO 27 NRES=MINRES,MAXRES
      IF(ABS(TRANSF(NRES,2)).GT.1)GOTO28
27    CONTINUE
      GOTO37
C
C              IF PUMPING IS POSSIBLE,FIND THE CORRECT PUMPSTATION.
C
28    IPSTN=INT(ABS(TRANSF(NRES,2)))
C
C              PRINT THE QUANTITY PUMPED EX-PUMPSTATION.
C
      CALL NMBR(115,TOTPMP(IPSTN),6,'(F6.0)')
      MAX=MAXPMP(IPSTN)
C
C              TURN ON PUMPING SUBPICTURE.'
C
      CALL ON(7)
      CALL POINTR(1,7,2)
C
C              MODIFY PUMPSTATION TITLE.
C
      GOTO(29,30,31) IPSTN
29    CALL CHANGT(1,'MURRAY BRIDGE')
      GOTO32
30    CALL CHANGT(1,'MANNUM')
      GOTO32
31    CALL CHANGT(1,'SWAN REACH')
32    CONTINUE
C
C              THERE IS A MAXIMUM OF 4 PUMPS AT ANY PUMPSTATION
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C
      IF(MAX-4.EQ.0)GOTO34
C
C           IF LESS THAN 4 PUMPS ARE AVAILABLE,TURN OFF THE
C           UNNECESSARY MENU ITEMS.
C
      DO 33 IPIC=100+MAX,104
33    CALL OFF(IPIC)
C
C           TURN ON THE REMAINING PUMP MENU ITEMS
C
34    DO 35 IPIC=101,100+MAX
35    CALL ON(IPIC)
C
C           TURN ON THE OTHER ITEMS
C
      DO 36 IPIC=105,114
36    CALL ON(IPIC)
      IF(IPSTN.EQ.3)CALL OFF(107)
      GOTO39
C
C           IF NO PUMPING IS AVAILABLE,TURN OFF ALL PUMP MENUS.
C
37    DO 38 IPIC=101,114
38    CALL OFF(IPIC)
      CALL OFF(7)
39    CONTINUE
C
C           BEFORE PASSING CONTROL TO THE SATELLITE,SPECIFY THE
C           PUMPING VARIABLE IPMP FOR USE IN THE SATELLITE
C           PROGRAM.
C
40    IF(ISYS.EQ.1)GOTO41
C
C           IF THE SUBSYSTEM IS NOT MYPONGA(=NO PUMPING) THEN EQUATE
C           THE SATELLITE AND HOST PUMPING VALUES.
C
      IPMP=IPUMP(IPSTN)
      GOTO42
41    IPMP=0
C
C           SET UP PROMPTS FOR LIGHTPEN INTERACTION.
C
42    IF(ISAT.EQ.1)GOTO43
      CALL SUBP(51)
      CALL OFF(51)
      CALL APNT(0.,140.,,,-3,-1)
      CALL TEXT(-2,' THE PUMPING CONFIGURATION AND',
     * 1,-2,' SYSTEM CONTROL MENU ITEMS ARE',
     * 1,-2,' READY FOR LIGHTPEN INTERACTION')
      CALL ESUB(51)
      CALL SUBP(52)
      CALL OFF(52)
      CALL APNT(0.,160.,,,-3,-1)
      CALL TEXT(-2,'NOTE:IN PREVIEW MODE')
      CALL ESUB(52)
43    CALL OFF(52)
      CALL ON(51)
C
C           PROGRAM IS READY FOR SATELLITE CONTROL TO REDUCE
C           RESPONSE TIME.
C
      CALL TOSAT(101,3,2,IPMP,1,ISYS,1,ISAT)
      CALL FRSAT(6,2,IPMP,2,ITRN,2,IPRVW)
C
C           SET FLAG FOR PROMPTING SUBPICTURES
```

```
C
      ISAT=1
C
C               USE THE RESULTS FROM THE SATELLITE PROGRAM TO MODIFY
C               THE HOST PROGRAM VALUES.
C
C               TURN ON PREVIEW INDICATOR.
C
      IF(IPRVW.EQ.1)CALL ON(ISYS*1000+20)
      IF(IPRVW.EQ.-1)CALL OFF(ISYS*1000+20)
C
C               USE IPRVW TO CHECK WHICH PROMPT SHOULD BE TURNED ON.
C
D     WRITE(10,620),IPMP,ITRN,IPRVW
D620  FORMAT(2X,'IPMP:',I4,'ITRN:',I3,'IPRVW:',I3)
      CALL OFF(51)
      CALL OFF(52)
      IF(IPRVW.EQ.1)CALL ON(52)
      IF(IPRVW.GT.-1)GOTO44
C
C               IF IN 'REVERT' MODE RESET TO INITIAL CONDITIONS.
C
      CALL BARGR(STOR,S,IMONTH)
      GOTO43
44    IF(ISYS.EQ.1)GOTO45
C
C               IF THE PUMPING CONFIGURATION HAS BEEN CHANGED IN THE
C               SATELLITE,MODIFY THE HOST PUMPING VARIABLE.
C
      IF(IPMP.NE.IPUMP(IPSTN))IPUMP(IPSTN)=IPMP
C
C
C               THE TRANSFER VARIABLE ITRN INDICATES WHETHER A
C               TRANSFER IS OCCURING BETWEEN STORAGES OR WHETHER A
C               STORAGE IS REQUIRING PUMPED SUPPLY(+1).OTHERWISE
C               ITRN=-1
C
45    GOTO(46,47,48,49,50,51),ISYS
C
C               MYPONGA TRANSFER TO HAPPY VALLEY?
46    MYPTRN=ITRN
      GOTO52
C
C               PUMPING INTO MOUNT BOLD?
C
47    NRES=2
      GOTO52
C
C               PUMPING INTO MILLBROOK?
C
48    NRES=6
      GOTO52
C
C               PUMPING INTO WARREN?
C
49    NRES=9
      GOTO52
C
C               PUMPING INTO SOUTH PARA?
C
50    NRES=10
      GOTO52
C
C               PUMPING INTO LITTLE PARA?
C
51    NRES=12
```

```
C
C           ADJUST TRANSF TO ALLOW FOR THE EFFECT OF ITRN.
C
52    IF(NRES.NE.9)GOTO53
C
C           IF WARREN RESERVOIR,DEFINE TRANSFER FROM MANNUM/ADELAIDE
C           PIPELINE AS REQUIRED.
C
      WARTRN=425.
      IF(ITRN.EQ.-1)WARTRN=0.
      GOTO54
C
C           SET THE CORRECT SIGN FOR THE 'TRANSF' ARRAY.
C
53    TRANSF(NRES,2)=ITRN*ABS(TRANSF(NRES,2))
C
C           IF NO TRANSFER REQUIRED;TRANSF<0.
C           SET TRANSFER VARIABLE 'TRAN'=0.
C
      IF(TRANSF(NRES,2).LT.0.)TRAN(ISYS)=0.
C
C           IF IN 'CHECK' MODE RETURN TO THE PROMPT FOR A NEW
C           SUBSYSTEM.
C
54    IF(IPRVW.EQ.10)GOTO15
C
C           DETERMINE THE MODE OF PROGRAM OPERATION.THIS IS
C           EITHER DETERMINISTIC (PREVIEW) OR STOCHASTIC
C           (FINAL ACCEPT).
C
      IF(IPRVW.NE.0)GOTO57
C
C           IF THE CONFIGURATION OF THE SUBSYSTEM 'ISYS' HAS BEEN
C           ACCEPTED (IPRVW=0),ADD ISYS TO THE CONTROL ARRAY.
C
      ICNTRL(ISYS)=1
C
C           CHECK WHETHER ALL SUBSYSTEMS UNDER CONSIDERATION HAVE
C           BEEN ACCEPTED;ARE THEY ALL IN THE CONTROL ARRAY?
C
      DO 55 JSYS=ISYSMN,ISYSMX
55    IF(ICNTRL(JSYS).NE.1)GOTO56
      GOTO58
C
C           IF ALL SUBSYSTEMS HAVE NOT BEEN ACCEPTED,THE PROGRAM
C           IS NOT YET READY FOR STOCHASTIC DATA AND SO REVERT TO
C           PREVIEW MODE (IPRVW=1).
C
56    IPRVW=1
      GOTO16
C
C           IN PREVIEW MODE USE DETERMINISTIC DATA TO CALCULATE
C           STORAGES IN CALCST.
C
57    IF(IPRVW.EQ.1)CALL CALCST
C
C           HERE 'BARGR' IS USED TO MODIFY THE BARGRAPHS IN THE
C           SUBSYSTEMS.
C
      CALL BARGR(STOR,S,IMONTH)
      CALL NMBR(115,TOTPMP(IPSTN),6,'(F6.0)')
      GOTO40
C
C           IF THE SYSTEM IS READY FOR STOCHASTIC DATA,EXPLAIN THE
C           CONDITION TO THE OPERATOR.
C
```

```
58      IF(MONTH.NE.MINREC)GOTO59
        CALL SUBP(53)
        CALL OFF(53)
        CALL APNT(0.,160.,,,-3,-1)
        CALL TEXT(-2,' THE WHOLE SYSTEM IS NOW',1,
     *  -2,' BEING BALANCED.')
        CALL ESUB(53)
59      CALL ON(53)
C
C                IF STOCHASTIC DATA REQUIRED,RECALCULATE STORAGES.
C
        DO 61 ISYS=ISYSMN,ISYSMX
        MINRES=IRANGE(ISYS,1)
        MAXRES=IRANGE(ISYS,2)
        CALL CALCST
C
C                ASSIGN THE NEW VALUES INTO THE CORRECT ARRAY
C
        DO 60 NRES=IRANGE(ISYS,1),IRANGE(ISYS,2)
60      STOR(NRES,1)=PRSTOR(NRES)
C
C                REINITIALLISE THE CONTROL ARRAY FOR NEXT MONTH
C
        ICNTRL(ISYS)=0
C
C                TURN OFF THE PREVIEW INDICATOR
C
        CALL OFF(ISYS*1000+20)
61      CONTINUE
C
C                'BARGR' USED TO UPDATE STORAGE GRAPHS.
C
        DO 62 ISYS=ISYSMN,ISYSMX
        MINRES=IRANGE(ISYS,1)
        MAXRES=IRANGE(ISYS,2)
62      CALL BARGR(STOR,S,IMONTH)
C
C                INCREMENT MONTH TIME STEP AND CHECK WHETHER IT HAS
C                REACHED THE END OF THE SIMULATION.
C
        MONTH=MONTH+1
        IF(MONTH.GT.MAXREC)GOTO65
C
C                IF STILL WITHIN THE TIME RANGE,INCREMENT THE OTHER
C                TIME VARIABLES ALSO.
C
        IMONTH=IMONTH+1
        JMONTH=JMONTH+1
        IF(IMONTH.GT.12)IMONTH=1
        IF(JMONTH.GT.12)GOTO63
C
C                PROMPT FOR A NEW SUB SYSTEM.
C
        GOTO64
63      JMONTH=1
        IYEAR=IYEAR+1
64      CALL OFF(53)
C
C                RETURN TO RESET TIME.
C
        GOTO14
C
C                PROMPT FOR OUTPUT.
C
65      CALL OFF(53)
        CALL SUBP(54)
```

```
      CALL APNT(0.,160.,,-3,-1)
      CALL TEXT(-2,' DO YOU REQUIRE A PRINTED COPY',
     * 1,-2,' OF THE STORAGE BEHAVIOUR')
      CALL TEXT(1,-2,' DURING THE SIMULATION?',
     * 1,-2,' TYPE "Y" FOR YES,"N" FOR NO.')
      CALL ESUB(54)
      TYPE66
66    FORMAT(5X,'ANSWER='$)
      ACCEPT67,ANSWER
67    FORMAT(A1)
      IF(ANSWER.EQ.'N')STOP
      CALL OUTDAT(MINREC,MAXREC,ISYSMN,ISYSMX,ISTMIN,ISTMAX)
      STOP
C
      END
C
C             THIS BLOCK DATA SUBPROGRAM DEFINES ALL THE INITIAL
C             CONDITIONS FOR THE START OF THE SIMULATION.
C             IT ALSO CONTAINS THE ONGOING OPERATING STORAGES FOR
C             THE SERVICE RESERVOIRS.
C
C
      BLOCK DATA
      COMMON /STORDAT/PRSTOR(12),STRMAX(12),STMAX(12),STMIN(12),
     * MAXFIN(12),MINFIN(12),FRAC,CSTKL1,FRACTN,COSTKL
     * /CORDAT/ISYS,MINRES,MAXRES,IPRVW
     * /CORPMP/PMPQNT(3,16,4),PMPCST(3,16,4),IRANGE(6,2),IPUMP(3),
     * ISYSMN,ISYSMX,SUMCAP(3),PUMP(3),ICOP,ICPY,
     * IHDCPY,ICONSD
     * /CORCAL/DETINF(6,2,12),MYPTRN,TRANSF(12,2),STOR(12,2),S(12,12),
     * IMONTH,MONTH,MINREC
      COMMON /CALPMP/PIPOFT(4,2,12),IMON,ISTMIN,ISTMAX,DEMMIL,
     * WARTRN,MAXPMP(3),EXSMIL
C
      LOGICAL*1 IHDCPY,ICONSD(6)
C
C             MAX STORAGES
C
      DATA STRMAX/26800.,47300.,0.,12700.,0.,16500.,24400.,3470.,
     * 5080.,51300.,4510.,21400./,
C
C             DEFAULT MODE AND PUMPING DATA
C
     * IPRVW,IPUMP/-1,3*111/,
C
C             THE STORAGE NUMBERS ASSOCIATED WITH THE SUBSYSTEMS
C
     * IRANGE/1,2,5,9,10,12,1,4,8,9,11,12/,
C
C             INTER-STORAGE TRANSFER AND PUMPING CAPACITIES
C
     * TRANSF/12*0.,-0.02400,-1.1553,3*0.,-2.08396,2*0.,3.0231,
     * -3.02310,0.,-2.055/,
C
C             DEFINITION OF TYPE OF STORAGE
C
     * STOR/12*0.,1.,1.,-10.,0.,-20.,1.,1.,0.,1.,1.,0.,1./,
C
C             OPERATING RULES FOR THE SERVICE RESERVOIRS
C
     * S/36*0.,3*8000.,10000.,11000.,2*12000.,11000.,2*9000.,2*8000.,
     * 36*0.,3*2000.,5*3000.,4*2000.,24*0.,12*4000.,12*0./
C
C             STARTING VALUES FOR THE RANGE OF PUMPING STATIONS USED
C
     * ISTMIN,ISTMAX/3,1/
```

```
C
      END
>
```

```
C     PROGRAM SATPRG:
C     THIS IS THE PROGRAM USED IN THE SATELLITE PROCESSOR.IT IS
C     RESPONSIBLE FOR PROCESSING ALL LIGHTPEN HITS AND ALSO DOES
C     SOME LIMITED SCREEN MANIPULATION.
C     THE REASON FOR THIS PROGRAM IS THAT LIGHTPEN INTERACTION IS
C     TOO SLOW IN RESPONSE TIME WHEN CONTROLLED FROM THE HOST
C     COMPUTER.
C
      SUBROUTINE USRSAT(B,I)
C
      LOGICAL*1 B(60),ISAT,ISET
C
      DIMENSION JPUMP(3),JJ(3,2),ICNTRL(6),IPIC(26)
C
      DATA JJ/1,5,8,4,7,12/
      DATA IPIC/1,2,3,4,5,6,21,22,23,24,101,102,103,104,105,106,107,
     *108,109,110,111,112,113,114,1001,1002/
C
C     CHECK THAT TRANSFER HAS BEEN MADE TO THIS SUBROUTINE
C
      IF(I.EQ.0.OR.B(1).LT.100.OR.B(1).GT.101)RETURN
      IF(B(1).EQ.100)GOTO10
C
C     DELAY MAIN PROGRAM
C
      CALL DHOST(6)
C
C     CONVERT DATA INTO USABLE FORM
C
      IPMP=INTEGR(B(2))
      ISYS=B(4)
      ISAT=B(5)
C
C     IF MYPONGA SUBSYSTEM,SKIP PUMP SETUP
C
      IF(ISYS.EQ.1)GOTO90
C
C     SET PUMPING CONTROL TO "NO PUMPING"
C
      IF(ISAT.NE.1.OR.IABS(ICNTRL(ISYS)).NE.1)ICNTRL(ISYS)=-1
      IF(IPMP.NE.JPMP)GOTO11
      IF(ISAT.EQ.1.AND.ISYSTM.EQ.ISYS)GOTO90
C
C     SET PUMPING CONFIGURATION
C
11    IT2=0
      JPUMP(1)=IPMP/100
      JPUMP(2)=(IPMP-JPUMP(1)*100)/10
      JPUMP(3)=IPMP-JPUMP(1)*100-JPUMP(2)*10
C
C     TURN OFF FLASHING PREVIOUS PUMP CONFIGURATION
C
      DO 1 J=101,112
      CALL POINTR(12,J)
1     CALL FLASH(12,-1)
C
C     TURN ON NEW PUMP OPERATION,FLASHING
C
      DO 2 J=1,3
      IT=100+JPUMP(J)+(JJ(J,1)-1)
      CALL POINTR(12,IT)
2     CALL FLASH(12,1)
      GOTO90
```

```
C
C       DELAY MAIN PROGRAM
C
10      CALL DHOST(1)
        GOTO100
C
C       TURN ON LIGHT BUTTONS - CHECK,PREVIEW,ACCEPT,REVERT
,C
90      DO 901 IT=21,24
901     CALL ON(IT)
C
C       BRANCH ACCORDING TO SUBSYSTEM
C
        ISET=1
        ITRN=ICNTRL(ISYS)
        IF(ISYS.EQ.ISYSTM)GOTO100
        IF(ISYS.GE.2)GOTO91
        GOTO(301,302),(3-ITRN)/2
91      IT=112+(3-ITRN)/2
        GOTO(411,412),(3-ITRN)/2
C
C       PREPARE TO CHECK FOR LIGHTPEN HITS
C
100     IHIT=0
101     CALL GRATTN(1,IRETRN,1)
        CALL LPEN(IH,IT)
C
C       CHECK WHETHER THE LIGHTPEN HITS AN ALLOWABLE SCREEN ELEMENT
C
        DO 102 NN=1,26
102     IF(IT.EQ.IPIC(NN))GOTO103
        GOTO100
103     IF(IH.EQ.0)GOTO101
C
C       DO NOT REGISTER THE HIT UNTIL IT HAS OCCURRED FOR 5 ITERATIONS
C
        IHIT=IHIT+1
        IF(IHIT.LT.5)GOTO101
        IF(IT.GT.100)ISET=0
C
C       DO NOT ALLOW MULTIPLE PREVIEWS
C
        IF(IT2.EQ.IT.AND.IT.EQ.21.AND.ISET.EQ.1)GOTO100
C
C       BRANCH ACCORDING TO THE SUBPICTURE THAT WAS TOUCHED
C
        IF(B(1).EQ.100.AND.1.LE.IT.AND.IT.LE.6)GOTO200
        IF(B(1).EQ.100)GOTO101
        IF(IT.GT.1000)GOTO300
        IF(IT.GT.100)GOTO400
        IF(IT.GT.20)GOTO500
        GOTO100
C
C       HAVING CHOSEN A NEW SUBSYSTEM,RETURN TO MAIN PROGRAM
C
200     CALL POINTR(11,IT,2)
        CALL INTENS(11,8)
        CALL TOHOST(1,IT)
        ISAT=0
        RETURN
C
C       MANIPULATION OF MYPONGA SUBSYSTEM
C
300     GOTO(301,302,301,302),IT-1000
301     ITRN=1
        IF(IABS(ICNTRL(1)).NE.1)GOTO3010
```

```
      CALL POINTR(12,1005)
      CALL FLASH(12,1)
3010  CALL OFF(1006)
      CALL OFF(1007)
      GOTO100
302   ITRN=-1
      IF(IABS(ICNTRL(1)).NE.1)GOTO3020
      CALL POINTR(12,1005)
      CALL FLASH(12,-1)
3020  CALL ON(1006)
      CALL ON(1007)
      GOTO100
C
C     PUMPING CONTROL
C
400   IF(IT.GE.113)GOTO410
      NUM=1
      IF(IT.GE.105)NUM=2
      IF(IT.GE.108)NUM=3
      DO 405 I=JJ(NUM,1),JJ(NUM,2)
      CALL POINTR(12,I+100)
405   CALL FLASH(12,-1)
      JPUMP(NUM)=IT-(100+(JJ(NUM,1)-1))
      CALL POINTR(12,IT)
      CALL FLASH(12,1)
      GOTO100
410   GOTO(411,412),(IT-112)
411   ITRN=1
      CALL POINTR(12,114)
      CALL OFF(ISYS*100)
      IF(ISYS.EQ.5)CALL OFF(501)
      GOTO413
412   ITRN=-1
      CALL POINTR(12,113)
      CALL ON(ISYS*100)
      IF(ISYS.EQ.5)CALL ON(501)
413   CALL FLASH(12,-1)
      CALL POINTR(12,IT)
      CALL FLASH(12,1)
      GOTO100
C
C     SYSTEM CONTROL
C
500   CALL OFF(IT)
      GOTO(510,520,530,540),(IT-20)
510   IPRVW=1
      GOTO6101
520   IPRVW=0
      GOTO6101
530   IPRVW=-1
      GOTO6101
540   IPRVW=10
C
C     CODE UP REQUIRED DATA AND RETURN TO MAIN PROGRAM
C
6101  IF(ISYS.EQ.1)GOTO611
      JPMP=JPUMP(1)*100+JPUMP(2)*10+JPUMP(3)
611   IT2=IT
      ISAT=0
      ISYSTM=ISYS
      ICNTRL(ISYS)=ITRN
      CALL TOHOST(2,JPMP,2,ITRN,2,IPRVW)
      RETURN
      END
>
```

```
C     SUBROUTINE STINIT PROMPTS FOR AND RECEIVES THE STARTING STORAGES
C     FOR ALL THE SUBSYSTEMS UNDER CONSIDERATION.
C                             _000_
C
      SUBROUTINE STINIT(ISYSMN,ISYSMX,IRANGE,STOR,IMONTH,S,STRMAX)
      DIMENSION IRANGE(6,2),STOR(12,2),S(12,12),STRMAX(12)
C
      INTEGER*4 ISTOR
C
C             PROMPT FOR STORAGE;STARTING AT FIRST SUBSYSTEM REQUESTED.
C
      ISYS=ISYSMN
141   NRES=IRANGE(ISYS,1)
      JRES=1
142   IF(STOR(NRES,2).GT.0.)GOTO143
      GOTO212
143   GOTO(150,160,170,180,190,200),ISYS
150   TYPE151
151   FORMAT(////2X,'STARTING STORAGE FOR MYPONGA'/
     * 2X,'(CAPACITY=26800ML)='$)
      GOTO210
160   TYPE162
162   FORMAT(////2X,'STARTING STORAGE FOR MOUNT BOLD'/
     * 2X,'(CAPACITY=47300ML)='$)
      GOTO210
170   GOTO(171,173),JRES
171   TYPE172
172   FORMAT(////2X,'STARTING STORAGE FOR MILLBROOK'/
     * 2X,'(CAPACITY=16500ML)='$)
      GOTO210
173   TYPE174
174   FORMAT(2X,'STARTING STORAGE FOR KANGAROO CREEK'/
     * 2X,'(CAPACITY=24400ML)='$)
      GOTO210
180   TYPE181
181   FORMAT(////2X,'STARTING STORAGE FOR WARREN'/
     * 2X,'(CAPACITY=5080ML)='$)
      GOTO210
190   TYPE192
192   FORMAT(////2X,'STARTING STORAGE FOR SOUTH PARA'/
     * 2X,'(CAPACITY=51300ML)='$)
      GOTO210
200   TYPE201
201   FORMAT(////2X,'STARTING STORAGE FOR LITTLE PARA'/
     * 2X,'(CAPACITY=21400ML)='$)
C
C             ACCEPT STORAGE VALUE
C
210   ACCEPT211,ISTOR
211   FORMAT(I5)
C
C             ASSIGN VALUE TO ARRAY
C
      STOR(NRES,1)=FLOAT(ISTOR)
C
C             PREVENT EXCESSIVE STORAGE BEING SPECIFIED
C
      IF(STOR(NRES,1).GT.STRMAX(NRES))GOTO142
      IF(NRES.NE.6)GOTO2110
C
C             SET MILLBROOK'S OPERATING STORAGE TO CURRENT VALUE
C
      LSTMON=IMONTH-1
      IF(IMONTH.EQ.1)LSTMON=12
```

```
      S(LSTMON,6)=STOR(6,1)
C
C               INCREMENT STORAGE NUMBER
C
2110  JRES=JRES+1
212   NRES=NRES+1
      IF(NRES.LE.IRANGE(ISYS,2))GOTO142
C
C               IF STORAGE 'NRES' IS NO LONGER IN SUBSYSTEM 'ISYS',
C               INCREMENT 'ISYS'.
C
      ISYS=ISYS+1
      IF(ISYS.LE.ISYSMX)GOTO141
      RETURN
      END
>
```

```
C     SUBROUTINE TIMSET MODIFIES THE SCREEN DIPLAY OF THE MONTHLY
C     PROGRESS IN THE SIMULATION.
C                     _OOO_
      SUBROUTINE TIMSET(JMONTH,MONTH,MINREC,IYEAR,IMONTH,IYEARS)
C
      COMMON /SETUP/IBAR,ICALC,SMAX(6),XMIN(12),YMIN(12),YMAX(12),
     *ICOUNT,ISTRT,MYP,NOTRAN,MLLBRK,LPARA,SPARA,IXS
C
      LOGICAL*1 STRNG(6),IBAR(6),ICALC(6),ISTRT,MYP,NOTRAN,MLLBRK,
     *LPARA,SPARA
C
      CALL POINTR(1,100,8)
C
C             CHECK WHETHER STARTING A NEW YEAR OR FIRST MONTH OF
C             SIMULATION.
C
      IF(JMONTH.EQ.1.OR.MONTH.EQ.MINREC)GOTO1
      GOTO2
C
C             MODIFY THE YEAR
C
1     CALL ITOA(IYEAR,4,STRNG)
      STRNG(5)=0
      CALL CHANGT(1,STRNG)
C
C             MODIFY THE MONTH
C
2     CALL ADVANC(1,4)
      MON=IMONTH
      CALL MNTH(MON,STRNG)
      CALL CHANGT(1,STRNG)
      IF(MONTH.EQ.MINREC.OR.IMONTH.EQ.1)GOTO3
      RETURN
C
C             INCREMENT THE DISPLAY OF THE NUMBER OF YEARS SIMULATED
C
3     STRNG(3)=0
      IF(MONTH.EQ.MINREC)ICOUNT=1
      CALL ADVANC(1,4)
      CALL ITOA(ICOUNT,2,STRNG)
      CALL CHANGT(1,STRNG)
      IF(ICOUNT.LT.IYEARS)ICOUNT=ICOUNT+1
      IF(MONTH.NE.MINREC)RETURN
      CALL ADVANC(1,4)
      CALL ITOA(IYEARS,2,STRNG)
      CALL CHANGT(1,STRNG)
C
      RETURN
      END
>
```

```
C       SUBROUTINE REDATR: READS THE ONCE ONLY DATA WHICH REMAINS
C               UNCHANGED THROUGHOUT THE PROGRAM RUN.
C
        SUBROUTINE REDATR(ISYSMN,ISYSMX,DETINF,MAXPMP,PMPQNT,
     *  PMPCST,EVAPN)
C
        DIMENSION DETINF(6,2,12),MAXPMP(3),PMPQNT(3,16,4),
     *  PMPCST(3,16,4),EVAPN(154,13),X(13)
C
C               AVERAGE MONTHLY INFLOW:
C               90% AND 10% PROBALILITY INFLOW
C
        OPEN(UNIT=7,NAME='DETINFL.DAT',TYPE='OLD',ACCESS='DIRECT',
     *  FORM='FORMATTED')
        J=1
        ISYS=ISYSMN
        MIN=(ISYSMN-1)*2+1
        DO 230 IREC=MIN,ISYSMX*2
        READ(7'IREC,215),(DETINF(ISYS,J,MON),MON=1,12)
215     FORMAT(12F7.0)
        IF(ISYS.EQ.ISYSMX.AND.J.EQ.2)GOTO230
        IF(J.EQ.2)GOTO220
        J=J+1
        GOTO230
220     ISYS=ISYS+1
        J=1
230     CONTINUE
        CLOSE(UNIT=7)
D       TYPE231
D231    FORMAT(2X,'END DETINFL')
C
C               PUMPING DATA
C
        OPEN(UNIT=7,NAME='PUMP.DAT',TYPE='OLD')
250     READ(7,260,END=290),(X(I),I=1,8)
260     FORMAT(8F7.2)
C
C               CHECK WHETHER DATA INDICATES A DIFFERENT PUMPSTATION
C
        IF(X(1).GT.0.)GOTO270
C
C               IF X(1)<0. USE THAT LINE OF DATA TO FIND WHICH OF THE
C               PUMPSTATIONS IS INDICATED,AND THE NUMBER OF PUMPS.
C
        IPSTN=INT(ABS(X(1)))
        MAXPMP(IPSTN)=INT(X(2))
        NTIME=1
D       TYPE261,IPSTN,MAXPMP(IPSTN)
D261    FORMAT(2X,'IPSTN',I4,'MAXPMP',I4)
        GOTO250
C
C               ASSIGN THE VALUES IN ARRAY 'X' TO CORRECT POSITIONS
C               IN THE STORAGE ARRAYS
C
270     NPUMPS=1
        MAX=MAXPMP(IPSTN)
        DO 280 I=1,(2*MAX-1),2
        PMPQNT(IPSTN,NTIME,NPUMPS)=X(I)
        PMPCST(IPSTN,NTIME,NPUMPS)=X(I+1)
280     NPUMPS=NPUMPS+1
        NTIME=NTIME+1
        GOTO250
290     CLOSE(UNIT=7)
D       TYPE291
```

```
D291    FORMAT(2X,'END PUMP')
C
C               EVAPORATION DATA
C
C               DATA FOR ALL RESERVOIRS IS IN ONE CONTINUOUS FILE SINCE
C               EACH RESERVOIR HAS A DATA SET OF A DIFFERENT LENGTH.
C
C
        OPEN(UNIT=7,NAME='EVAP.DAT',TYPE='OLD')
        DO 310 IREC=1,153
        READ(7,301),X
301     FORMAT(13F7.0)
        DO 305 JMON=1,13
305     EVAPN(IREC,JMON)=X(JMON)
310     CONTINUE
320     CLOSE(UNIT=7)
D       TYPE321
D321    FORMAT(2X,'END EVAP')
        RETURN
        END
>
```

```
C     SUBROUTINE OUTDAT: READS STORED DATA FOR THE SIMULATION AND
C             PROVIDES AN ORDERLY OUTPUT FORMAT FOR EXAMINATION
C
      SUBROUTINE OUTDAT(MINREC,MAXREC,ISYSMN,ISYSMX,ISTMIN,ISTMAX)
C
      DIMENSION X(14)
C
C             SET INITIAL VALUES
C             CALCULATION OF MONTH NUMBER (FINANCIAL YEAR)
C
      KMON=MINREC-(MINREC/12)*12
      K=(KMON-1)/6
      IMON=KMON+((-1)**K)*6
C
C             STARTING RECORDS IN FILES
C
      ICOP=1
      ICPY=1
      IREC=MINREC
C
C             RECALL THAT CURRENT DATA SET STARTS IN 1976
C
      IYEAR=(MINREC-1)/12+1976
C
      OPEN(UNIT=7,NAME='OUTPUT.DAT',TYPE='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECORDSIZE=100,ASSOCIATEVARIABLE=ICOP)
      OPEN(UNIT=8,NAME='OUTPMP.DAT',TYPE='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECORDSIZE=42,ASSOCIATEVARIABLE=ICPY)
      IYR=IYEAR
C
C             FINANCIAL YEAR HEADINGS
C
949   IF(IYR.GT.IYEAR)IMON=1
      IF(IMON.GT.6)WRITE(10,950) IYR-1,IYR
      IF(IMON.LE.6)WRITE(10,950) IYR,IYR+1
950   FORMAT(///2X,'YEAR=',I4,'/',I4)
C
C             TABLE HEADINGS
C
      WRITE(10,951)
951   FORMAT(/1X,'*YEAR*MONTH*SYSTEM',4('*STORAGE* INFLOW'),
     * '* DEMAND*  SPILL*DEFICIT* EXTRAN*    PUMP*    COST')
C
C             READ AND WRITE DATA OF STORAGE PARAMETERS
C
      DO 954 ISYS=ISYSMN,ISYSMX
      WRITE(10,1)
1     FORMAT(/)
      JYR=IYR
      DO 954 MON=IMON,12
C
C             CALENDAR MONTH CALC
C
      K=(MON-1)/6
      JMON=MON+((-1)**K)*6
C
      READ(7'ICOP,952) (X(I),I=1,14)
952   FORMAT(13F7.0,F9.0)
      WRITE(10,953) JYR,JMON,ISYS,(X(I),I=1,14)
953   FORMAT(1X,'*',I4,'*',2X,I2,1X,'*',2X,I1,3X,13('*',F7.0),'*',F8.0)
      IF(JMON.NE.12)GOTO954
      JYR=JYR+1
954   CONTINUE
C
```

```
C                   READ AND WRITE PUMPSTATION PARAMETERS
C
      WRITE(10,955)
955   FORMAT(//1X,'*YEAR*STN.PUMP*MONTH*PUMPS*DURATION*WEEKS*',
     X'TOT.PUMP*OFFTAKES*AVAIL.PUMP*RES.PUMP*COST')
C
      DO 958 JPSTN=ISTMIN,ISTMAX
      KYR=IYR
      DO 958 MON=IMON,12
      K=(MON-1)/6
      JMON=MON+((-1)**K)*6
      READ(8'ICPY,956) (X(I),I=1,8)
956   FORMAT(3F2.0,4F7.0,F8.0)
      WRITE(10,957) KYR,JPSTN,JMON,(X(I),I=1,8)
957   FORMAT(1X,'*',I4,'*',3X,I2,3X,'*',2X,I2,1X,'*',2X,F2.0,1X,
     *'*',3X,F2.0,3X,'*',2X,F2.0,1X,'*',2(F8.0,'*'),2X,
     *2(F8.0,'*'),F8.0)
      IF(JMON.NE.12)GOTO958
      KYR=KYR+1
958   IF(JPSTN.EQ.ISTMAX)IREC=IREC+1
      IF(IREC.GT.MAXREC)GOTO959
      IYR=IYR+1
      GOTO949
959   CLOSE(UNIT=7)
      CLOSE(UNIT=8)
C
C                   READ AND WRITE SUBSYSTEM PERFORMANCE DATA
C
      OPEN(UNIT=7,NAME='SUBFORM.DAT',TYPE='OLD',ACCESS='DIRECT',
     *FORM='FORMATTED',RECORDSIZE=78,ASSOCIATEVARIABLE=ISUB)
      MAXM=MAXREC+1-MINREC
      INTRVL=ISYSMX+1-ISYSMN
      WRITE(10,9600)
9600  FORMAT(6X//' PERFORMANCE DATA'/2X,'*YEAR*MONTH*SYSTEM* TOT.INF',
     X'* TOT.DEM* TRANSFR*  COST:$*    SPILL* DEFICIT*  CENTS/KL*',
     X'   DEM/TRAN*DEM-TRN/INF*')
      DO 972 K=1,3
      GOTO(961,962,963),K
961   WRITE(10,9610)
9610  FORMAT(4X/2X,'MONTHLY:')
      GOTO964
962   WRITE(10,9620)
9620  FORMAT(4X/2X,'YEARLY:')
      GOTO964
963   WRITE(10,9630)
9630  FORMAT(4X/2X,'SIMULATION-LONG:')
964   DO 972 ISYS=ISYSMN,ISYSMX
      JYR=IYEAR
      MMON=KMON
      ISTART=(K-1)*INTRVL+(ISYS+1-ISYSMN)
C
C                   LOOP DATA RECORDS
C
      DO 972 ISUB1=ISTART,MAXM*3*INTRVL,3*INTRVL
      GOTO(970,965,966),K
965   IF(MMON.NE.6)GOTO971
      GOTO970
966   IF(ISUB1.NE.ISTART+(MAXM-1)*INTRVL*3)GOTO971
970   ISUB=ISUB1
      READ(7'ISUB,9700),(X(II),II=1,9)
9700  FORMAT(6F8.0,3F10.3)
      WRITE(10,9710) JYR,MMON,ISYS,(X(II),II=1,9)
9710  FORMAT(2X,'*',I4,'*',1X,I2,2X,'*',2X,I2,2X,'*',6(F8.0,'*'),
     *3(F10.3,'*'))
971   MMON=MMON+1
      IF(MMON.LE.12)GOTO972
```

```
        MMON=1
        JYR=JYR+1
972     CONTINUE
        CLOSE(UNIT=7)
C
C               READ AND WRITE DATA ON WHOLE SYSTEM PERFORMANCE
C
        OPEN(UNIT=7,NAME='TOTFORM.DAT',TYPE='OLD',ACCESS='DIRECT',
     *  FORM='FORMATTED',RECORDSIZE=78,ASSOCIATEVARIABLE=ITOT)
        DO 992 K=1,3
        GOTO(980,981,982),K
980     WRITE(10,9610)
        GOTO983
981     WRITE(10,9620)
        GOTO983
982     WRITE(10,9630)
983     JYR=IYEAR
        MMON=KMON
        DO 992 ITOT1=K,MAXM*3,3
        GOTO(990,984,985),K
984     IF(MMON.NE.6)GOTO991
        GOTO990
985     IF(ITOT1.NE.MAXM*3)GOTO991
990     ITOT=ITOT1
        READ(7'ITOT,9700),(X(II),II=1,9)
        WRITE(10,9710) JYR,MMON,ISYS,(X(II),II=1,9)
991     MMON=MMON+1
        IF(MMON.LE.12)GOTO992
        MMON=1
        JYR=JYR+1
992     CONTINUE
        CLOSE(UNIT=7)
        RETURN
        END
>
```

```
C     SUBROUTINE SCREEN: SETS UP THE OVERALL DISPLAY FORMAT FOR THE
C             WHOLE SCREEN.
C
      SUBROUTINE SCREEN
C
      CALL SUBP(100)
      CALL OFF(100)
      CALL APNT(10.,970.,,-4)
C
C             TITLE BLOCK,LOCATION AND TIME DATA
C
      CALL TEXT(-2,'REGION:')
      CALL RPNT(0.,0.)
      CALL TEXT('0000000000000000')
      CALL APNT(10.,945.,,-4)
      CALL TEXT(-2,'YEAR:')
      CALL RPNT(0.,0.)
      CALL TEXT('0000')
      CALL APNT(10.,920.,,-4)
      CALL TEXT(-2,'STATUS AT START OF: ')
      CALL RPNT(0.,0.)
      CALL TEXT('0000000')
      CALL APNT(10.,895.,,-4)
      CALL TEXT(-2,'YEAR ')
      CALL RPNT(0.,0.)
      CALL TEXT('00')
      CALL RPNT(0.,0.)
      CALL TEXT(-2,' IN TOTAL SIMULATION OF ')
      CALL RPNT(0.,0.)
      CALL TEXT('00')
      CALL RPNT(0.,0.)
      CALL TEXT(-2,' YEARS')
C
C             COMMENCE SCREEN SEGMENTATION
C
      CALL APNT(0.,0.,,-1)
      CALL LVECT(0.,1000.,,1)
      CALL LVECT(1000.,0.)
      CALL LVECT(0.,-1000.)
      CALL LVECT(-1000.,0.)
      CALL LVECT(0.,890.,,-1)
      CALL LVECT(830.,0.,,1)
      CALL LVECT(0.,110.,,-1)
      CALL LVECT(0.,-1000.,,1)
      CALL LVECT(5.,575.,,-4)
C
C             SUBSYSTEM MENU
C
      CALL TEXT(-2,'SUBSYSTEMS')
      CALL SUBP(1)
      CALL APNT(835.,505.,1,-4)
      CALL TEXT('MYPONGA')
      CALL ESUB(1)
      CALL SUBP(2)
      CALL APNT(835.,475.,1,-4)
      CALL TEXT('ONKAPARINGA')
      CALL ESUB(2)
      CALL SUBP(3)
      CALL APNT(835.,445.,1,-4)
      CALL TEXT('TORRENS')
      CALL ESUB(3)
      CALL SUBP(4)
      CALL APNT(835.,415.,1,-4)
      CALL TEXT('WARREN+NTH.')
```

```
      CALL ESUB(4)
      CALL SUBP(5)
      CALL APNT(835.,385.,1,-4)
      CALL TEXT('SOUTH PARA')
      CALL ESUB(5)
      CALL SUBP(6)
      CALL APNT(835.,355.,1,-4)
      CALL TEXT('LITTLE PARA')
      CALL ESUB(6)
C
C           COMPLETE SCREEN SEGMENTS
C
      CALL APNT(1000.,600.,-1,-1)
      CALL LVECT(-170.,0.,,1)
      CALL LVECT(0.,-350.,,-1)
      CALL LVECT(-830.,0.,,1)
      CALL LVECT(150.,0.,,-1)
      CALL LVECT(0.,640.,,1)
      CALL LVECT(-140.,-25.,,-4)
C
C           SET UP TITLES FOR ECONOMIC CRITERIA,SYSTEM COMMUNICATIONS,
C           PUMPING CONFIGURATIONS.
C
      CALL TEXT(-2,'ECONOMIC')
      CALL LVECT(-112.,-25.,,-4)
      CALL TEXT(-2,'CRITERIA')
      CALL LVECT(-112.,-620.,,-4)
      CALL TEXT(-2,'SYSTEM COMMUNICATIONS:')
      CALL APNT(510.,220.,,-4)
      CALL TEXT(-2,'PUMPING CONFIGURATION:')
      CALL SUBP(7)
      CALL LVECT(-310.,-30.,,-4)
      CALL TEXT('             ')
      CALL RPNT(0.,0.,,-3)
      CALL TEXT('(')
      CALL NMBR(115,0.,6,'(F6.0)')
      CALL TEXT(-2,'ML)')
      CALL ESUB(7)
      CALL APNT(500.,250.,,-1)
      CALL LVECT(0.,-250.,,1)
      CALL SUBP(90)
      CALL APNT(0.,790.,,-3,-1)
C
C           COMPLETE THE ECONOMIC CRITERIA SECTION
C
      CALL TEXT(-2,'  COST/KL')
      CALL LVECT(-112.,-25.,,-3)
      CALL NMBR(91,0.00,5,'(F5.2)')
      CALL LVECT(-70.,-25.,,-3)
      CALL TEXT(-2,'CENTS/KL')
      CALL APNT(0.,700.,,-3,-1)
      CALL TEXT(-2,' FRACTION',1,-2,' OF DEMAND',1,-2,' SUPPLIED')
      CALL TEXT(1,-2,' BY PUMPS')
C
C           SIMPLE BAR GRAPH
C
      CALL APNT(25.,300.,,-2,-1,1)
      CALL SVECT(50.,0.,,3)
      CALL LVECT(0.,300.)
      CALL TEXT(-2,'100%')
      CALL SVECT(-56.,0.,,-2)
      CALL SVECT(-50.,0.,,2)
      CALL LVECT(0.,-300.)
      CALL LVECT(0.,0.,,-2)
      CALL SVECT(50.,0.,,2)
      CALL SVECT(5.,-25.,,-2)
```

```
        CALL NMBR(93,0.,4,'(F4.0)')
        CALL TEXT('%')
        CALL ESUB(90)
C
C                PUMPING CONFIGURATION MENU
C
        CALL MENU(515.,255.,0.,114,'NO PUMPING')
        CALL MENU(685.,255.,0.,113,'PUMP')
        CALL MENU(880.,830.,-100.,21,'PREVIEW','ACCEPT','REVERT')
        CALL MENU(880.,925.,0.,24,'CHECK')
        CALL MENU(550.,150.,-30.,101,'1PUMP','2PUMP','3PUMP','4PUMP')
        CALL MENU(630.,150.,-30.,105,'OFFPK','ONPK','SONPK')
        CALL MENU(710.,150.,-30.,108,'INTER','1WEEK','2WEEK','3WEEK',
     *  'MONTH')
        CALL ESUB(100)
C
C                INITIALLY TURN OFF ALL PUMPING MENUS
C
        DO 213 JSUB=101,112
213     CALL OFF(JSUB)
C
        RETURN
        END
>
```

```
C       SUBROUTINE MNTH SUPPLIES THE NAME OF THE CURRENT MONTH AS A TAG
C       FOR VARIOUS SCREEN ELEMENTS.
C                                 _000_
        SUBROUTINE MNTH(I,STRNG)
        LOGICAL*1 A(59),STRNG(10)
        DATA A/0,'J','A','N',0,'F','E','B',0,
     *  'M','A','R','C','H',0,'A','P','R','I','L',0,
     *  'M','A','Y',0,'J','U','N','E',0,
     *  'J','U','L','Y',0,'A','U','G','U','S','T',0,
     *  'S','E','P','T',0,'O','C','T',0,
     *  'N','O','V',0,'D','E','C',0/
C
C                 DETERMINE CALENDAR MONTH NUMBER
C
        K=(I-1)/6
        JMON=I+(((-1)**K)*6)
C
        J=0
        K=1
C
C                 SORT THROUGH ARRAY 'A' UNTIL THE CORRECT MONTH IS FOUND
C
31      IF(A(K).EQ.0)J=J+1
        IF(J.EQ.JMON)GOTO32
        K=K+1
        GOTO31
32      J=1
33      K=K+1
C
C                 ASSIGN NAME TO ARRAY
C
        STRNG(J)=A(K)
        J=J+1
        IF(A(K).NE.0)GOTO33
C
        RETURN
        END
>
```

```
C     SUBROUTINE CALCST:THE MAIN CALCULATION ROUTINE.IT CONTROLS ALL
C     CALCULATIONS ASSOCIATED WITH EACH SUBSYSTEM FOR THE CURRENT MONTH
C     DETERMINISTIC,FUTURE PREDICTIVE,AND CURRENT MONTH STOCHASTIC
C     STORAGE ANALYSIS.
C     IT CALLS ALL OTHER SUBROUTINES NEEDED FOR CALCULATIONS ON STORAGES
C     AND ALSO CONTROLS THE SUBROUTINES FOR FILING OUTPUT (HRDCOP),AND
C     OPERATOR PERFORMANCE CALCULATIONS (SKILL).
C                           _000_
      SUBROUTINE CALCST
C
      COMMON /STORDAT/PRSTOR(12),STRMAX(12),STMAX(12),STMIN(12),
     * MAXFIN(12),MINFIN(12),FRAC,CSTKL1,FRACTN,COSTKL
     * /CORDAT/ISYS,MINRES,MAXRES,IPRVW
     * /CORCAL/DETINF(6,2,12),MYPTRN,TRANSF(12,2),STOR(12,2),S(12,12),
     * IMONTH,MONTH,MINREC
     * /CORPMP/PMPQNT(3,16,4),PMPCST(3,16,4),IRANGE(6,2),IPUMP(3),
     * ISYSMN,ISYSMX,SUMCAP(3),PUMP(3),ICOP,ICPY,
     * IHDCPY,ICONSD
      COMMON /CALPMP/PIPOFT(4,2,12),IMON,ISTMIN,ISTMAX,DEMMIL,
     * WARTRN,MAXPMP(3),EXSMIL
     * /SETUP/IBAR,ICALC,SMAX(6),XMIN(12),YMIN(12),YMAX(12),ICOUNT,
     * ISTRT,MYP,NOTRAN,MLLBRK,LPARA,SPARA,IXS
     * /CALHLD/DTDEM(6,12),STDEM(6,12),STOINF(13,12),DEMMYP(2,12),
     * WARSPL,HAPVLY,IDTDEM,ISTDEM,ISTINF,PSPPLY,ISPPLY
     * /PMPCPY/IPSTN,TOTPMP(3),COST(3),TRAN(6),CAPCTY
C
      LOGICAL*1 ICALC(6),IBAR(6),ISTRT,MYP,NOTRAN,ISWTCH,MLLBRK,
     * ICONSD(6),IHDCPY,LPARA,SPARA
C
      DIMENSION ST(12),DEFCIT(6),SPILL(6)
C
      DATA CAPMYS,CAPMYW,CAPSUM,CSTMIL/2400.,3530,7150.,8./
C
C             SET LOCAL MONTH COUNTER
C
      IMON=IMONTH
C
C             SET INDEX FOR DEMAND FILES ACCORDING TO VALUE TAKEN
C             BY `IPRVW`.
C
      J=1
      IF(IPRVW.EQ.0)J=2
C
C
C             CHECK WHETHER IT IS THE FIRST TIME THROUGH FOR THE
C             SUBSYSTEM,OR IF A NEW YEAR HAS STARTED.IN EITHER
C             CASE NEW DATA MUST BE READ FROM FILES.
C
      IF(ISTRT.EQ.1.AND.IMON.EQ.1.AND.MONTH.GT.MINREC)GOTO3
      IF(ISTRT.EQ.1)GOTO4
C
C             READ THE NEXT YEAR`S WORTH OF DATA.
C
3     CALL CALDAT(ISTRT)
4     IF(ICALC(ISYS).EQ.1)GOTO5
C
C             IF SUBSYSTEM HAS NOT ALREADY BEEN THROUGH `CALCST`
C             -I.E.PROGRAM INITIALLISATION-SET CYCLE NUMBER TO
C             PREDICTION CYCLES ONLY.
C
      NCYCL=2
      GOTO8
C
C             SET UP THE STARTING CYCLE NUMBER FOR THE CALCULATION
```

```
C
5       NCYCL=1
C
C               STORAGE CALCULATION:BOTH DETERMINISTIC AND STOCHASTIC-
C
C               DEFINE LOCAL STORAGE VARIABLE VALUES.
C
8       DO 9 NRES=MINRES,MAXRES
C
C               STORAGE FOR SERVICE RESERVOIRS
C
        IF(STOR(NRES,2).EQ.0.)STOR(NRES,1)=S(IMON,NRES)
C
C               VARIABLE STORAGES+WEIRS
C
9       ST(NRES)=STOR(NRES,1)
C
C               INITIALLIZE DERIVED DATA FOR EACH CYCLE.
C
10      SUMSTR=0.
        DEMAND=0.
        SPILL(ISYS)=0.
C
C               EVALUATE THE NEXT MONTH NUMBER.
C
        NXTMON=IMON+1
        IF(IMON.EQ.12)NXTMON=1
C
C               SKIP THE FOLLOWING CALCULATIONS IF EITHER THE STORAGE
C               UNDER CONSIDERATION IS NOT MILLBROOK (NRES=6),OR IT IS
C               THE LAST CALULATION FOR A YEAR AND THE PROGRAM IS NOT
C               BEING INITIATED.
C
        IF(ISYS.NE.3.AND.ISYS.NE.6.OR.IMONTH.EQ.12.AND.ICALC(3).EQ.1)GOTO103
C
C               DEFINE STORAGE FOR MILLBROOK.
C
C               SET UP NEXT MONTH`S VALUE FOR MILLBROOK (NRES=6).
C
        IF(NCYCL.GE.2.OR.S(NXTMON,6).EQ.0.)S(NXTMON,6)=S(IMON,6)
103     CONTINUE
D       WRITE(10,1),NCYCL,IMONTH,ISYS,S(NXTMON,6)
D1      FORMAT(6X,'NCYCL',I4,'IMONTH',I4,'ISYS',I4,'S(NXTMON,6)',F7.0)
C
C               SKIP CALCULATION IF IT IS THE MYPONGA (ISYS=1)
C               SUBSYSTEM IN PREDICTIVE MODE FOR THE CURRENT MONTH
C               OR CALCULATIONS ARE IN THE PREDICTION CYCLES AND
C               CALCULATIONS ARE NOT FOR THE FINAL MONTH OF THE
C               YEAR.
C
        IF(ISYS.EQ.1.AND.NCYCL.EQ.1.AND.IPRVW.EQ.1.OR.
     *  NCYCL.GE.2.AND.IMON.NE.IMONTH)GOTO14
C
C               DEFINE THE INTER-SUBSYSTEM TRANSFERS FOR MYPONGA AND
C               WARREN SPILL IN THE CURRENT MONTH ONLY.
C
        GOTO(11,12,14,14,13,14),ISYS
C
C               TRANSFER OUT OF MYPONGA (NRES=1)
C
11      TRANSF(1,1)=-1*HAPVLY
C
C               IF NO TRANSFER,SET ARRAY ELEMENT TO 0.
C
        IF(MYPTRN.EQ.-1)TRANSF(1,1)=0.
D       WRITE(10,1100),TRANSF(1,1)
```

```
        GOTO14
C
C               MYPONGA TRANSFER RECEIVED BY HAPPY VALLEY
C
12      TRANSF(4,1)=HAPVLY
        IF(MYPTRN.EQ.-1)TRANSF(4,1)=0.
D       WRITE(10,1100),TRANSF(4,1)
        GOTO14
C
C               TRANSFER RECEIVED BY SOUTH PARA (NRES=10) WHEN
C               WARREN SPILLS.
C
13      TRANSF(10,1)=WARSPL
D       WRITE(10,1100),TRANSF(10,1)
D1100   FORMAT(2X,'TRANSF',F7.0)
C
C               START CALCULATION LOOP
C
14      DO 100 NRES=MINRES,MAXRES
C
C               CHECK WHETHER NRES IS A RESERVOIR OR WEIR AND BRANCH
C               ACCORDINGLY
C
D       WRITE(10,2) NRES,STOR(NRES,2),IMONTH,ISYS
D2      FORMAT(2X,'NRES',I2,'STOR2',F7.0,'IMONTH',I4,'ISYS',I4)
        IF(STOR(NRES,2).GE.0.)GOTO20
C
C               IF `NRES` IS A WEIR,SKIP EVAPORATION CALCULATIONS
C
        IF(NCYCL.GE.2)GOTO33
        GOTO30
C
C               CALCULATE EVAPORATION
C
20      CALL EVAPOR(ST(NRES),NRES,IMON,EV)
C
C               ADD EVAPORATION TO DEMAND
C
        DEMAND=DEMAND+EV
D       WRITE(10,2100),NRES,ST(NRES),EV,IMON,ISYS
D2100   FORMAT(2X,'RES',I4,'STOR',F7.0,'EVAP',F6.2,'MONTH',I4,
D    *  'ISYS',I5)
C
C               STOCHASTIC INFLOW?
C               IF IN `ACCEPT` MODE AND FOR CURRENT MONTH ONLY.
C
30      IF(IPRVW.EQ.0.AND.NCYCL.EQ.1)GOTO31
        GOTO32
C
C               ADD STOCHASTIC INFLOW TO EACH STORAGE.
C
31      ST(NRES)=ST(NRES)+STOINF(NRES,IMON)
D       WRITE(10,3100) ST(NRES),STOINF(NRES,IMON)
D3100   FORMAT(2X,'STOR',F7.0,'STOINF',F7.0)
32      CONTINUE
C
C               IF NRES IS NOT A WEIR,SKIP THE WEIR CALCULATIONS.
C
        IF(STOR(NRES,2).GE.0.)GOTO34
C
C               IF NRES IS A WEIR DETERMINE THE TRANSFER TO OTHER
C               STORAGES.
C
33      CALL WEIR(STOR(NRES,2),ST(NRES),TRANS)
C
C               IF GUMERACHA WEIR,GOTO50
```

```
C
      IF(NRES.EQ.5)GOTO50
C
C               INCLUDE CLARENDON INFLOW IN HAPPY VALLEY TRANSFER.
C
      TRANSF(4,1)=TRANSF(4,1)+TRANS
C
C               ALL CLARENDON INFLOW NOT TAKEN BY HAPPY VALLEY IS
C               SPILLED FROM THE SYSTEM.
C
      SPILL(2)=SPILL(2)+ST(3)-TRANS
      GOTO60
C
C               IF GUMERACHA WEIR,THEN ASSIGN TRANSFER TO MILLBROOK
C               RESERVOIR (NRES=6).
C
50    TRANSF(6,1)=TRANS
C
C               KANGAROO CREEK (NRES=7) TRANSFER IS THE EXCESS GUMERACHA
C               INFLOW NOT TAKEN BY MILLBROOK.
C
      TRANSF(7,1)=ST(5)-TRANS
C
C               ASSUME ZERO HOLDING STORAGE IN WEIRS
C               I.E. ALL INFLOW IS EITHER TRANSFERRED OR SPILLED OUT OF
C                    THE SYSTEM.
C
60    ST(NRES)=0.
34    IF(NRES.NE.10.AND.NRES.NE.12.OR.NCYCL.GE.2)GOTO39
C
C               IF SOUTH PARA (NRES=10) OR LITTLE PARA (NRES=12) SET UP
C               THE TRANSFER PROMPT AND DETERMINE HOW MUCH WATER IS
C               TRANSFERRED TO THEM.
C
      CALL SUPPLY(IPRVW,ISYS,TRAN(ISYS),SPARA,LPARA,IXS,
     * TRANSF(NRES,2),PIPOFT(4,J,IMON))
C
39    IF(NRES.EQ.12)GOTO390
      IF(NRES.NE.6)GOTO21
C
C               PROMPT FOR MILLBROOK RESERVOIR STORAGE.
C
      IF(NCYCL.EQ.1)CALL TORRNS(DEMMIL,XSDEM,
     * PSPPLY,ISPPLY,IPRVW,EV,MLLBRK,STOINF(6,IMON),S(IMON,6),
     * S(NXTMON,6),PIPOFT(4,J,IMON),TRAN(6),TRANSF(6,1),
     * TRANSF(6,2))
C
C               IF EITHER MILLBROOK OR LITTLE PARA RESERVOIRS,CALCULATE
C               THE AMOUNT SUPPLIED OUT OF MILLBROOK (WHEN REQUESTED)
C               AFTER NEXT MONTH'S STORAGE IS SATISFIED.
C
390   EXSMIL=0.
      IF(IPRVW.EQ.1.AND.ISPPLY.EQ.1)EXSMIL=S(IMON,6)-S(NXTMON,6)
D     WRITE(10,3900) EXSMIL,S(IMON,6),S(NXTMON,6)
D3900 FORMAT(2X,'EXSMIL',F7.0,'S(IMON,6)',F7.0,'S(NXTMON,6)',F7.0)
C
C               CHECK WHETHER PUMPING TO THE STORAGE IS REQUIRED
C
21    IF(TRANSF(NRES,2).EQ.0..OR.ISYS.EQ.1)GOTO26
C
C               DETERMINE PUMPING TO SUBSYSTEM.
C
      CALL PMP(ISYS,IPRVW,NRES,NCYCL,PSPPLY,ISPPLY)
C
C               FOR PREDICTION CYCLES NOT DURING PROGRAM INITIALLISATION
C               SKIP THE FOLLOWING.
```

```
C
        IF(NCYCL.GE.2.AND.ICALC(ISYS).EQ.1)GOTO26
C
C               FOR FIRST MONTH OF PROGRAM USAGE,RECORD PUMPING.
C
        IF(NCYCL.EQ.2.AND.IMON.EQ.IMONTH)GOTO22
        IF(NCYCL.GE.2)GOTO26
C
C               IF FIRST TIME THROUGH(NCYCL=2,IMON=IMONTH),OR USING
C               CURRENT DATA(NCYCL=1),DETERMINE THE INITIAL PUMPING
C               PERFORMANCE DATA-INCLUDING PUMPING FROM MILLBROOK.
C
C               START BY RECORDING MILLBROOK'S PUMPING AND COSTS.
C
22      TOTTRN=DEMMIL
        TOTCST=CSTMIL*DEMMIL
        TOTDEM=0.
C
C               SUM THE VALUES FOR THE THREE MAJOR PUMPING STATIONS.
C
23      DO 24 JPSTN=ISTMIN,ISTMAX
        TOTCST=TOTCST+COST(JPSTN)
        TOTTRN=TOTTRN+TOTPMP(JPSTN)
        TOTDEM=TOTDEM+PIPOFT(JPSTN,J,IMONTH)
24      CONTINUE
C
C               IF SIMULATION INCLUDES MANNUM PUMPSTATION,ADD ANSTEY
C               HILL TREATMENT WORKS DEMAND TO TOTAL DEMAND.
C               I.E. A DIRECT OFFTAKE.
C
        IF(ISTMIN.LE.2.AND.ISTMAX.GE.2)TOTDEM=TOTDEM+PIPOFT(4,J,IMONTH)
C
C               ADD SUBSYSTEM DEMANDS TO THE TOTAL.
C
        DO 25 JSYS=ISYSMN,ISYSMX
C
C               IF IPRVW NOT 0. ADD DETERMINISTIC DEMAND.
C
        IF(ABS(IPRVW).EQ.1)TOTDEM=TOTDEM+DTDEM(JSYS,IMONTH)
C
C               IF IPRVW 0. ADD STOCHASTIC DEMAND.
C
        IF(IPRVW.EQ.0)TOTDEM=TOTDEM+STDEM(JSYS,IMONTH)
25      CONTINUE
C
C               CALCULATE AVERAGE COST PER KILOLITRE AND FRACTION OF
C               DEMAND SUPPLIED BY PUMPS.
C
        CSTKL1=TOTCST/(TOTDEM*10.)
        FRAC=TOTTRN/TOTDEM
D       WRITE(10,2500),TOTCST,TOTTRN,TOTDEM,CSTKL1,FRAC
D2500   FORMAT(2X,'TOTCST',F9.2,'TOTTRN',F7.0,'TOTDEM',F7.0,'CSTKL1',
D     * F9.2,'FRAC',F7.2)
        IF(IPRVW.NE.0.AND.ICALC(ISYS).EQ.1)GOTO26
C
C               DEFINE THE EXTERNAL COST AND DEMAND FRACTION VARIABLES
C               ONLY WHEN USING REAL (IPRVW=0),OR WHEN IT IS THE FIRST
C               TIME THROUGH THE PROGRAM (ICALC(ISYS)=0).
C
        COSTKL=CSTKL1
        FRACTN=FRAC
C
C               DEFINE THE PUMPING TRANSFER FOR MYPONGA (ISYS=1).
C               I.E. NO PUMPING AVAILABLE.
C
26      IF(ISYS.EQ.1)TRAN(ISYS)=0.
```

```
C
C           ADD THE AVAILABLE TRANSFER 'TRAN(ISYS)' TO THE RESERVOIR
C           TRANSF(NRES,1) IF REQUIRED
C
      TRNSFR=0.
C
C           ONLY ALLOW PUMPED TRANSFER FOR CURRENT MONTH,TO THOSE
C           RESERVOIRS REQUESTING IT.
C
      IF(TRANSF(NRES,2).GT.1..AND.NCYCL.EQ.1)TRNSFR=TRAN(ISYS)
      TRANSF(NRES,1)=TRANSF(NRES,1)+TRNSFR
D     WRITE(10,2900),ST(NRES),TRANSF(NRES,1),ISYS
D2900 FORMAT(2X,'ST',F7.0,'TRANSF(NRES,1)',F7.0,'ISYS',I4)
C
C           ADD TRANSFER TO STORAGE
C
      ST(NRES)=ST(NRES)+TRANSF(NRES,1)
D     WRITE(10,3000),ST(NRES)
D3000 FORMAT(2X,'ST',F7.0)
C
C           RE-INITIALLIZE TRANSF ARRAY.
C
      TRANSF(NRES,1)=0.
C
C           INCLUDE STORAGE IN SUM OF STORAGES.
C
100   SUMSTR=SUMSTR+ST(NRES)
D     WRITE(10,1000),SUMSTR,ISYS
D1000 FORMAT(2X,'SUMSTR',F7.0,'ISYS',I4)
C
C
C           IF NOT IN STOCHASTIC MODE,INFLOW HAS NOT YET BEEN ADDED.
C
D     WRITE(10,1001),IPRVW,NCYCL
D1001 FORMAT(2X,'IPRVW',I4,'NCYCL',I4)
      IF(IPRVW.EQ.0.AND.NCYCL.EQ.1)GOTO120
C
C           IF IN TORRENS SUBSYSTEM (ISYS=3) HOLD THE VALUE OF
C           THE SUMMED STORAGES,WITH OUT-OF-SUBSYSTEM TRANSFER
C           REMOVED,IN 'ASTOR'.
C
      IF(ISYS.EQ.3)ASTOR=SUMSTR-EXSMIL
C
C           ADD DETERMINISTIC INFLOW TO SUMSTR.
C
      GOTO(102,101,102),NCYCL
101   SUMSTR=SUMSTR+DETINF(ISYS,2,IMON)
D     WRITE(10,1000),SUMSTR
      GOTO119
102   SUMSTR=SUMSTR+DETINF(ISYS,1,IMON)
D     WRITE(10,1000),SUMSTR
C
C           IF TRANSFER NOT REQUIRED SKIP CALCULATION.
C
119   IF(ISYS.NE.3.OR.ISPPLY.LE.-1)GOTO120
C
C           DETERMINE THE AMOUNT OF WATER AVAILABLE FOR SUPPLYING
C           ANSTEY HILL(DETERMINISTIC ONLY).
C           ASSUME ALL UNUSED INFLOW CAN BE TRANSFERRED.
C
      AVAIL=SUMSTR-ASTOR
      IF(AVAIL.GE.0.)SUMSTR=ASTOR
C
C           MATCH THE AVAILABLE OFFTAKE TO DEMAND.
C
      GOTO(1190,1191,1191),NCYCL
```

```
C
C               AMOUNT AVAILABLE GREATER THAN COMBINED ANSTEY HILL AND
C               LITTLE PARA REQUIREMENTS?
C
1190  IF(AVAIL.GT.(PIPOFT(4,1,IMON)+TRAN(6)))
     *SUMSTR=ASTOR+AVAIL-(PIPOFT(4,1,IMON)+TRAN(6))
      GOTO120
C
C               AMOUNT AVAILABLE GREATER THAN ANSTEY HILL DEMAND ALONE.
C
1191  IF(AVAIL.GT.PIPOFT(4,1,IMON))
     *SUMSTR=ASTOR+AVAIL-PIPOFT(4,1,IMON)
C
C               ADJUST DEMAND FOR STOCHASTIC OR DETERMINISTIC REQUIREMENT.
C
120   IF(NCYCL-2) 121,122,122
121   IF(IPRVW.NE.0)GOTO122
      DEMAND=DEMAND+STDEM(ISYS,IMON)
      GOTO123
122   DEMAND=DEMAND+DTDEM(ISYS,IMON)
      IF(NCYCL.EQ.1.OR.ISYS.NE.3)GOTO1220
C
C               IF TORRENS SUBSYSTEM AND NOT WORKING ON CURRENT DATA,
C               DETERMINE WHETHER MANNUM/ADELAIDE PIPELINE CAPACITY IS
C               EXCEEDED BY ANSTEY HILL DEMAND.
C
      XSDEM=PIPOFT(4,1,IMON)-CAPSUM
      IF(XSDEM.LT.0.)XSDEM=0.
C
C               INCREASE TORRENS SUBSYSTEM DEMAND TO SHARE LOAD IF
C               PIPELINE CAPACITY IS EXCEEDED.
C
1220  IF(ISYS.EQ.3.AND.XSDEM.GT.0.)DEMAND=DEMAND+XSDEM
C
C               ALLOW FOR MANNUM PUMPING IN WARREN STORAGE (ISYS=4) FOR
C               CURRENT MONTH.
C
123   IF(ISYS.EQ.4.AND.WARTRN.EQ.425..AND.NCYCL.EQ.1)SUMSTR=SUMSTR+WARTRN
C
C               SATISFY THE DEMAND FROM SUMSTR.
C
      SUMSTR=SUMSTR-DEMAND
C
C               IF,FOR THE CURRENT MONTH,MILLBROOK SUPPLIES OUTSIDE THE
C               TORRENS SUBSYSTEM (ISYS=3),ADJUST SUMSTR.
C
      IF(ISYS.EQ.3.AND.IPRVW.EQ.0.AND.NCYCL.EQ.1.AND.ISPPLY.EQ.1)
     *SUMSTR=SUMSTR-DEMMIL
D     WRITE(10,1002),SUMSTR,DEMAND,ISPPLY,DEMMIL
D1002 FORMAT(2X,'SUMSTR',F7.0,'DEMAND',F7.0,'ISPPLY',I3,
D    *'DEMMIL',F7.0)
C
C               NOW DECOMPOSE SUMSTR INTO ITS INDIVIDUAL STORAGES.
C
150   DO 200 NRES=MINRES,MAXRES
C
C               MILLBROOK (NRES=6) IS A SPECIAL CASE.
C
      IF(NRES.EQ.6)GOTO151
C
C               IF THE STORAGE FOR NRES IS UNSPECIFIED,SKIP ASSIGNMENT.
C
      IF(S(IMON,NRES).EQ.0.)GOTO200
C
C               ASSIGN SPECIFIC OPERATING STORAGES TO HAPPY VALLEY
C               HOPE VALLEY,MILLBROOK,AND BAROSSA RESERVOIRS.
```

```
C
C               MILLBROOK RESERVOIR-SPECIAL CASE.
C               LIMIT MILLBROOK STORAGE TO THAT WHICH CAN BE
C               OBTAINED FROM INFLOW TO THE RESERVOIR ALONE.
C
151     IF(NRES.NE.6.OR.NCYCL.GE.2)GOTO152
        IF(IPRVW.EQ.0.AND.S(NXTMON,6).GT.ST(6))
     *  S(NXTMON,6)=ST(6)
152     ST(NRES)=S(NXTMON,NRES)
C
C               NOW REMOVE S(NXTMON,NRES) FROM SUMSTR.
C
        SUMSTR=SUMSTR-ST(NRES)
C
C               FIND THE UNSPECIFIED RESERVOIR IN THE SUBSYSTEM.
C               I.E. THE STORAGE THAT HAS NO SET OPERATING RULES;
C                    CAN BE DRAWN DOWN OR CAN SPILL ACCORDING TO INFLOW.
C
200     IF(S(IMON,NRES).EQ.0..AND.STOR(NRES,2).GT.0.)JRES=NRES
D       WRITE(10,2000),JRES,ISYS
D2000   FORMAT(2X,'UNSPEC',I4,'ISYS',I4)
C
C               CALCULATE THE INTERCONNECTIONS BETWEEN RESERVOIRS.
C               (ONLY FOR CURRENT MONTH:NCYCL=1).
C
        IF(NCYCL.GE.2)GOTO211
C
C               MYPONGA TRANSFER-
C               USE MYPTRN TO DERTERMINE WHETHER A TRANSFER OCCURS
C
        IF(ISYS.EQ.1.AND.MYPTRN.GT.0)GOTO201
        IF(ISYS.GT.1)GOTO211
C
C               SET UP SCREEN INDICATION OF NUL TRANSFER
C               NUMBR IS A GRAPHICS PACKAGE SUBROUTINE
C
        CALL NMBR(1021,0.,6,'(F6.0)')
        CALL NMBR(2021,0.,6,'(F6.0)')
        IF(MYPTRN.EQ.-1)HAPVLY=0.
        GOTO211
C
C               PROMPT FOR THE QUANTITY OF TRANSFER FROM MYPONGA,
C               IF IN 'PREVIEW' MODE.
C
201     IF(IPRVW.EQ.0)GOTO205
C
C               IF THE TOTAL STORAGE IS ALREADY IN DEFICIT,GOTO207
C
        IF(SUMSTR.LE.0.)GOTO207
C
C               PROMPT FOR TRANSFER.
C
        IF(MYP.EQ.1)GOTO202
        CALL SUBP(61)
        CALL OFF(61)
        CALL APNT(0.,160.,,-3,-1)
        CALL TEXT(-2,' TYPE IN REQUIRED TRANSFER TO',
     *  1,-2,' ONKAPARINGA SYSTEM AND',
     *  1,-2,' PRESS "CR"')
        CALL ESUB(61)
        MYP=1
202     CALL OFF(52)
        CALL ON(61)
        TYPE203
203     FORMAT(2X,' NEW TRANSFER='$)
        READ(5,204,ERR=2040),MYPTRN
```

```
204     FORMAT(I5)
        GOTO2041
2040    CALL CLR
        GOTO202
2041    CALL CLR
        CALL OFF(61)
        CALL ON(52)
C
C               CONVERT THE TYPED IN TRANSFER VALUE TO THE INTERNAL
C               OFFTAKE VARIABLE TO HAPPY VALLEY RESERVOIR.
C
        HAPVLY=FLOAT(MYPTRN)
C
C               DETERMINE WHETHER STOCHASTIC (J=1) OR DETERMINISTIC (J=2)
C               DATA IS TO BE USED.
C
205     J=2
        IF(IPRVW.EQ.0)J=1
C
C               SET MYPONGA TRUNK MAIN CAPACITY TO THE SUMMER OR WINTER
C               MAXIMUM CAPACITY.
C
        CAPMYP=CAPMYW
        IF(4.LE.IMON.AND.IMON.LE.9)CAPMYP=CAPMYS
C
C               FIND THE SPARE CAPACITY OF MYPONGA TRUNK MAIN AFTER
C               REMOVAL OF LOCAL WATER DISTRICT DEMANDS.
C
        CAPMYP=CAPMYP-DEMMYP(J,IMON)
D       WRITE(10,2050),CAPMYP
D2050   FORMAT(2X,'CAPMYP',F7.0)
C
C               CHECK FOR EXCEEDENCE OF PIPELINE CAPACITY IF STOCHASTIC DATA
C               IS BEING USED.
C
        IF(IPRVW.EQ.0.AND.HAPVLY.GT.CAPMYP)SUMSTR=SUMSTR+HAPVLY-CAPMYP
C
C               REDUCE TRANSFER TO THE LIMIT
C
        IF(HAPVLY.GT.CAPMYP)HAPVLY=CAPMYP
        IF(IPRVW.EQ.0)GOTO211
C
C               NOW REMOVE THE TRANSFER FROM THE STORAGE AND CHECK WHETHER
C               IT EMPTIES.
C
        SUMSTR=SUMSTR-HAPVLY
        IF(SUMSTR.GE.0.)GOTO211
C
C               IF TRANSFER 'HAPVLY' MAKES THE STORAGE NEGATIVE,REDUCE
C               'HAPVLY' SO THAT IT ONLY JUST EMPTIES MYPONGA.
C
        HAPVLY=HAPVLY+SUMSTR
        SUMSTR=0.
D       WRITE(10,2060),MYPTRN,HAPVLY
D2060   FORMAT(2X,'MYPTRN',I5,'HAPVLY',F7.0)
        GOTO211
C
C               IF SUMSTR IS ALREADY NEGATIVE OR ZERO,THERE IS NO SPARE
C               CAPACITY FOR SUPPLYING A TRANSFER-PROMPT THE OPERATOR.
C
207     IF(NOTRAN.EQ.1)GOTO2071
        CALL SUBP(62)
        CALL OFF(62)
        CALL APNT(0.,160.,,,-3,-1)
        CALL TEXT(-2,' THERE IS NO SPARE STORAGE',
     *  1,-2,' WITH WHICH TO SUPPLY A TRANSFER.',
```

```
     *    1,-2,' PRESS "CR" TO ACKNOWLEGE.')
          CALL ESUB(62)
          NOTRAN=1
2071      CALL OFF(52)
          CALL ON(62)
          READ(5,2072),CR
2072      FORMAT(F)
          CALL OFF(62)
          CALL ON(52)
          HAPVLY=0.
          CALL ON(1006)
          CALL ON(200)
          CALL POINTR(1,1005)
          CALL FLASH(1,-1)
C
211       IF(ISYS.GT.1.OR.NCYCL.GE.2)GOTO213
C
C                PRINT THE TRANSFER ON THE SCREEN.
C
          CALL NMBR(1021,HAPVLY,6,'(F6.0)')
          CALL NMBR(2021,HAPVLY,6,'(F6.0)')
C
C                APPLY THE REMAINING 'SUMSTR' TO THE UNSPECIFIED RESERVOIR
C                IN THE SUBSYSTEM.
C
213       ST(JRES)=SUMSTR
          IF(ISYS.NE.3.OR.NCYCL.GE.2.OR.IPRVW.NE.0)GOTO212
C
C                CHECK TORRENS SUBSYSTEM AT HOPE VALLEY FOR EXCESS INFLOW
C                FROM DEEP CREEK WHICH CANNOT BE USED FOR THE CURRENT MONTH
C
          ADJST3=STDEM(3,IMON)-STOINF(8,IMON)-(S(IMON,8)-S(NXTMON,8))
          IF(ADJST3.GT.0.)ADJST3=0.
C
C                THIS EXCESS HAS ALREADY BEEN ADDED TO THE UNSPECIFIED
C                STORAGE THROUGH 'SUMSTR'-REMOVE IT.
C
          ST(JRES)=ST(JRES)+ADJST3
212       CONTINUE
D         WRITE(10,2110),ST(JRES),ISYS,ADJST3
D2110     FORMAT(2X,'UNSPEC STOR',F7.0,'ISYS',I4,'ADJST3',F7.0)
          IF(SUMSTR.GE.0.)GOTO400
          IF(NCYCL.GE.2)GOTO300
C
C                IF THIS VARIABLE STORAGE IS <0.,CHECK WHETHER THERE IS
C                AN UPSTREAM RESERVOIR TO SUPPLY IT.
C
          IF(JRES.EQ.MINRES)GOTO300
C
C                IF THERE IS SUCH A STORAGE,MODIFY IT ACCORDINGLY.
C
          ST(JRES-1)=ST(JRES-1)+ST(JRES)
          ST(JRES)=0.
C
C                IF THIS SUPPLY CANNOT DELIVER ALL REQUIREMENTS,DEFINE
C                A DEFICIT.
C
          IF(ST(JRES-1).GE.0.)GOTO400
          SUMSTR=ST(JRES-1)
          ST(JRES-1)=0.
C
C                IF NO UPSTREAM STORAGE,OR INSUFFICIENT SUPPLY
C
300       IF(IPRVW.EQ.0.AND.NCYCL.EQ.1)DEFCIT(ISYS)=SUMSTR
          ST(JRES)=0.
C
```

```
C                 IF SUMSTR >0
C
400       CONTINUE
C
C                 IS THERE ANY SPILL?
C
          IF(ST(JRES).LT.STRMAX(JRES))GOTO401
          SPILL(ISYS)=SPILL(ISYS)+ST(JRES)-STRMAX(JRES)
          ST(JRES)=STRMAX(JRES)
          GOTO402
401       CONTINUE
402       IF(NCYCL.GE.2)GOTO403
C
C                 INCLUDE SPILLAGE OF WARREN RESERVOIR TO SOUTH PARA.
C
          IF(ISYS.EQ.4)WARSPL=SPILL(4)
C
C                 ALLOW SPILL OF EXCESS INFLOW TO HOPE VALLEY FROM
C                 DEEP CREEK CATCHMENT.
C
          IF(ISYS.EQ.3)SPILL(3)=SPILL(3)-ADJST3
C
C                 THE SUBSYSTEM IS NOW BALANCED FOR THE CURRENT
C                 MONTH(IMON).
C                 ASSIGN THE VALUES TO ARRAYS CONSISTENT WITH THE MODE
C                 OF OPERATION.
C
403       DO 460 NRES=MINRES,MAXRES
          IF(NCYCL.EQ.1)GOTO451
C
C                 DO NOT ASSIGN DATA TO THE SPECIFIED STORAGES,WEIRS OR
C                 SERVICE RESERVOIRS.
C
          IF(STOR(NRES,2).LE.0..OR.NRES.EQ.6)GOTO451
C
C                 ASSIGN MONTH TO MAX AND MIN PREDICTION ARRAYS.
C
          GOTO(421,422) NCYCL-1
421       MAXFIN(NRES)=IMON
          GOTO430
422       MINFIN(NRES)=IMON
C
C                 RECORD THE EXTREME CONDITIONS.
C
430       IF(ST(NRES).EQ.0..OR.SPILL(ISYS).GT.0.)ISWTCH=1
C
C                 ASSIGN THE STORAGE VALUE TO ITS APPROPRIATE ARRAY.
C
          GOTO(451,452,453),NCYCL
451       IF(NCYCL.GT.1)GOTO460
          PRSTOR(NRES)=ST(NRES)
          GOTO460
C
C                 UPPER CONFIDENCE LIMIT
C
452       STMAX(NRES)=ST(NRES)
          GOTO460
C
C                 LOWER CONFIDENCE LIMIT
C
453       STMIN(NRES)=ST(NRES)
460       CONTINUE
C
C                 IF THE FINAL VALUES FOR THE SUBSYSTEM HAVE BEEN ESTABLISHED
C                 THEN FILE THEM IN A HARD COPY FILE.
C
```

```
        IF(IPRVW.EQ.0.AND.NCYCL.EQ.1)GOTO4601
        GOTO461
C
C               DEFINE THE OUT-OF-SUBSYSTEM TRANSFERS.
C
4601    EXTRAN=0.
        IF(ISYS.LE.2)EXTRAN=((-1)**ISYS)*HAPVLY
        IF(ISYS.EQ.3)EXTRAN=-DEMMIL
        IF(ISYS.EQ.5)EXTRAN=WARSPL
        IF(ISYS.NE.6)GOTO46011
        EXTRAN=TRAN(6)
C
C               IF MILLBROOK CANNOT SUPPLY ALL OF LITTLE PARA TRANSFER,
C               NONE GOES TO RELIEVE ANSTEY HILL DEMAND.
C
        IF(PSPPLY.LT.0.)EXTRAN=DEMMIL
46011   IF(ISYS.LT.4.OR.ISYS.GT.5.OR.TRAN(4).GE.0.)GOTO4602
C
C               DEFINE TRANSFER OUT OF WARREN INTO SOUTH PARA.
C
        IF(ISYS.EQ.4)EXTRAN=TRAN(4)
        IF(ISYS.EQ.5)EXTRAN=EXTRAN+ABS(TRAN(4))
D       WRITE(10,4603) WARSPL,EXTRAN,PUMP(IPSTN)
D4603   FORMAT(2X,'WARSPL',F7.0,'EXTRAN',F7.0,'PUMP',F7.0)
C
C               RECORD ALL DATA IN A FILE BY CALLING SUBROUTINE 'HRDCOP'.
C
4602    CALL HRDCOP(ISYS,MINREC,STOR,STOINF,DEMAND,SPILL(ISYS),
     *  DEFCIT(ISYS),EXTRAN,PSPPLY)
C
C               IF ALL SUBSYSTEMS HAVE BEEN NOTED IN HRDCOP,CALCULATE
C               THE PERFORMANCE PARAMETERS OF THE OPERATOR.
C
        IF(ISYS.EQ.ISYSMX)CALL SKILL
C
C               IF EXTREME CONDITIONS OCCUR (ISWCH=1) TERMINATE CALCULATION.
C
461     IF(ISWTCH.EQ.1)IMON=12
        ISWTCH=0
C
C               DETERMINE WHETHER TO INCREMENT 'NCYCL' AND REPEAT THE
C               CALCULATIONS OR PERFORM THE FINAL CALCULATIONS.
C
        IF(NCYCL.EQ.3.AND.IMON.EQ.12)GOTO500
        IF(NCYCL.GE.2.AND.IMON.LT.12)GOTO490
        NCYCL=NCYCL+1
        IMON=IMONTH
C
C               IF FIRST TIME THROUGH (WHEN ONLY PREDICTING),OR IN
C               FINAL MONTH,THEN REARRANGE IMON.
C
        IF(ICALC(ISYS).NE.1.OR.IMONTH.EQ.12)IMON=IMONTH-1
C
C               ASSIGN STARTING VALUES FOR NEXT CYCLE
C
        DO 470 NRES=MINRES,MAXRES
        ST(NRES)=STOR(NRES,1)
        IF(IPRVW.GE.0.AND.IMONTH.NE.12.AND.ICALC(ISYS).EQ.1)
     *  ST(NRES)=PRSTOR(NRES)
470     CONTINUE
C
C               SET MONTH COUNTER 'IMON'.
C
490     IMON=IMON+1
D       WRITE(10,4900),(NRES,ST(NRES),NRES=MINRES,MAXRES)
D4900   FORMAT(2X,4(I2,F7.0))
```

```
D       WRITE(10,4901),HAPVLY,ISYS
D4901   FORMAT(2X,'HAPVLY',F7.0,'ISYS',I4)
        GOTO10
C
C               SET FLAGS TO INDICATE USE OF THIS SUBROUTINE.
C
500     IF(ICALC(ISYS).NE.1)ICALC(ISYS)=1
        IF(ISTRT.NE.1)ISTRT=1
        RETURN
        END
>
```

```
C
C     SUBROUTINE CALDAT: AT THE START OF EACH SIMULATED FINANCIAL YEAR
C             NEW MONTHLY DEMANDS AND INFLOWS ARE READ AND STORED IN
C             THE APPROPRIATE ARRAYS,FOR THE WHOLE YEAR.
C             DEMANDS FOR EACH SUPPLIED DISTRICT ARE ASSIGNED TO ONE OF
C             THE SIX SUBSYSTEMS.
C
      SUBROUTINE CALDAT(ISTRT)
C
      COMMON /CALPMP/PIPOFT(4,2,12),IMON,ISTMIN,ISTMAX,DEMMIL,
    * WARTRN,MAXPMP(3),EXSMIL
    * /CALHLD/DTDEM(6,12),STDEM(6,12),STOINF(13,12),DEMMYP(2,12),
    * WARSPL,HAPVLY,IDTDEM,ISTDEM,ISTINF,PSPPLY,ISPPLY
    * /CORCAL/DETINF(6,2,12),MYPTRN,TRANSF(12,2),STOR(12,2),S(12,12),
    * IMONTH,MONTH,MINREC
C
      DIMENSION X(11),DETDEM(12,12),STODEM(12,12)
C
      DATA CAPSS,CAP5W/3310.,4860./
C
      IF(ISTRT.EQ.1.AND.IMONTH.EQ.1)GOTO92
C
C             READ DETERMINISTIC DEMAND,STOCHASTIC DEMAND AND STOCHASTIC
C             INFLOW FOR THE NEXT 12 MONTHS(OR TO THE END OF THE YEAR
C             IF IT IS THE FIRST TIME THROUGH).
C
C             SET ASSOCIATE VARIABLES FOR THE FIRST TIME OF READING FILES
C
      IDTDEM=MONTH
      ISTDEM=MONTH
      ISTINF=MONTH
C
92    MON=IMONTH
C
C             OPEN AND READ FILES
C
C             DETERMINISTIC DEMAND
C
      OPEN(UNIT=7,NAME='DETDEM.DAT',TYPE='OLD',ACCESS='DIRECT',
    * FORM='FORMATTED',ASSOCIATEVARIABLE=IDTDEM)
C
C             STOCHASTIC DEMAND
C
      OPEN(UNIT=8,NAME='STOCDEM.DAT',TYPE='OLD',ACCESS='DIRECT',
    * FORM='FORMATTED',ASSOCIATEVARIABLE=ISTDEM)
C
C             STOCHASTC INFLOW
C
      OPEN(UNIT=9,NAME='STOINF.DAT',TYPE='OLD',ACCESS='DIRECT',
    * FORM='FORMATTED',ASSOCIATEVARIABLE=ISTINF)
95    READ(7'IDTDEM,96),(DETDEM(IDISTR,MON),IDISTR=1,12)
96    FORMAT(12F7.0)
      READ(8'ISTDEM,97),(STODEM(IDISTR,MON),IDISTR=1,12)
97    FORMAT(12F10.2)
      READ(9'ISTINF,98),(X(I),I=1,11)
98    FORMAT(11F10.2)
C
C             ARRANGE STOCHASTIC INFLOW IN ARRAY FOR EACH STORAGE
C             IN THE MODEL
C
      NOINF=0
      DO 981 ISTOR=1,12
      STOINF(ISTOR,MON)=X(ISTOR-NOINF)
```

```
      IF(STOR(ISTOR,2).NE.0.OR.ISTOR.EQ.8)GOTO981
C
C              IF STORAGE IS A SERVICE RESERVOIR,BESIDES HOPE VALLEY
C              WHICH RECEIVES DEEP CREEK INFLOW,SET STOCHASTIC INFLOW
C              TO ZERO.
C
      NOINF=NOINF+1
      STOINF(ISTOR,MON)=0.
981   CONTINUE
C
C              SPLIT UP DETDEM AND STODEM ACCORDING TO THE DIVISION OF
C              DEMAND AMONG THE SUBSYSTEMS,NOT THE RESERVOIRS.
C
C              MYPONGA
C
      DTDEM(1,MON)=DETDEM(8,MON)+DETDEM(12,MON)
      STDEM(1,MON)=STODEM(8,MON)+STODEM(12,MON)
      DEMMYP(1,MON)=STODEM(8,MON)
      DEMMYP(2,MON)=DETDEM(8,MON)
C
C              ONKAPARINGA
C
      DTDEM(2,MON)=DETDEM(7,MON)+DETDEM(11,MON)
      STDEM(2,MON)=STODEM(7,MON)+STODEM(11,MON)
C
C              TORRENS
C
      DTDEM(3,MON)=DETDEM(6,MON)
      STDEM(3,MON)=STODEM(6,MON)
C
C              WARREN & NORTHERN
C
      DTDEM(4,MON)=DETDEM(3,MON)
      STDEM(4,MON)=STODEM(3,MON)
C
C              SOUTH PARA
C
C              SET SUMMER AND WINTER BAROSSA TRUNK MAIN CAPACITIES
C
      CAPBAR=CAP5W
      IF(4.LE.MON.AND.MON.LE.9)CAPBAR=CAP5S
      DPCENT=1.
      SPCENT=1.
C
C              IF DEMAND ON SOUTH PARA SUBSYSTEM EXCEEDS CAPACITY OF
C              BAROSSA TRUNK MAIN REDUCE THE DEMAND.
C
      IF(DETDEM(1,MON).GT.CAPBAR)DPCENT=CAPBAR/DETDEM(1,MON)
      IF(STODEM(I,MON).GT.CAPBAR)SPCENT=CAPBAR/STODEM(1,MON)
      DTDEM(5,MON)=DETDEM(1,MON)*DPCENT
      STDEM(5,MON)=STODEM(1,MON)*SPCENT
C
C              LITTLE PARA
C
C              LITTLE PARA SUPPLIES ANY EXCESS
C
      DTDEM(6,MON)=DETDEM(2,MON)+(1.-DPCENT)*DETDEM(1,MON)
      STDEM(6,MON)=STODEM(2,MON)+(1.-SPCENT)*STODEM(1,MON)
C
C              MURRAY BRIDGE/ONKAPARINGA PIPELINE OFFTAKES
C
      PIPOFT(1,1,MON)=DETDEM(9,MON)
      PIPOFT(1,2,MON)=STODEM(9,MON)
C
C              MANNUM/ADELAIDE PIPELINE OFFTAKES
C
```

```
      PIPOFT(2,1,MON)=DETDEM(10,MON)
      PIPOFT(2,2,MON)=STODEM(10,MON)
C
C             SWAN REACH/STOCKWELL PIPELINE OFFTAKES SET TO ZERO
C             ASSUME WARREN SUBSYSTEM TRIES TO SUPPLY ALL DEMANDS FIRST.
C
      PIPOFT(3,1,MON)=0.
      PIPOFT(3,2,MON)=0.
C
C             DIRECT DEMAND FROM MANNUM PIPELINE
C             THIS IS THE ANSTEY HILL FILTRATION PLANT DEMAND
C
      PIPOFT(4,1,MON)=DETDEM(4,MON)+DETDEM(5,MON)
      PIPOFT(4,2,MON)=STODEM(4,MON)+STODEM(5,MON)
C
C             INCREMENT MONTH AND CHECK WHETHER YEAR IS FINISHED
C
      MON=MON+1
      IF(MON.LE.12)GOTO95
      CLOSE(UNIT=7)
      CLOSE(UNIT=8)
      CLOSE(UNIT=9)
C
      RETURN
      END
>
```

```
C     SUBROUTINE HRDCOP IS RESPONSIBLE FOR STORING THE RESULTS OF
C     THE SIMULATION FOR LATER RETREVAL.
C
      SUBROUTINE HRDCOP(ISYS,MINREC,STOR,STOINF,DEMAND,SPILL,
     * DEFCIT,EXTRAN,PSPPLY)
C
      COMMON /PMPCPY/IPSTN,TOTPMP(3),COST(3),TRAN(6),CAPCTY
     * /CORPMP/PMPQNT(3,16,4),PMPCST(3,16,4),IRANGE(6,2),IPUMP(3),
     * ISYSMN,ISYSMX,SUMCAP(3),PUMP(3),ICOP,ICPY,
     * IHDCPY,ICONSD
     * /CALPMP/PIPOFT(4,2,12),IMON,ISTMIN,ISTMAX,DEMMIL,WARTRN,
     * MAXPMP(3),EXSMIL
     * /RESULT/PERFRM(7,9,3),SYSSTR(6,12,14),SYSPMP(3,12,8),ISUB,ITOT
C
      LOGICAL*1 IHDCPY,ICONSD(6)
C
      DIMENSION STOR(12,2),STOINF(13,12)
C
      DATA CSTMIL/8./
C
C             DETERMINE THE COSTS (PUMPED TRANSFERS ONLY) SHARED
C             AMONG THE SUBSYSTEMS.
C
C             IF MYPONGA OR NO PUMPING,SKIP CALCS
C
      IF(ISYS.EQ.1.OR.TOTPMP(IPSTN).EQ.0.)GOTO1
C
C             DEFINE FRACTION AS THE PUMPED TRANSFER INTO THE SUBSYSTEM
C
      PART=TRAN(ISYS)
      IF(ISYS.EQ.2)GOTO114
      GOTO(110,111,112,113),(ISYS-2)
C
C             TORRENS SUBSYSTEM COSTS ARE AFFECTED BY MILLBROOK
C             SUPPLYING OUT OF THE SUBSYSTEM TO ANSTEY HILL 'EXTRAN'
C
110   IF(TRAN(3)+EXTRAN.GE.-5.E-4)PART=PART+EXTRAN
      IF(TRAN(3)+EXTRAN.LT.-5.E-4)PART=PART-TRAN(3)
      GOTO114
C
C             IF THE NET WARREN SUBSYSTEM TRANSFER IS OUT RATHER
C             THAN IN,IT GETS NO COSTS AND SOUTH PARA IS BILLED
C
111   IF(TRAN(4).LE.0.)PART=0.
      GOTO114
C
C             SOUTH PARA,RELYING ON BOTH WARREN SUBSYSTEM TRANSFERS
C             AND SWAN REACH PUMPING MUST ACCOUNT FOR ITS SHARE OF
C             SWAN REACH SUPPLIES
C
112   IF(TOTPMP(3).LE.TRAN(5))PART=TOTPMP(3)
      GOTO114
C
C             IF LITTLE PARA INFLOW EXTRAN IS NOT ALL SUPPLIED BY
C             TORRENS SUBSYSTEM,BUT SOME BY MANNUM PUMPING,CONSIDER
C             ONLY THE MANNUM CONTRIBUTION FOR THE PRESENT.
C
113   IF(SYSSTR(3,IMON,13)-EXTRAN.LT.-5.E-4)PART=PART-
     * (EXTRAN-SYSSTR(3,IMON,13))
C
C             INITIAL COST CALCULATIONS
C
114   CSTPRT=COST(IPSTN)*PART/TOTPMP(IPSTN)
      GOTO2
```

```
1     CSTPRT=0.
C
2     IF(ISYS.NE.4.AND.ISYS.NE.5)GOTO24
C
C             SKIP CALCS IF NO WARREN INFLOW FROM PUMPS
C
      IF(TRAN(4).GE.0..OR.WARTRN.EQ.0.)GOTO24
C
C             PUMPED INFLOW TO WARREN
C
      N=1
      IF(ABS(TRAN(4)).GE.WARTRN)N=2
      GOTO(21,22),(ISYS-3)
C
C             WARREN TAKES THE COST OF WATER TRANSFERRED FROM MANNUM
C             TO ADELAIDE PIPELINE BUT NOT SUPPLIED TO SOUTH PARA
C
21    IF(N.EQ.1)ADCST=(WARTRN+TRAN(4))*COST(2)/TOTPMP(2)
      IF(N.EQ.2)ADCST=0.
      GOTO23
C
C             SOUTH PARA GETS COST OF WARREN WATER TRANSFERRED FROM
C             MANNUM ADELAIDE PIPELINE
C
22    IF(N.EQ.1)ADCST=ABS(TRAN(4))*COST(2)/TOTPMP(2)
      IF(N.EQ.2)ADCST=WARTRN*COST(2)/TOTPMP(2)
23    CSTPRT=CSTPRT+ADCST
C
C             ADD COST OF TRANSFERRING WATER FROM MANNUM/ADELAIDE
C             PIPELINE TO WARREN SUBSYSTEM
C
24    IF(ISYS.EQ.4.AND.TRAN(4).GE.0..AND.WARTRN.EQ.425.)
     * CSTPRT=CSTPRT+WARTRN*COST(2)/TOTPMP(2)
C
C             ADD COST OF MILLBROOK PUMPING FOR LITTLE PARA TRANSFER
      IF(ISYS.EQ.6.AND.EXTRAN.GT.0) CSTPRT=CSTPRT+CSTMIL*EXTRAN
C
C             ASSIGN STORAGE AND INFLOW DATA TO DATA ARRAY
C
      I=1
      DO 3 NRES=IRANGE(ISYS,1),IRANGE(ISYS,2)
      SYSSTR(ISYS,IMON,I)=STOR(NRES,1)
      SYSSTR(ISYS,IMON,I+1)=STOINF(NRES,IMON)
3     I=I+2
C
C             STORE REMAINING ELEMENTS
C
      SYSSTR(ISYS,IMON,9)=DEMAND
      SYSSTR(ISYS,IMON,10)=SPILL
      SYSSTR(ISYS,IMON,11)=DEFCIT
C
C             INTER-SUBSYSTEM SUPPLY
C
      SYSSTR(ISYS,IMON,12)=EXTRAN
C
C             PUMPED TRANSFER
C
      SYSSTR(ISYS,IMON,13)=TRAN(ISYS)
C
C             IF A TRANSFER IS AN OUTFLOW NOT AN INFLOW DO NOT ASSIGN
C             TO THIS ELEMENT
C
      IF(TRAN(ISYS).LT.0.)SYSSTR(ISYS,IMON,13)=0.
C
C             ADJUST LITTLE PARA TRANSFER FOR MILLBROOK SUPPLY
C
```

```
      IF(ISYS.EQ.6)SYSSTR(6,IMON,13)=SYSSTR(6,IMON,13)-EXTRAN
C
C           SOUTH PARA PUMPED
C
      IF(ISYS.EQ.5)SYSSTR(5,IMON,13)=PART
C
C           ADD MANNUM/ADELAIDE PIPELINE TRANSFER TO WARREN SUBSYSTEM
C           PUMPED INFLOW
C
      IF(ISYS.EQ.4.AND.WARTRN.EQ.425.)
    * SYSSTR(4,IMON,13)=SYSSTR(4,IMON,13)+WARTRN
      SYSSTR(ISYS,IMON,14)=CSTPRT
C
C           STORE PUMPING DATA
C
C           TORRENS SUBSYSTEM IS NOT INCLUDED SINCE LITTLE PARA ALSO
C           USES THE PUMPING AND ITS OPERATION IS CALCULATED AFTER
C           TORRENS.HENCE LITTLE PARA TRIGGERS MANNUM/ADELAIDE
C           PUMPING DATA STORAGE.
C
      IF(ISYS.EQ.2.OR.ISYS.GT.4)GOTO5
      GOTO6
C
C           NUMBER OF PUMPS
C
5     NPMPS=IPUMP(IPSTN)/100
C
C           TIME OF DAY
C
      JTIME=(IPUMP(IPSTN)-NPMPS*100)/10
C
C           WEEKS IN THE MONTH
C
      WEEKS=(IPUMP(IPSTN)-NPMPS*100-JTIME*10)-1
      SYSPMP(IPSTN,IMON,1)=NPMPS
      SYSPMP(IPSTN,IMON,2)=JTIME
      SYSPMP(IPSTN,IMON,3)=WEEKS
C
C           TOTAL PUMPED AT STATION
C
      SYSPMP(IPSTN,IMON,4)=TOTPMP(IPSTN)
C
C           PIPELINE DEMANDS BEFORE METRO ADELAIDE
C
      SYSPMP(IPSTN,IMON,5)=PIPOFT(IPSTN,2,IMON)
C
C           ADD ANSTEY HILL DEMANDS TO MANNUM PIPELINE DEMANDS
C
      IF(IPSTN.EQ.2)SYSPMP(2,IMON,5)=
    * SYSPMP(2,IMON,5)+PIPOFT(4,2,IMON)
C
C           DEFINE AMOUNT SUPPLIED BY MILLBROOK INTO MANNUM/ADELAIDE
C           PIPELINE
C
      IF(IPSTN.EQ.2.AND.PSPPLY.GE.0.)SYSPMP(2,IMON,7)=PSPPLY
C
C           NET VOLUME AVAILABLE FOR TRANSFERS
C
      SYSPMP(IPSTN,IMON,6)=SYSPMP(IPSTN,IMON,4)+
    * SYSPMP(IPSTN,IMON,7)-SYSPMP(IPSTN,IMON,5)
C
C           COST OF PUMPING
C
      SYSPMP(IPSTN,IMON,8)=COST(IPSTN)
C
C           ADD MILLBROOK PUMPING COSTS TO MANNUM/ADELAIDE PIPELINE
```

```
C               COSTS
C
      IF(IPSTN.EQ.2.AND.PSPPLY.GT.0.)SYSPMP(2,IMON,8)=
     * SYSPMP(2,IMON,8)+CSTMIL*PSPPLY
C
6     IF(IMON.LT.12.OR.ISYS.LT.ISYSMX)GOTO15
C
C               STORE DATA AT THE END OF EACH YEAR IN FILES
C
      IF(IHDCPY.EQ.1)GOTO11
      IHDCPY=1
      ICOP=1
      ICPY=1
      OPEN(UNIT=7,NAME='OUTPUT.DAT',TYPE='NEW',ACCESS='DIRECT',
     * FORM='FORMATTED',RECORDSIZE=100,ASSOCIATEVARIABLE=ICOP)
      OPEN(UNIT=8,NAME='OUTPMP.DAT',TYPE='NEW',ACCESS='DIRECT',
     * FORM='FORMATTED',RECORDSIZE=42,ASSOCIATEVARIABLE=ICPY)
      GOTO12
11    OPEN(UNIT=7,NAME='OUTPUT.DAT',TYPE='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECORDSIZE=100,ASSOCIATEVARIABLE=ICOP)
      OPEN(UNIT=8,NAME='OUTPMP.DAT',TYPE='OLD',ACCESS='DIRECT',
     * FORM='FORMATTED',RECORDSIZE=42,ASSOCIATEVARIABLE=ICPY)
C
C               DETERMINE MONTH IN FINANCIAL YEAR
C
12    KMON=MINREC-12*(MINREC/12)
      K=(KMON-1)/6
      JMON=KMON+((-1)**K)*6
C
C               WRITE DATA
C
      DO 13 JSYS=ISYSMN,ISYSMX
      DO 13 MON=JMON,12
      WRITE(7'ICOP,100),(SYSSTR(JSYS,MON,J),J=1,14)
100   FORMAT(13F7.0,F9.0)
13    CONTINUE
      DO 14 JPSTN=ISTMIN,ISTMAX
      DO 14 MON=JMON,12
      WRITE(8'ICPY,102),(SYSPMP(JPSTN,MON,J),J=1,8)
102   FORMAT(3F2.0,4F7.0,F8.0)
14    CONTINUE
      CLOSE(UNIT=7)
      CLOSE(UNIT=8)
15    RETURN
      END
>
```

```
C        SUBROUTINE SKILL CALCULATES AND STORES THE PERFORMANCE
C        DATA GENERATED DURING THE SIMULATION FOR THE OPERATOR.
C
         SUBROUTINE SKILL
C
         COMMON /CORPMP/PMPQNT(3,16,4),PMPCST(3,16,4),IRANGE(6,2),
     *   IPUMP(3),ISYSMN,ISYSMX,SUMCAP(3),PUMP(3),ICOP,ICPY,IHDCPY,
     *   ICONSD
     *   /CALHLD/DTDEM(6,12),STDEM(6,12),STOINF(13,12),DEMMYP(2,12),
     *   WARSPL,HAPVLY,IDTDEM,ISTDEM,ISTINF,PSPPLY,ISPPLY
     *   /CORCAL/DETINF(6,2,12),MYPTRN,TRANSF(12,2),STOR(12,2),
     *   S(12,12),IMONTH,MONTH,MINREC
     *   /RESULT/PERFRM(7,9,3),SYSSTR(6,12,14),SYSPMP(3,12,8),ISUB,ITOT
C
C
         LOGICAL*1 IHDCPY,ICONSD(6)
C
         IF(MONTH.GT.MINREC)GOTO5
C
C                  SET ASSOCIATE VARIABLES
C
         ISUB=1
         ITOT=1
C
         OPEN(UNIT=7,NAME='SUBFORM.DAT',TYPE='NEW',ACCESS='DIRECT',
     *   FORM='FORMATTED',RECORDSIZE=78,EXTENDSIZE=1,
     *   ASSOCIATEVARIABLE=ISUB)
         OPEN(UNIT=8,NAME='TOTFORM.DAT',TYPE='NEW',ACCESS='DIRECT',
     *   FORM='FORMATTED',RECORDSIZE=78,EXTENDSIZE=1,
     *   ASSOCIATEVARIABLE=ITOT)
         GOTO6
 5       OPEN(UNIT=7,NAME='SUBFORM.DAT',TYPE='OLD',ACCESS='DIRECT',
     *   FORM='FORMATTED',RECORDSIZE=78,ASSOCIATEVARIABLE=ISUB)
         OPEN(UNIT=8,NAME='TOTFORM.DAT',TYPE='OLD',ACCESS='DIRECT',
     *   FORM='FORMATTED',RECORDSIZE=78,ASSOCIATEVARIABLE=ITOT)
C
C                  K=1      MONTHLY PERFORMANCE
C                  K=2      ANNUAL PERFORMANCE
C                  K=3      TOTAL SIMULATION PERFORMANCE
C
 6       DO 500 K=1,3
C
C                  INITIALLISE THE PERFRM ARRAY ELEMENTS IF
C                  REQUIRED.
C
         IF(K.EQ.2.AND.IMONTH.NE.1.OR.K.EQ.3)GOTO100
C
C                  INITIALLISATION.
C
         DO 10 J=1,9
         PERFRM(7,J,K)=0.
         DO 10 JSYS=ISYSMN,ISYSMX
 10      PERFRM(JSYS,J,K)=0.
C
C                  ASSIGN DATA TO ARRAY ELEMENTS
C
 100     DO 200 JSYS=ISYSMN,ISYSMX
C
C                  INFLOW INTO EACH SUBSYSTEM
C
         DO 110 NRES=IRANGE(JSYS,1),IRANGE(JSYS,2)
 110     PERFRM(JSYS,1,K)=PERFRM(JSYS,1,K)+STOINF(NRES,IMONTH)
C
C                  TOTAL DEMAND
```

```
C
      PERFRM(JSYS,2,K)=PERFRM(JSYS,2,K)+STDEM(JSYS,IMONTH)
C
C           TOTAL TRANSFER INTO SUBSYSTEM:PUMPING AND
C           TRANSFERS.
C
      PERFRM(JSYS,3,K)=PERFRM(JSYS,3,K)+SYSSTR(JSYS,IMONTH,13)+
     *SYSSTR(JSYS,IMONTH,12)
C
C           TOTAL COST OF WATER.
C
      PERFRM(JSYS,4,K)=PERFRM(JSYS,4,K)+SYSSTR(JSYS,IMONTH,14)
C
C           TOTAL  SPILL
C
      PERFRM(JSYS,5,K)=PERFRM(JSYS,5,K)+SYSSTR(JSYS,IMONTH,10)
C
C           TOTAL DEFICIT
C
      PERFRM(JSYS,6,K)=PERFRM(JSYS,6,K)+SYSSTR(JSYS,IMONTH,11)
C
C           COST OF SUPPLYING DEMAND-CENTS/KL
C
      IF(PERFRM(JSYS,2,K).EQ.0.)GOTO120
      PERFRM(JSYS,7,K)=PERFRM(JSYS,4,K)/(PERFRM(JSYS,2,K)*10)
      GOTO130
120   PERFRM(JSYS,7,K)=0.
C
C           FRACTION OF EXTERNAL TRANSFERS USED FOR
C           DEMAND
C
130   IF(PERFRM(JSYS,3,K).LE.5.E-4)GOTO140
      PERFRM(JSYS,8,K)=PERFRM(JSYS,2,K)/PERFRM(JSYS,3,K)
      GOTO150
140   PERFRM(JSYS,8,K)=0.
C
C           FRACTION OF NATURAL INFLOW USED FOR DEMAND
C
150   IF(PERFRM(JSYS,1,K).EQ.0.)GOTO160
      PERFRM(JSYS,9,K)=(PERFRM(JSYS,2,K)-PERFRM(JSYS,3,K))
     */PERFRM(JSYS,1,K)
      GOTO200
160   PERFRM(JSYS,9,K)=0.
C
200   CONTINUE
C
C           NOW TAKE THE SAME PAREMETERS FOR THE WHOLE SYSTEM.
C
      DO 300 JELEMT=1,6
      DO 300 JSYS=ISYSMN,ISYSMX
300   PERFRM(7,JELEMT,K)=PERFRM(7,JELEMT,K)+PERFRM(JSYS,JELEMT,1)
C
      IF(PERFRM(7,2,K).EQ.0.)GOTO310
      PERFRM(7,7,K)=PERFRM(7,4,K)/(PERFRM(7,2,K)*10)
      GOTO320
310   PERFRM(7,7,K)=0.
C
320   IF(PERFRM(7,3,K).LE.5.E-4)GOTO330
      PERFRM(7,8,K)=PERFRM(7,2,K)/PERFRM(7,3,K)
      GOTO340
330   PERFRM(7,8,K)=0.
C
340   IF(PERFRM(7,1,K).EQ.0.)GOTO350
      PERFRM(7,9,K)=(PERFRM(7,2,K)-PERFRM(7,3,K))/PERFRM(7,1,K)
      GOTO360
350   PERFRM(7,9,K)=0.
```

```
C
C                   WRITE THE VALUES ONTO FILE
C
360     DO 361 JSYS=ISYSMN,ISYSMX
361     WRITE(7'ISUB,540),(PERFRM(JSYS,JELEMT,K),JELEMT=1,9)
        WRITE(8'ITOT,540),(PERFRM(7,JELEMT,K),JELEMT=1,9)
540     FORMAT(6F8.0,3F10.3)
C
500     CONTINUE
C
        CLOSE(UNIT=7)
        CLOSE(UNIT=8)
C
600     RETURN
        END
.PIP>
```

```
 C       PROGRAM EVAPOR:CALCULATES EVAP FROM SUPPLIED STORAGE VS EVAPORATION
C        CURVES AT EACH RESERVOIR FOR EACH MONTH OF THE YEAR.
C
         SUBROUTINE EVAPOR(STR,NRES,IMON,EV)
         COMMON/EVAPDAT/EVAPN(154,13)
         DIMENSION EVAP(2),STOR(2)
C
         I=1
C
C                READ EVAPORATION DATA UNTIL INDEX FOR THE DESIRED STORAGE
C                IS FOUND.
C
10       IF(NRES.EQ.ABS(EVAPN(I,1)))GOTO11
         I=I+1
         GOTO10
C
C                DETERMINE THE POSITION IN THE DATA CORRESPONDING TO THE
C                CURRENTLY HELD VOLUME.
C
11       J=I+1
111      IF(STR.LE.EVAPN(J,1))GOTO12
         J=J+1
         GOTO111
C
C                ASSIGN VALUES FOR CALCULATION.
C
12       STOR(1)=EVAPN(J-1,1)
         STOR(2)=EVAPN(J,1)
         EVAP(1)=EVAPN(J-1,IMON+1)
         EVAP(2)=EVAPN(J,IMON+1)
C
C                INTERPOLATE THE EVAPORATION.
C
         EV=((STR-STOR(1))/(STOR(2)-STOR(1)))*(EVAP(2)-EVAP(1))+EVAP(1)
         RETURN
         END
```

```
C       SUBROUTINE WEIR DETERMINES THE TRANSFER OF NATURAL INFLOW AT
C       EACH OF THE TWO WEIRS INTO THE RESPECTIVE RESERVOIR STORAGES
C       ACCORDING TO THE WEIR CHARACTERISTICS IN 'WIRTRF'.
C
      SUBROUTINE WEIR(STOR,ST,TRANS)
C
      DIMENSION WIRTRF(2,4)
C
      DATA WIRTRF/4200.,11000.,4200.,11000.,17450.,46125.,9100.,24200./
C
C
C               DETERMINE WHICH WEIR IS BEING CONSIDERED.
C               EITHER CLARENDON (IWEIR=1),OR GUMERACHA (IWEIR=2).
C
410   IWEIR=-INT(STOR/10.)
C
C               FIND THE ELEMENT IN TRANSFER FUNCTION ARRAY MATCHING
C               THE CURRENT STORAGE(=INFLOW ONLY)
C
      J=1
41    IF(ST.LE.WIRTRF(IWEIR,J))GOTO42
      J=J+2
C
C               IF THE COUNTER 'J' IS OUTSIDE THE RANGE OF THE ARRAY,THEN
C               THE HYDRAULIC CAPACITY OF THE TRANSFER TUNNEL HAS BEEN
C               REACHED.
C
      IF(J.EQ.5)GOTO45
      GOTO41
C
C               HAVING NOW MATCHED THE CATCHMENT INFLOW,THE NEXT CONSEC-
C               UTIVE ELEMENT IN THE ARRAY GIVES THE AVAILABLE TRANSFER.
C
42    J=J+1
C
C               LINEAR INTERPOLATION IS USED TO CALCULATE BETWEEN THE
C               SUPPLIED DATA POINTS.
C
      GOTO(43,44),J/2
43    TRANS=ST*WIRTRF(IWEIR,2)/WIRTRF(IWEIR,1)
      GOTO46
44    TRANS=WIRTRF(IWEIR,2)+((ST-WIRTRF(IWEIR,1))/
     *(WIRTRF(IWEIR,3)-WIRTRF(IWEIR,1)))*(WIRTRF(IWEIR,4)
     *-WIRTRF(IWEIR,2))
      GOTO46
45    TRANS=WIRTRF(IWEIR,4)
C
46    RETURN
      END
>
```

```
C     SUBROUTINE PMP: CALLED BY SUBROUTINE 'CALCST' TO EVALUATE THE
C     TOTAL PUMPED VOLUME FROM A PUMPSTATION AND ALSO THE TRANSFERS
C     FROM THE ASSOCIATED PIPELINES TO ANY STORAGE REQUESTING EXTRA
C     INFLOW.COST OF PUMPING AT THE STATION IS FINALLY CALULATED.
C                       _000_
      SUBROUTINE PMP(ISYS,IPRVW,NRES,NCYCL,PSPPLY,ISPPLY)
C
C
      COMMON /CALPMP/PIPOFT(4,2,12),IMON,ISTMIN,ISTMAX,DEMMIL,
     * WARTRN,MAXPMP(3),EXSMIL
     * /CORPMP/PMPQNT(3,16,4),PMPCST(3,16,4),IRANGE(6,2),IPUMP(3),
     * ISYSMN,ISYSMX,SUMCAP(3),PUMP(3),ICOP,ICPY,
     * IHDCPY,ICONSD
      COMMON /CORCAL/DETINF(6,2,12),MYPTRN,TRANSF(12,2),STOR(12,2),
     * S(12,12),IMONTH,MONTH,MINREC
     * /PMPCPY/IPSTN,TOTPMP(3),COST(3),TRAN(6),CAPCTY
     * /SETUP/IBAR,ICALC,SMAX(6),XMIN(12),YMIN(12),YMAX(12),ICOUNT,
     * ISTRT,MYP,NOTRAN,MLLBRK,LPARA,SPARA,IXS
C
      LOGICAL*1 NUL,IHDCPY,ICONSD(6),IBAR(6),ICALC(6),ISTRT,MYP,
     * NOTRAN,MLLBRK,IXS,NUM(5)
C
      REAL NOWPMP(3)
C
      DIMENSION NTIME(3,3)
C
      DATA NTIME,CAPSUM/1,15,16,1,15,16,1,14,14,7150./
C
C             FIND WHICH PUMPSTATION IS REQUIRED AND WHAT THE
C             OFFTAKE CAPACITY IS-FROM TRANSF.
C
      IPSTN=INT(ABS(TRANSF(NRES,2)))
      CAPCTY=(ABS(TRANSF(NRES,2))-IPSTN)*100000
      SUMCAP(IPSTN)=0.
D     WRITE(10,1200) IPSTN,CAPCTY,IPUMP(IPSTN)
D1200 FORMAT(2X,'PUMP',2X,'IPSTN',I2,'CAPCTY',F7.0,'IPUMP',I5)
C
C             UPDATE THE NUMBER OF OFFTAKES FROM THE PUMPSTATION
C
      DO 135 JSYS=ISYSMN,ISYSMX
      DO 135 JRES=IRANGE(JSYS,1),IRANGE(JSYS,2)
C
C             CHECK WHETHER THE STORAGE IS MYPONGA RESERVOIR (NO PUMPING).
C
      IF(ABS(TRANSF(JRES,2)).LT.1)GOTO135
C
C             DETERMINE THE PUMPSTATIONS IN USE
C
      ISTN=ABS(INT(TRANSF(JRES,2)))
C
C             ADJUST MAXIMUM AND MINIMUM PUMPSTATION INDICES FOR THE AREA
C             OF SIMULATION.
C
      IF(ISTN.LT.ISTMIN)ISTMIN=ISTN
      IF(ISTN.GT.ISTMAX)ISTMAX=ISTN
      IF(ISTN.NE.IPSTN.OR.TRANSF(JRES,2).LT.1)GOTO135
C
C             IF IT IS THE CURRENT PUMPSTATION AND PUMPING IS DESIRED
C             INCREMENT 'SUMCAP' (NUMBER OF OFFTAKES).
C
      SUMCAP(IPSTN)=SUMCAP(IPSTN)+1.
135   CONTINUE
C
C             IGNORE INCREMENTED NUMBER OF OFFTAKES IF PREDICTIVE MODE.
```

```
C
      IF(NCYCL.GE.2)SUMCAP(IPSTN)=0.
C
C             ALLOW FOR LEAVING ALL VALVES SHUT,DESPITE PUMPING
C             BEING SPECIFIED,BY RESETTING 'IWKS' VARIABLE.
C
C             IF THERE ARE OFFTAKES FROM THE PIPELINE,OR IF IT IS
C             SWAN REACH,GOTO CALCULATION WITHOUT MODIFICATION.
C             THIS IS BECAUSE WARREN RESERVOIR IS ALWAYS AVAILABLE TO
C             ACCEPT PUMPED INFLOW.
C
      IF(SUMCAP(IPSTN).GT.0..OR.IPSTN.EQ.3)GOTO140
      IWKS=0
      GOTO141
C
C             THE CURRENT PUMPING OPERATION FOR THE PUMPSTATION
C             IS GIVEN BY IPUMP(IPSTN).DECOMPOSE THIS TO GIVE THE
C             REQUIRED ELEMENTS FOR DETERMINING THE ACTUAL
C             QUANTITY PUMPED.
C
C
C             NUMBER OF PUMPS
C
140   NPUMPS=IPUMP(IPSTN)/100
C
C             TIME OF DAY: OFF-PEAK,ON-PEAK,SPECIAL-ON-PEAK
C
      N=(IPUMP(IPSTN)-NPUMPS*100)/10
      JTIME=NTIME(N,IPSTN)
C
C             WEEKS WITHIN THE MONTH
C
      IWKS=(IPUMP(IPSTN)-NPUMPS*100-N*10)-1
C
C             IF IN PREDICTIVE MODE,CALCULATE MINIMUM PUMPING REQUIREMENT
C
      IF(NCYCL.GE.2)IWKS=0
141   CONTINUE
D     WRITE(10,1400) SUMCAP(IPSTN),NPUMPS,N,IWKS,ISTMIN,ISTMAX
D1400 FORMAT(2X,'SUMCAP',F3.0,'NPUMPS',I2,'N',I2,'IWKS',I2,
D    *'ISTMIN',I4,'ISTMAX',I4)
C
C             USE THE STOCHASTIC OR DETERMINISTIC PIPELINE OFFTAKE
C             DEPENDING ON THE VALUE OF 'IPRVW'.
C
      J=1
      IF(IPRVW.EQ.0.AND.NCYCL.EQ.1)J=2
C
C             CALCULATION OF PIPELINE OFFTAKES
C
      PIPOFF=PIPOFT(IPSTN,J,IMON)
      IF(IPSTN.NE.2)GOTO148
C
C             MANNUM/ADELAIDE PIPELINE:
C             ADD ANSTEY HILL TREATMENT WORKS DEMAND TO PIPELINE OFFTAKE.
C
      PIPOFF=PIPOFF+PIPOFT(4,J,IMON)
      IF(IPRVW.EQ.1.OR.NCYCL.GE.2)GOTO142
C
C             ALLOW FOR THE PUMPED SUPPLY FROM MILLBROOK RESERVOIR-
C             ACCEPT MODE (IPRVW=0) AND CURRENT MONTH ONLY.
C
      PIPOFF=PIPOFF-PSPPLY
      GOTO146
C
C             INCLUDE LITTLE PARA OFFTAKE IN PIPELINE DEMAND.
```

```
C
142   IF(NCYCL.EQ.1)PIPOFF=PIPOFF+TRAN(6)
C
C               IF NOT SUPPLYING FROM MILLBROOK RESERVOIR,GOTO CHECK
C               CAPACITY OF MANNUM-ADELAIDE PIPELINE.
C
      IF(ISPPLY.LE.-1)GOTO146
C
C               DEFINE THE POTENTIAL PIPELINE DEMAND ON MILLBROOK.
C               PREVIEW MODE (IPRVW=1) ONLY.
C
      MILDEM=PIPOFT(4,1,IMON)
      IF(NCYCL.EQ.1)MILDEM=MILDEM+TRAN(6)
C
C               DEFINE THE PREDICTED AVAILABLE TRANSFER AS BEING THE
C               AVERAGE TORRENS SYSTEM INFLOW (OPTIMISTIC),AND SEE
C               HOW MUCH OF IT IS USED.
C
D     WRITE(10,1430) EXSMIL
D1430 FORMAT(2X,'EXSMIL',F7.0)
      GOTO(143,144,143),NCYCL
143   AVAIL=DETINF(3,1,IMON)-MILDEM+EXSMIL
      GOTO145
144   AVAIL=DETINF(3,2,IMON)-MILDEM+EXSMIL
C
C               MATCH 'MILDEM' TO OFFTAKE IF REQUIRED.
C
145   CONTINUE
D     WRITE(10,1450) AVAIL,PIPOFF,MILDEM
D1450 FORMAT(2X,'AVAIL',F7.0,'PIPOFF',F7.0,'MILDEM',I6)
C
C               MODIFY DEMAND ON PUMPS IF A TRANSFER IS AVAILABLE.
C
      IF(AVAIL.LT.0..AND.ABS(AVAIL).LE.MILDEM)PIPOFF=
     *PIPOFF-(MILDEM+AVAIL)
      IF(AVAIL.GE.0.)PIPOFF=PIPOFF-MILDEM
C
146   IF(NCYCL.GE.2)GOTO148
C
C               CHECK CAPACITY OF CRITICAL SECTION OF MANNUM-ADELAIDE
C               PIPELINE.
C
      XSDEM=PIPOFF-PIPOFT(2,J,IMON)-CAPSUM
      IF(XSDEM.LE.0.)XSDEM=0.
D     WRITE(10,1460) XSDEM
D1460 FORMAT(2X,'XSDEM',F7.0)
      IF(XSDEM.EQ.0.)GOTO147
C
C               IF PIPELINE CAPACITY IS EXCEEDED-
C               REDUCE DEMAND ON PUMPS BY THE FRACTION THAT EXCEEDS
C               THE CAPACITY.
C
      PIPOFF=PIPOFF-XSDEM
C
C               SET THE FLAG ON MILLBROOK TO INDICATE THAT IT MUST
C               SUPPLY.
C
      IF(TRANSF(6,2).LT.0..AND.ABS(ISPPLY).EQ.1)
     *ISPPLY=ISPPLY*10
C
C               CHANGE THE TRANSFER CHARACTERISTIC TO REQUESTING INFLOW
C               INTO MILLBROOK.THIS EXCESS WATER THEN BYPASSES THE PIPE-
C               LINE SECTION WITH THE CRITICAL CAPACITY AND RE-ENTERS
C               THE PIPELINE VIA THE MILLBROOK RESERVOIR PUMPS.
C
```

```
C
C               IF WARREN SUBSYSTEM REQUESTS TRANSFER,INCLUDE IN OFFTAKE.
C
147     IF(WARTRN.EQ.425.)PIPOFF=PIPOFF+425.
148     CONTINUE
D       WRITE(10,1490),PIPOFF,PIPOFT(IPSTN,J,IMON)
D1490   FORMAT(2X,'PIPOFF',F7.0,'PIPOFT',F7.0)
C
C               IF PUMPING IS ONLY INTERMITTENT(IWKS=0) OR IF
C               WHOLE MONTH IS USED(IWKS=4) GOTO150
C
        IF(IWKS.EQ.0.OR.IWKS.EQ.4)GOTO150
        WEEKS=FLOAT(IWKS)
        GOTO170
C
C               FIND HOW MANY DAYS IN MONTH 'IMON',AND THE NUMBER OF
C               WEEKS 'WKS'.
C
150     GOTO(3,3,2,3,2,3,3,1,3,2,3,2),IMON
1       NDAYS=28
        GOTO151
2       NDAYS=30
        GOTO151
3       NDAYS=31
151     WKS=NDAYS/7.
C
C               IF THERE ARE SPECIAL PUMPING CONDITIONS IN THE TORRENS
C               SYSTEM,GOTO CALCULATION.
C
        IF(NUL.GE.1)GOTO158
C
C               DEFINE THE TRUE NUMBER OF WEEKS USED.
C
        IF(IWKS.EQ.0)GOTO158
        WEEKS=WKS
        GOTO170
C
C               FOR INTERMITTENT PUMPING,CALCULATE HOW MUCH PUMPING
C               IS NEEDED TO SATISFY PIPELINE DEMANDS ALONE.
C
C               RE-INITIALLIZE VARIABLES.
C
158     JPMPS=1
        JTIME=1
C
C               DEFINE PUMP DEMAND:ON MANNUM/ADELAIDE PIPELINE,'NUL'
C               INDICATES CERTAIN CONSTRAINTS,SEE LATER IN SUBROUTINE.
C
160     DEMAND=PIPOFF
        IF(NUL.EQ.2)DEMAND=PIPOFF+XSDEM
        IF(NUL.EQ.3)DEMAND=PIPOFF+TRAN(3)
C
C               CALCULATE PUMPED VOLUME BY DETERMINING THE NUMBER OF
C               WEEKS REQUIRED TO SATISFY DEMAND.
C               O.K. IF 'WEEKS' IS LESS THAN MONTHLY TOTAL.
C
        WEEKS=DEMAND/PMPQNT(IPSTN,JTIME,JPMPS)
        IF(WEEKS.LE.WKS)GOTO163
C
C               IF THE QUANTITY WILL NOT SUPPLY THE REQUIRED AMOUNT
C               WITHIN THE MONTH(WKS) THEN INCREMENT 'JPMPS'.
C               (MORE ECONOMICAL THAN 'JTIME' INCREMENTS)
C
        JPMPS=JPMPS+1
C
C               CHECK THE MAX NUMBER OF PUMPS AVAILABLE.
```

```
C
      IF(JPMPS.GT.MAXPMP(IPSTN))GOTO162
      GOTO160
C
C               IF JPMPS GREATER THAN THE MAXIMUM PUMPS AVAILABLE,
C               INCREMENT JTIME AND START AGAIN.
C
162   JPMPS=1
      JTIME=JTIME+1
      GOTO160
C
C               ASSIGN CALCULATION VARIABLE.
C
163   NPUMPS=JPMPS
C
C               IF CALCULATIONS ARE FOR CURRENT MONTH,OR FIRST TIME
C               THROUGH FOR THE SUBSYSTEM,DEFINE THE PUMPING STRATEGY.
C
      IF(NCYCL.EQ.1.OR.NCYCL.EQ.2.AND.ICALC(ISYS).NE.1.AND.
     * IMON.EQ.IMONTH)GOTO164
      GOTO165
C
C               REDEFINE THE PUMPING VARIABLE ACCORDING TO THE MODIFIED
C               STRATEGY.
C
C               RECORD TIME OF DAY USED AS OFF-PEAK,ON-PEAK,OR
C               SPECIAL-ON-PEAK.
C
164   N=1
      IF(JTIME.GT.NTIME(1,IPSTN))N=2
      IF(JTIME.GT.NTIME(2,IPSTN))N=3
C
C               RECOMPOSE THE PUMPING CHARACTERISTIC
C
      IPUMP(IPSTN)=NPUMPS*100+N*10+INT(WEEKS)+1
165   NUL=0
D     WRITE(10,1630),IPSTN,IPUMP(IPSTN)
D1630 FORMAT(2X,'IPSTN',I4,'IPUMP',I6)
C
C               NOW CALCULATE THE ACTUAL QUANTITY PUMPED AND THE
C               REDUCED AMOUNT AVAILABLE AFTER PIPELINE OFFTAKES
C               ARE SATISFIED
C
170   NOWPMP(IPSTN)=PMPQNT(IPSTN,JTIME,NPUMPS)*WEEKS
      IF(IPSTN.NE.2.OR.NCYCL.GE.2)GOTO1700
C
C               EXAMINE MANNUM-ADELAIDE PIPELINE.
C
D     WRITE(10,1640) NOWPMP(2),PIPOFF,XSDEM
D1640 FORMAT(2X,'NOWPMP',F7.0,'PIPOFF',F7.0,'XSDEM',F7.0)
C
C               INSUFFICIENT SUPPLY
C
      IF(NOWPMP(2)-(PIPOFF+XSDEM).LT.-5.E-4)NUL=2
C
C               TOO MUCH SUPPLY
C
      IF(ABS(ISPPLY).EQ.10.AND.NOWPMP(2)-(PIPOFF+XSDEM)
     *.GT.5.E-4)NUL=2
C
C               IN EITHER CASE,RECALCULATE PUMPED VOLUME.
C
      IF(NUL.EQ.2)GOTO150
C
C               REMOVE OFFTAKES FROM THE QUANTITY PUMPED
C               TO FIND QUANTITY AVAILABLE AS TRANSFER
```

```
C               I.E.THE FRACTION NOT ALREADY SPOKEN FOR.
C
1700    PUMP(IPSTN)=NOWPMP(IPSTN)-PIPOFF
D       WRITE(10,1799),NRES,NOWPMP(IPSTN),PUMP(IPSTN),WEEKS,JTIME,NPUMPS
D1799   FORMAT(2X,'NRES',I2,'NOWPMP',F7.0,'PUMP',F9.3,'WEEKS',F3.1,
D     * 'JTIME',I3,'NPUMPS',I3)
C
C               ENSURE THAT AVAILABLE PUMPING IS NOT NEGATIVE (WITHIN
C               LIMITS).
C
        IF(PUMP(IPSTN).GE.-5.E-4)GOTO171
D       WRITE(10,1791) PUMP(IPSTN)
D1791   FORMAT(5X,'NUL',4X,'PUMP',F9.3)
C
C               IF INSUFFICIENT PUMPING-'PUMP(IPSTN)' NEGATIVE-SET 'NUL'
C               AND RECALCULATE.
C
1701    NUL=1
        GOTO150
171     IF(TRANSF(NRES,2).GT.0.)GOTO172
C
C               IF PUMPING O.K. BUT NO TRANSFERS ARE REQUESTED,CHECK
C               SOME LIMITS.
C
D       WRITE(10,1792) PUMP(IPSTN)
D1792   FORMAT(5X,'TRANSF',4X,'PUMP',F9.3)
C
C               IF LITTLE PARA NEEDS NO TRANSFER,BUT MILLBROOK DOES,O.K.
C
        IF(ISYS.EQ.6.AND.TRANSF(6,2).GT.0.)GOTO180
C
C               IF EXCESS MURRAY BRIDGE PUMPING IS AVAILABLE BUT MOUNT
C               BOLD NEEDS NO TRANSFER,MODIFY PUMPING.
C
1711    IF(NRES.EQ.2.AND.PUMP(1).GT.5.E-4)GOTO1701
D       WRITE(10,1793) TRAN(3),TRAN(6),PUMP(2),DEMMIL
D1793   FORMAT(2X,'TRAN3',F7.0,'TRAN6',F7.0,'PUMP2',F7.0,'DEMMIL',F7.0)
        IF(ISYS.EQ.6)IFIN=1
C
C               IF EXCESS MANNUM PUMPING IS AVAILABLE BUT NO MILLBROOK
C               OR LITTLE PARA TRANSFER IS NEEDED,MODIFY PUMPING.
        IF(IPSTN.EQ.2.AND.PUMP(2).GT.5.E-4)GOTO1701
        GOTO180
C
C               DEFINE THE TRANSFER AVAILABLE TO NRES UNDER THE
C               EXISTING PUMPING CONDITIONS
C
172     GOTO(173,174,175),IPSTN
C
C               ONKAPARINGA
C
173     TRAN(2)=PUMP(1)
        GOTO180
C
C               CHECK CAPACITIES OF MAINS AGAINST PROPOSED TRANSFERS.
C
174     GOTO(1746,1741),(ISYS/3)
C
C               IF PREDICTING FUTURE MONTHS,OR MANNUM/ADELAIDE PIPELINE
C               LIMITS HAVE ALREADY BEEN CHECKED,SKIP CALCS.
C
1741    IF(NCYCL.GE.2.OR.IFIN.EQ.1)GOTO180
        IFIN=0
C
C               CHECK MANNUM/ADELAIDE PIPELINE LIMITS WITH NO MILLBROOK
C               TRANSFER.
```

```
C
      IF(TRANSF(6,2).LT.0.)GOTO1711
      GOTO180
C
C             SET MILLBROOK TRANSFER.
C
1746  TRAN(3)=PUMP(2)
      IF(IPRVW.EQ.1.OR.NCYCL.GE.2)GOTO180
C
C             IF IN 'ACCEPT MODE (STOCHASTIC DATA) AND CURRENT MONTH,
C             CHECK THAT THE OFFTAKE CAPACITY IS NOT EXCEEDED.
C
      IF(TRAN(3).LE.CAPCTY)GOTO180
C
C             IF OFFTAKE CAPACITY EXCEEDED,RECALCULATE TRANSFER AND
C             PUMPING.
C
      TRAN(3)=CAPCTY
      NUL=3
      GOTO150
C
C             SOUTH PARA AND WARREN SYSTEMS
C
175   IF(ISYS.EQ.5.OR.NCYCL.GE.2)GOTO180
C
C             DEFINE WARREN TRANSFER.
C
      TRAN(4)=PUMP(3)-TRAN(5)
C
C             MODIFY TRANSFER ON SCREEN.
C
180   IF(ISYS.GE.5.AND.NCYCL.EQ.1)CALL NMBR(ISYS*1000+21,TRAN(ISYS),
     * 6,'(F6.0)')
C
C             IF CURRENT MONTH OR PROGRAM INITIALLISATION,SET TOTAL PUMPING
C             FROM PUMPSTATION TO CURRENT VALUE.
C
      IF(NCYCL.EQ.1.OR.NCYCL.EQ.2.AND.IMON.EQ.IMONTH.AND.
     * ICALC(ISYS).NE.1)GOTO181
      GOTO182
C
C             SET EXTERNAL PUMPING VARIABLE TO INTERNAL VARIABLE
C
181   TOTPMP(IPSTN)=NOWPMP(IPSTN)
C
C             CALCULATE TOTAL COST OF PUMPING.
C
      COST(IPSTN)=PMPCST(IPSTN,JTIME,NPUMPS)*TOTPMP(IPSTN)
182   CONTINUE
D     WRITE(10,1800) NOWPMP(IPSTN),PIPOFF,PUMP(IPSTN),TRAN(ISYS)
D1800 FORMAT(2X,'NOWPMP',F6.0,'PIPOFF',F6.0,'PUMP(IPSTN)',F6.0,
D    * 'TRAN',F6.0)
      RETURN
      END
>
```

```
C       SUBROUTINE SUPPLY: SUPPLIES INTERACTIVE PROMPTS FOR OFFTAKES TO
C               SOUTH PARA OR LITTLE PARA SUBSYSTEMS.
C               FLAGS LPARA AND SPARA PREVENT REDEFINITION OF THE PROMPT
C               EACH TIME IT IS CALLED.
C
        SUBROUTINE SUPPLY(IPRVW,ISYS,TRAN,LPARA,SPARA,IXS,
     *  TRANSF,PIPOFT)
C
        LOGICAL*1 LPARA,SPARA
C
        DATA CAPW3,CAPS3,CAPSUM/9515.,6470.,7150./
C
C               IF IPRVW=0 ('ACCEPT' MODE) OR NO TRANSFER REQUESTED
C               DO NOT PROMPT.
C
        IF(IPRVW.EQ.0.OR.TRANSF.LT.0.)GOTO36
        CAPCTY=(TRANSF-INT(TRANSF))*1.E5
C
        GOTO(1750,1740),ISYS-4
C
C               SET UP PROMPT FOR LITTLE PARA TRANSFER
C
1740    IF(LPARA.EQ.1)GOTO1742
        CALL SUBP(63)
        CALL OFF(63)
        CALL APNT(0.,160.,,-3,-1)
        CALL TEXT(-2,' TYPE IN DESIRED OFFTAKE FROM',
     *  1,-2,' THE PIPELINE TO LITTLE PARA,',
     *  1,-2,' AND PRESS "CR".')
        CALL TEXT(1,-2,' (OFFTAKE CAPACITY=5500ML)')
        CALL ESUB(63)
        LPARA=1
1742    CALL OFF(52)
        CALL ON(63)
        TYPE1743
1743    FORMAT(2X,'NEW TRANSFER='$)
        READ(5,1744,ERR=1745),ITRAN
1744    FORMAT(I)
        GOTO1746
1745    CALL CLR
        GOTO1742
1746    CALL CLR
        CALL OFF(63)
        CALL ON(52)
        TRAN=FLOAT(ITRAN)
C
C               CHECK FOR TRANSFER CAPACITY
C
        IF(TRAN.GT.CAPCTY)TRAN=CAPCTY
C
        GOTO36
C
C               SET UP PROMPT FOR SOUTH PARA TRANSFER
C
1750    IF(SPARA.EQ.1)GOTO1751
        CALL SUBP(64)
        CALL OFF(64)
        CALL APNT(0.,160.,,-3,-1)
        CALL TEXT(-2,' TYPE IN DESIRED TRANSFER TO',
     *  1,-2,' SOUTH PARA,AND PRESS "CR".',
     *  1,-2,' (TRANSFER CAPACITY=2310ML)')
        CALL ESUB(63)
        SPARA=1
1751    CALL OFF(52)
```

```
      CALL ON(64)
      TYPE1752
1752  FORMAT(2X,'NEW TRANSFER='$)
      READ(5,1753,ERR=1754),ITRAN
1753  FORMAT(I)
      GOTO1755
1754  CALL CLR
      GOTO1751
1755  CALL CLR
      CALL OFF(64)
      CALL ON(52)
      TRAN=FLOAT(ITRAN)
C
C             CHECK FOR EXCEEDENCE OF TRANSFER CAPACITY
C
      IF(TRAN.GT.CAPCTY)TRAN=CAPCTY
C
36    IF(ISYS.EQ.5)RETURN
C
C             HAVING ESTABLISHED LITTLE PARA TRANSFER,CHECK WHETHER
C             CAPACITY OF GRAVITY SECTION OF MANNUM/ADELAIDE PIPELINE
C             IS EXCEEDED.
C
      CAPANS=CAPW3
      IF(4.LE.IMON.AND.IMON.LE.9)CAPANS=CAPS3
      PMPANS=PIPOFT+TRAN
      IF(PMPANS.GT.CAPANS)TRAN=TRAN-(PMPANS-CAPANS)
      IF(TRAN.LT.0.)TRAN=0.
C
      IF(TRAN.EQ.0.)RETURN
C
C             IF AN EXCESSIVE TRANSFER IS REQUESTED,REPROMPT FOR
C             CONFIRMATION OR CHANGE.
C
      XSDEM=PIPOFT+TRAN-CAPSUM
      IF(XSDEM.LE.0.)XSDEM=0.
      IF(XSDEM.EQ.0..OR.IPRVW.EQ.0)RETURN
C
      IF(IXS.EQ.1)GOTO37
      CALL SUBP(66)
      CALL OFF(66)
      CALL APNT(0.,160.,,,-3,-1)
      CALL TEXT(-2,' TOTAL DEMAND IS ')
      CALL RPNT(0.,0.)
      CALL TEXT('000000')
      CALL RPNT(0.,0.)
      CALL TEXT(-2,'ML.',1,-2,' GREATER THAN CAPACITY OF',
     * 1,-2,' MANNUM/ADELAIDE PIPELINE.')
      CALL TEXT(1,-2,' REDUCE LITTLE PARA TRANSFER ?',
     * 1,-2,' TYPE `Y` FOR YES,`N` FOR NO.')
      CALL ESUB(66)
      IXS=1
37    CALL POINTR(1,66,4)
      IXSDEM=JINT(XSDEM)
      ENCODE(4,38,NUM) IXSDEM
38    FORMAT(I4)
      CALL CHANGT(1,NUM)
      CALL OFF(52)
      CALL ON(66)
      TYPE380
380   FORMAT(2X,'ANSWER='$)
      READ(5,381) ANSWER
381   FORMAT(A1)
      CALL OFF(66)
      CALL CLR
      CALL ON(52)
```

```
      IF(ANSWER.EQ.'N')RETURN
      GOTO1740
      END
>
```

```
C       SUBROUTINE TORRNS: CONTROL OF PROMPTS TO THE OPERATOR FOR MILLBROOK
C               RESERVOIR STORAGE AND SUPPLY TO ANSTEY HILL FILTRATION
C               PLANT.
C                               _000_
        SUBROUTINE TORRNS(DEMMIL,XSDEM,PSPPLY,ISPPLY,IPRVW,EV,
     *  MLLBRK,STOINF,S1,S2,PIPOFT,TRAN,TRNSF1,TRNSF2)
C
        LOGICAL*1 MLLBRK
C
        DATA CAPSUM/7150./
C
        IF(IPRVW.EQ.0)GOTO143
        IF(MLLBRK.EQ.1)GOTO140
C
C               PROMPT MILLBROOK STORAGE
C
        CALL SUBP(60)
        CALL OFF(60)
        CALL APNT(0.,160.,,-3,-1)
        CALL TEXT(-2,' PLEASE TYPE IN THE REQUIRED',
     *  1,-2,' STORAGE FOR MILLBROOK RES.',
     *  1,-2,' AND THEN PRESS THE "CR" KEY.')
        CALL ESUB(60)
140     CALL OFF(52)
        CALL ON(60)
C
C               ACCEPT NEW STORAGE FOR MILLBROOK RESERVOIR
C
        TYPE1401
1401    FORMAT(2X,' NEW STORAGE='$)
        READ(5,141,ERR=1410),ISTOR
141     FORMAT(I5)
        GOTO1411
1410    CALL CLR
        GOTO140
1411    CALL OFF(60)
C
C               NEW STORAGE FOR MILLBROOK
C
        CALL CLR
        S2=FLOAT(ISTOR)
        IF(MLLBRK.EQ.1)GOTO142
C
C               PROMPT ANSTEY HLL SUPPLY
C
        CALL SUBP(65)
        CALL OFF(65)
        CALL APNT(0.,160.,,-3,-1)
        CALL TEXT(-2,' WILL ANSTEY HILL BE SUPPLIED',
     *  1,-2,' BY MILLBROOK RESERVOIR?',
     *  1,-2,' TYPE "Y" FOR YES,"N" FOR NO.')
        CALL ESUB(65)
        MLLBRK=1
C
C               ACCEPT OPERATOR DECISION
C
142     CALL ON(65)
        TYPE1420
1420    FORMAT(2X,'ANSWER='$)
        ACCEPT1421,ANSWER
1421    FORMAT(A1)
        IF(ANSWER.EQ.'Y')ISPPLY=1.
        IF(ANSWER.EQ.'N')ISPPLY=-1.
        CALL OFF(3022)
```

```
C
C               TURN ON SCREEN INDICATOR THAT MILLBROOK SUPPLIES ANSTEY HILL
C
        IF(ISPPLY.EQ.1.)CALL ON(3022)
        CALL CLR
        CALL OFF(65)
        CALL ON(52)
C
C               SINCE ISPPLY CAN BE MODIFIED IN OTHER ROUTINES,RETURN IT
C               TO ITS UNITY VALUE.
C
143     ISPPLY=ISPPLY/ABS(ISPPLY)
C
C               DETERMINE WHETHER DESIRED SUPPLY EXCEEDS GRAVITY CAPACITY
C               OF PIPELINE
C
        XSDEM=PIPOFT+TRAN-CAPSUM
        IF(XSDEM.LE.0.)XSDEM=0.
C
C               IF ONLY PREVIEWING OPERATION,RETURN
C
        IF(IPRVW.NE.0)RETURN
C
C               DETERMINE THE AVAILABLE SUPPLY IN MILLBROOK RESERVOIR GIVEN
C               THE DESIRED STORAGE LEVEL S2
C
        DEMMIL=S1-S2+STOINF+TRNSF1-EV
        IF(ISPPLY.EQ.-1.OR.DEMMIL.LE.0.)DEMMIL=0.
        IF(ISPPLY.EQ.-1.AND.XSDEM.GT.0.)GOTO1430
        GOTO1439
C
C               IF NO SUPPLY TO ANSTEY HILL WAS REQUESTED BY THE OPERATOR
C               BUT DEMAND CAN ONLY BE SUPPLIED IF MILLBROOK IS USED,
C               RESET PUMPING PLAN TO ALLOW PUMPING AND SET FLAG ISPPLY
C
1430    DEMMIL=XSDEM
        IF(TRNSF2.LT.0.)ISPPLY=-10
C
C               RESET PUMPING COEFFICIENT
C
        TRNSF2=ABS(TRNSF2)
C
C               ADD LITTLE PARA TRANSFER TO PIPELINE DEMAND FOR WHICH
C               MILLBROOK IS PARTLY RESPONSIBLE
C
        PSPPLY=-TRAN
        RETURN
C
C               IF MILLBROOK IS TO SUPPLY INTO THE PIPELINE CHECK THAT
C               SUFFICIENT IS SUPPLIED.THIS MAY MEAN CHANGING THE
C               PUMPING INFLOW FOR THE TORRENS SYSTEM TO OBTAIN EXTRA.
C
C               FIND THE PART OF THE AVAILABLE TRANSFER TO BE SUPPLIED
C               ONLY BY THE RESERVOIR
C
1439    PSPPLY=DEMMIL-TRAN
C
C               SET FLAG FOR EXTRA PUMPING
C
        IF(DEMMIL.LT.XSDEM.AND.TRNSF2.LT.0.)ISPPLY=10
C
C               SET SUPPLY TO EQUAL THE UNSATISFIED DEMAND
C
        IF(DEMMIL.LT.XSDEM)DEMMIL=XSDEM
        IF(PSPPLY.LE.PIPOFT)RETURN
C
```

```
C                 IF AVAILABLE MILLBROOK SUPPLY IS GREATER THAN REQUIRED,
C                 MODIFY IT TO SUIT.
C
      PSPPLY=PIPOPT
C
C                 DEFINE TOTAL MILLBROOK SUPPLY
C
      DEMMIL=PSPPLY+TRAN
      RETURN
      END
>
```

```
C     SUBROUTINE BARGR IS RESPONSIBLE FOR DRAWING AND MODIFYING ALL
C     STORAGE GRAPHS ON THE SCREEN.
C                         _000_
C
      SUBROUTINE BARGR(STOR,S,IMON)
C
      COMMON/STORDAT/PRSTOR(12),STRMAX(12),STMAX(12),STMIN(12),
     * MAXFIN(12),MINFIN(12),FRAC,CSTKL1,FRACTN,COSTKL
     * /CORDAT/ISYS,MINRES,MAXRES,IPRVW
     * /SETUP/IBAR,ICALC,SMAX(6),XMIN(12),YMIN(12),YMAX(12),ICOUNT,
     * ISTRT,MYP,NOTRAN,MLLBRK,LPARA,SPARA,IXS
     * /BAR/YGR(12),AMIN(12),AMAX(12)
C
      LOGICAL*1 STRNG(10),NUM(6),IBAR(6),ICALC(6),IFLAG,MLLBRK,
     * ISTRT,MYP,NOTRAN,LPARA,SPARA
C
      DIMENSION S(12,12),STOR(12,2)
C
      INTEGER*4 ISTRMX,IST,ISTMAX,ISTMIN
C
      DATA Y,YT/500.,300./
     * STRNG,NUM/10*0.,6*0/
C
C             CHECK WHETHER THE GRAPHS HAVE BEEN ALREADY DRAWN
C
      IF(IBAR(ISYS).EQ.1)GOTO10
C
C             DEPENDING ON THE NUMBER OF STORAGES IN THE SYSTEM,CHOOSE
C             THE STARTING X-COORDINATE FOR THE GRAPHS
C
      GOTO(1,2,3,1,2,1),ISYS
1     X=610.
      GOTO4
2     X=550.
      GOTO4
3     X=685.
4     SMAX(ISYS)=0.
C
C             FIND THE LARGEST STORAGE.THIS WILL BE THE REFERENCE VALUE
C
      DO 5 NRES=MINRES,MAXRES
5     IF(STRMAX(NRES).GT.SMAX(ISYS)) SMAX(ISYS)=STRMAX(NRES)
C
C             SET UP THE STANDARD GRAPH SPACING
C
      X1=225.
      Y1=63.
C
10    IREDUC=0
      ISUBP=ISYS*1000
      IF(IBAR(ISYS).EQ.1)GOTO11
C
      CALL DISPLY(-1)
      CALL SUBP(ISUBP)
      CALL OFF(ISUBP)
C
C             SET UP PREVIEW INDICATOR.
C
      CALL SUBP(ISUBP+20)
      CALL OFF(ISUBP+20)
      CALL APNT(170.,860.,,,-3,1)
      CALL TEXT(-2,'PREVIEW MODE')
      CALL ESUB(ISUBP+20)
C
```

```
C                  DRAW TRANSFER INDICATOR.
C
        IF(ISYS.EQ.4)GOTO11
        IF(ISYS.NE.3)GOTO101
        CALL SUBP(3022)
        CALL OFF(3022)
        CALL APNT(170.,830.,,-3,-1)
        CALL TEXT(-2,'MILLBROOK SUPPLIES ANSTEY HILL')
        CALL ESUB(3022)
        GOTO11
101     CALL APNT(170.,830.,,-3,-1)
        CALL TEXT(-2,'LAST TRANSFER=')
        CALL APNT(370.,830.,,-3,-1)
        CALL NMBR(ISUBP+21,0.,6,'(F6.0)')
C
C              SET UP THE DRAWING LOOP FOR THE GRAPHS.IT ALSO CONTROLS
C              THE ADJUSTMENT OF EXISTING GRAPHS.
C
11      DO 200 NRES=MINRES,MAXRES
C
C              SINCE WEIRS ARE NOT INCLUDED IN THE SCREEN FORMAT,THEY
C              DO NOT NEED TO BE DRAWN
C
        IF(STRMAX(NRES).EQ.0.)GOTO200
C
C              IF IPRVW IS IN 'ACCEPT' OR 'REVERT' MODE,USE ACTUAL
C              RATHER THAN PREDICTED DATA
C
D       WRITE(10,1100) NRES,S(IMON,NRES)
D1100   FORMAT(2X,'NRES',I4,'S(IMON,NRES)',F7.0)
        IF(IPRVW.LE.0.OR.IBAR(ISYS).NE.1)GOTO13
C
C              IF NO PREDICTIVE DATA HAS BEEN GENERATED,AS IN THE CASE
C              OF THE OPERATOR SPECIFIED STORAGES,SKIP THE ASSIGNMENTS
C
        IF(S(IMON,NRES).NE.0.)GOTO12
        B=STMIN(NRES)
        C=STMAX(NRES)
12      A=PRSTOR(NRES)
        GOTO15
13      IF(S(IMON,NRES).NE.0.)GOTO14
        B=STMIN(NRES)
        C=STMAX(NRES)
14      A=STOR(NRES,1)
15      IF(S(IMON,NRES).NE.0.)GOTO16
        MX=MAXFIN(NRES)
        MN=MINFIN(NRES)
        AMAX(NRES)=C*300./SMAX(ISYS)
        AMIN(NRES)=B*300./SMAX(ISYS)
C
C              IF THE GRAPHS ARE ALREADY DRAWN DO NOT RECALCULATE THEIR
C              COORDINATES
C
16      IF(IBAR(ISYS).EQ.1)GOTO17
        YMAX(NRES)=300.*STRMAX(NRES)/SMAX(ISYS)
        XMIN(NRES)=X-(NRES-MINRES-IREDUC)*X1
        YMIN(NRES)=Y-(NRES-MINRES-IREDUC)*Y1
17      YGR(NRES)=YMAX(NRES)*A/STRMAX(NRES)
C
C              IF THE GRAPHS ARE ALREADY DRAWN,SUBPICTURES DO NOT NEED
C              TO BE DEFINED
C
        IPIC=ISUBP+(NRES+1-MINRES-IREDUC)*100
        IF(IBAR(ISYS).EQ.1)GOTO150
C
C              NOW DEFINE THE GRAPHS FOR EACH RESERVOIR
```

```
C
         CALL BAR(IPIC,NRES,S(IMON,NRES))
C
         CALL POINTR(1,IPIC,2)
         GOTO(20,30,40,50,60,70),ISYS
20       CALL CHANGT(1,'MYPONGA')
         GOTO100
30       GOTO(31,32),(NRES+1)-(MINRES+IREDUC)
31       CALL CHANGT(1,'MOUNT BOLD')
         GOTO100
32       CALL CHANGT(1,'HAPPY VALLEY')
         GOTO100
40       GOTO(41,42,43),(NRES+1)-(MINRES+IREDUC)
41       CALL CHANGT(1,'MILLBROOK')
         GOTO100
42       CALL CHANGT(1,'KANGAROO CRK')
         GOTO100
43       CALL CHANGT(1,'HOPE VALLEY')
         GOTO100
50       CALL CHANGT(1,'WARREN')
         GOTO100
60       GOTO(61,62),(NRES+1)-(MINRES+IREDUC)
61       CALL CHANGT(1,'SOUTH PARA')
         GOTO100
62       CALL CHANGT(1,'BAROSSA')
         GOTO100
70       CALL CHANGT(1,'LITTLE PARA')
100      CONTINUE
C
C                 THIS SECTION OF THE PROGRAM FILLS IN THE NUMERICAL TITLES
C                 IN THE SUBPICTURE,AND ALSO MODIFIES GRAPH LEVELS WHEN
C                 NECESSARY
C
150      GALL POINTR(1,IPIC,6)
         IF(IBAR(ISYS).EQ.1)GOTO152
         ISTRMX=JINT(STRMAX(NRES))
         ENCODE(5,151,NUM) ISTRMX
151      FORMAT(I5)
         CALL CHANGT(1,NUM)
         IF(IBAR(ISYS).EQ.0)GOTO153
152      CALL ADVANC(1,4)
         CALL CHANGE(1,XMIN(NRES),YGR(NRES)+YMIN(NRES))
         CALL ADVANC(1,3)
         GOTO154
153      CALL ADVANC(1,7)
154      IST=JINT(A)
         ENCODE(5,151,NUM) IST
         CALL CHANGT(1,NUM)
         IF(S(IMON,NRES).NE.0.)GOTO200
         IF(IBAR(ISYS).EQ.1)GOTO155
         CALL ADVANC(1,2)
         GOTO156
155      CALL POINTR(1,IPIC,21)
         CALL CHANGE(1,0.,AMAX(NRES)-AMIN(NRES))
         CALL POINTR(1,IPIC,14)
         CALL CHANGE(1,XMIN(NRES)+55.,YMIN(NRES)-25.+AMIN(NRES))
         CALL ADVANC(1,4)
         CALL CHANGE(1,XMIN(NRES)+55.,YMIN(NRES)+AMIN(NRES))
         CALL POINTR(1,IPIC,15)
156      ISTMIN=JINT(B)
         ENCODE(5,151,NUM) ISTMIN
         CALL CHANGT(1,NUM)
         CALL ADVANC(1,2)
         CALL MNTH(MN,STRNG)
         CALL CHANGT(1,STRNG)
         CALL ADVANC(1,8)
```

```
        ISTMAX=JINT(C)
        ENCODE(5,151,NUM) ISTMAX
        CALL CHANGT(1,NUM)
        CALL ADVANC(1,2)
        CALL MNTH(MX,STRNG)
        CALL CHANGT(1,STRNG)
C
C               IF NOT A RESERVOIR ,INCREMENT IREDUC
C
200     IF(STRMAX(NRES).EQ.0.)IREDUC=IREDUC+1
C
        IF(IABS(IPRVW).EQ.1)GOTO201
        FRAC=FRACTN
        CSTKL1=COSTKL
201     IF(FRAC.GT.1.)FRAC=1.
        YFRAC=FRAC*300.
        CALL NMBR(91,CSTKL1,5,'(F5.2)')
        CALL POINTR(1,90,15)
        CALL CHANGE(1,0.,YFRAC)
        CALL NMBR(93,(FRAC*100.),4,'(F4.0)')
        IF(IBAR(ISYS).EQ.1)GOTO300
C
C               THE FOLLOWING SECTIONS OF CODE FILL IN THE GAPS ON THE
C               SCREEN TO GIVE A SCHEMATIC REPRESENTATION OF EACH
C               SUBSYSTEM.
C
        GOTO(1000,2000,3000,4000,5000,6000),ISYS
C
C               MYPONGA
C
1000    CALL APNT(XMIN(1)+25.,YMIN(1),,-3,,1)
        CALL LVECT(-70.,-150.,,3)
        CALL LVECT(-85.,-15.)
        CALL LVECT(-135.,0.,,-3)
        CALL TEXT(-2,'HINDMARSH')
        CALL LVECT(-126.,-25.,,-3)
        CALL TEXT(-2,'VALLEY')
        CALL LVECT(126.,40.,,-3)
        CALL LVECT(-120.,30.,,3)
        CALL SVECT(-60.,0.)
        CALL LVECT(-175.,0.,,-3)
        CALL TEXT(-2,'MYPONGA W.D.')
        CALL LVECT(67.,0.,,-3)
        CALL LVECT(-50.,90.,,3)
        CALL CROSS(1006)
        CALL MENU(420.,470.,-25.,1001,'OPEN','SHUT')
        CALL LVECT(-228.,25.,,-3)
        CALL TEXT(-2,'CHRISTIES')
        CALL LVECT(-126.,-25.,,-3)
        CALL TEXT(-2,'DOWNS')
        CALL LVECT(66.,25.,,-3)
        CALL LVECT(0.,200.)
        CALL SUBP(1005)
        CALL LVECT(-84.,5.,,-3)
        CALL TEXT(-2,'HAPPY VALLEY')
        CALL ESUB(1005)
        CALL ESUB(ISUBP)
        GOTO300
C
C               ONKAPARINGA
C
2000    CALL APNT(XMIN(2)+25.,YMIN(2),,-3,,1)
        CALL LVECT(50.,-125.,,3)
        CALL CROSS(200)
        CALL LVECT(50.,-125.)
        CALL LVECT(-100.,250.,,-3)
```

```
      CALL SVECT(-50.,-50.,,3)
      CALL LVECT(-100.,-50.)
      CALL RPNT(-56.,-25.,,-3)
      CALL TEXT(-2,'CLARENDON')
      CALL LVECT(-126.,-25.,,-3)
      CALL TEXT(-2,'WEIR')
      CALL RPNT(0.,50.,,-3)
      CALL SVECT(-50.,37.,,,,3)
      CALL RPNT(-25.,0.,,-3,,1)
      CALL LVECT(0.,-100.,,3)
      CALL CROSS(1007)
      CALL LVECT(-135.,0.,,-3)
      CALL TEXT(-2,'CHRISTIES')
      CALL LVECT(-126.,-25.,,-3)
      CALL TEXT(-2,'DOWNS')
      CALL LVECT(65.,25.,,-3)
      CALL SVECT(15.,-35.,,3)
      CALL SVECT(-28.,-25.,,-3)
      CALL TEXT(-2,'FROM')
      CALL LVECT(-77.,-25.,,-3)
      CALL TEXT(-2,'MYPONGA')
      CALL LVECT(-64.,185.,,-3)
      CALL SVECT(-15.,-50.,,3)
      CALL LVECT(-75.,0.)
      CALL LVECT(-90.,0.,,-3)
      CALL TEXT(-2,'DEMAND')
      CALL ESUB(ISUBP)
      GOTO300
C
C                TORRENS
C
3000  CALL APNT(XMIN(6)+25.,YMIN(6),,-3)
      CALL LVECT(-27.,-133.,,3,,3)
      CALL LVECT(-14.,-67.,,,,1)
      CALL CROSS(300)
      CALL SVECT(-14.,-50.)
      CALL LVECT(-112.,92.,,-3)
      CALL TEXT(-2,'GUMERACHA')
      CALL LVECT(-60.,-25.,,-3)
      CALL TEXT(-2,'WEIR')
      CALL LVECT(18.,50.,,-3)
      CALL LVECT(-158.,10.,,3)
      CALL SVECT(-15.,60.)
      CALL LVECT(200.,63.,,-3)
      CALL SVECT(-30.,-60.,,3)
      CALL LVECT(-155.,-63.)
      CALL APNT(XMIN(7)+25.,YMIN(7),,-3)
      CALL LVECT(-135.,-135.,,3)
      CALL RPNT(-28.,-25.,,-3)
      CALL TEXT(-2,'GORGE')
      CALL LVECT(-70.,-25.,,-3)
      CALL TEXT(-2,'WEIR')
      CALL RPNT(-28.,50.,,-3)
      CALL LVECT(-65.,75.,,3,,3)
      CALL RPNT(-25.,0.,,-3)
      CALL SVECT(-15.,-50.,,3,,1)
      CALL LVECT(-42.,-25.,,-3)
      CALL TEXT(-2,'DEMAND')
      CALL ESUB(ISUBP)
      GOTO300
C
C                WARREN
C
4000  CALL APNT(XMIN(9)+25.,YMIN(9),,-3,,1)
      CALL LVECT(13.,-80.,,3)
      CALL CROSS(400)
```

```
      CALL LVECT(7.,-45.)
      CALL RPNT(-28.,-30.,,-3)
      CALL TEXT(-2,'FROM')
      CALL LVECT(-133.,-30.,,-3)
      CALL TEXT(-2,'MANNUM-ADELAIDE')
      CALL LVECT(-168.,-30.,,-3)
      CALL TEXT(-2,'PIPELINE:')
      CALL LVECT(-88.,215.,,-3)
      CALL LVECT(-180.,-80.,,3)
      CALL SVECT(0.,-30.)
      CALL CROSS(501)
      CALL SVECT(0.,-30.)
      CALL RPNT(-14.,-30.,,-3)
      CALL TEXT(-2,'TO')
      CALL LVECT(-84.,-30.,,-3)
      CALL TEXT(-2,'SOUTH PARA')
      CALL LVECT(-70.,120.,,-3)
      CALL LVECT(-60.,100.,,3)
      CALL SVECT(-50.,0.)
      CALL LVECT(-126.,30.,,-3)
      CALL TEXT(-2,'NORTHERN')
      CALL LVECT(-98.,-30.,,-3)
      CALL TEXT(-2,'DEMAND')
      CALL LVECT(-63.,-30.,,-3)
      CALL TEXT(-2,'AND')
      CALL LVECT(-91.,-30.,,-3)
      CALL TEXT(-2,'WARREN W.D.')
      CALL LVECT(36.,60.,,-3)
      CALL LVECT(-30.,150.,,3)
      CALL LVECT(-70.,60.,,-3)
      CALL TEXT(-2,'SWAN REACH')
      CALL LVECT(-119.,-30.,,-3)
      CALL TEXT(-2,'PUMPING')
      CALL ESUB(ISUBP)
      GOTO300
C
C              SOUTH PARA
C
5000  CALL APNT(XMIN(10)+25.,YMIN(10),,-3,,1)
      CALL LVECT(50.,-125.,,3)
      CALL CROSS(500)
      CALL LVECT(50.,-125.)
      CALL LVECT(-100.,250.,,-3)
      CALL LVECT(-175.,-125.,,3)
      CALL RPNT(-42.,-25.,,-3)
      CALL TEXT(-2,'BAROSSA')
      CALL LVECT(-98.,-25.,,-3)
      CALL TEXT(-2,'WEIR')
      CALL RPNT(-14.,50.,,-3)
      CALL SVECT(-25.,60.,,,,3)
      CALL RPNT(-25.,0.,,-3)
      CALL SVECT(-50.,-50.,,3,,1)
      CALL SVECT(-60.,0.)
      CALL ESUB(ISUBP)
      GOTO300
C
C              LITTLE PARA
C
6000  CALL APNT(XMIN(12)+25.,YMIN(12),,-3,,1)
      CALL LVECT(20.,-125.,,3)
      CALL CROSS(600)
      CALL LVECT(20.,-125.)
      CALL LVECT(-40.,250.,,-3)
      CALL LVECT(-100.,-50.,,3)
      CALL LVECT(-140.,-70.)
      CALL LVECT(-160.,0.,,-3)
```

```
        CALL TEXT(-2,'GROUNDWATER')
        CALL LVECT(-154.,-25.,,-3)
        CALL TEXT(-2,'RECHARGE')
        CALL LVECT(188.,95.,,-3)
        CALL LVECT(-140.,70.,,3)
        CALL LVECT(-90.,0.,,-3)
        CALL TEXT(-2,'DEMAND')
        CALL ESUB(ISUBP)
C
C                NOW TURN ON THE WHOLE SUBPICTURE
C
300     CALL DISPLY(0)
        IBAR(ISYS)=1
        RETURN
        END
>
```

```
C     SUBROUTINE BAR: USED TO SET UP ALL BAR GRAPHS USED IN THE GRAPHICS
C
      SUBROUTINE BAR(IPIC,NRES,S)
C
      COMMON /SETUP/IBAR,ICALC,SMAX(6),XMIN(12),YMIN(12),YMAX(12),
     * ICOUNT,ISTRT,MYP,NOTRAN,MLLBRK,LPARA,SPARA,IXS
     * /BAR/YGR(12),AMIN(12),AMAX(12)
C
      LOGICAL*1 IBAR(6),ICALC(6),IFLAG,ISTRT,MYP,NOTRAN,MLLBRK,
     * LPARA,SPARA
C
      CALL SUBP(IPIC)
C
C             SET UP TITLE BLOCK
C
      CALL APNT(XMIN(NRES)-50.,YMIN(NRES)+50.+YMAX(NRES),,-3,-1)
      CALL TEXT('0000000000000')
C
C             DRAW BAR ELEMENT
C
      CALL APNT(XMIN(NRES),YMIN(NRES),,,,1)
      CALL LVECT(0.,YMAX(NRES),,3)
      CALL LVECT(-70.,0.,,-3)
      CALL TEXT('00000')
      CALL SVECT(50.,0.,,3)
      CALL LVECT(0.,-YMAX(NRES))
      CALL SVECT(-50.,0.)
C
C             INSERT LEVEL INDICATOR AT CURRENT STORAGE
C
      CALL APNT(XMIN(NRES),YGR(NRES)+YMIN(NRES),,-3)
      CALL SVECT(50.,0.,,3,,3)
      CALL LVECT(-125.,-25.,,-3)
C
C             SET STORAGE BLOCK
C
      CALL TEXT('00000')
      IF(S.NE.0)GOTO149
C
C             SET UP END OF YEAR STORAGE INDICATORS ON THE RIGHT OF
C             THE BAR
C
      CALL APNT(XMIN(NRES)+55.,YMIN(NRES)-25.+AMIN(NRES),,-3)
C
C             LOWER STORAGE BLOCK
C
      CALL TEXT('00000')
      CALL VECT(-70.,-25.,,-3)
C
C             MONTH OF OCCURRENCE BLOCK
C
      CALL TEXT('0000000')
C
C             DRAW CONNECTED LEVELS
C
      CALL APNT(XMIN(NRES)+55.,YMIN(NRES)+AMIN(NRES),,-3)
      CALL SVECT(50.,0.,,3)
      CALL RPNT(-25.,0.,,-3)
      CALL LVECT(0.,AMAX(NRES)-AMIN(NRES),,3)
      CALL RPNT(25.,0.,,-3)
      CALL SVECT(-50.,0.,,3)
      CALL RPNT(0.,5.,,-3)
C
```

```
C               UPPER STORAGE BLOCK
C
        CALL TEXT('00000')
        CALL LVECT(-70.,25.,,-3)
C
C               MONTH OF OCCURRENCE BLOCK
C
        CALL TEXT('0000000')
149     CALL ESUB(IPIC)
C
        RETURN
        END
>
```

```
C     SUBROUTINE CROSS:USED TO SIGNIFY A VALVE ON THE SCHEMATICS.
C             EACH USAGE IS A DIFFERENT SUBPICTURE.
C
      SUBROUTINE CROSS(IT)
C
      CALL SUBP(IT)
      CALL SVECT(12.,12.,,1)
      CALL RPNT(0.,-24.,,-1)
      CALL SVECT(-24.,24.,,1)
      CALL RPNT(0.,-24.,,-1)
      CALL SVECT(12.,12.,,1)
      CALL ESUB(IT)
C
      RETURN
      END
```

BIBLIOGRAPHY

1. ENGINEERING AND WATER SUPPLY DEPARTMENT,
SOUTH AUSTRALIA.
"Metropolitan Adelaide Water Resources Study"
Vol I and II.
Lib. Ref. E.W.S. 77/42, June 1978.

2. DIGITAL EQUIPMENT CORPORATION.
Decgraphic - 11 FORTRAN programming manual March 1978.
Order No. AA-5428C-TC.

3. SIGVALDASON, O.T.
"Models for scheduling releases from multi-reservoir systems : a state of the art review".
Environmental Aspects of Irrigation and Drainage.
PPS from the Conf. 21-23 July, 1976, pp 331-48.

4. MAIDMENT, D.R.
"Water resources control through systems analysis".
Water Supply and Management, Vol. 2., p 243-251.
Pergamon Press Ltd. 1978.

5. CROLEY, T.E. II
"Sequential deterministic optimisation in reservoir operation".
Journal of the Hydraulics division (ASCE)
Vol. 100, No. 3, March 1974, p 443 +.

6. SINGH, V.P., MAHMOOD, K.
"Computer modelling in water resource systems".
Summer computer simulation conference, Los Angeles, CA, USA, 24-26 July, 1978. Proceedings pp 575-83.

7. KISIEL, C.C.
"Objective function and constraints in water resources systems".
Mathematical Models in Hydrology, Proceedings of the Warsaw symposium, Poland, July 1971 (session XV)
IAHS/UNESCO, Paris, France, 1974, Vol. 3. 1974
pp 1283-1299.

8. CROLEY, T.E. II
"Sequential stochastic optimisation for reservoir systems".
Journal of the hydraulics division (ASCE), Vol. 100, No. 1, January 1974, pp 201-219.

9. ROHDE, F.G. NAPARAXAWONG, K.
"Modified standard operation rules for reservoirs".
Water for Survival. Journal of Hydrology Vol. 51, 1981
L.R. Beard (Guest Editor) pp 169-177.

10. CHOW, V.T.
"Optimal operation of water resources systems - I"
Mathematical Models in Hydrology, Proceedings of the Warsan Symposium, Poland, July 1971 (session XVI)
Vol. 3 1974, pp 1300-1312.

11. LOUCKS, D.P.
"Surface - water quantity management models"
Systems approach to Water Management.
McGraw-Hill. New York. 1976 (Ed:Asit K. Biswas)
p 156-218 (chapter 5).

12. ASKEW, A.J., GYEH, W.A., HALL, W.A.
"Optimal design and operation of reservoir systems"
Mathematical Models in Hydrology, Proceedings of the Warsaw Symposium, Poland, July 1971.
IAHS/UNESCO, Paris, France, 1974.
Vol. 2, 1974, pp 942-949.

13. HARBOE, R. and SCHULTZ, G.A.
"Applications of simulation to specific water projects"
Water for Survival. Journal of Hydrology Vol. 51, pp 131-138.
L.R. Beard (Guest editor) 1981.

14. KISIEL, C.C.
"Objective function and constraints in water resources systems".
Mathematical Models in Hydrology, Proceedings of the Warsaw Symposium, Poland, July 1971.
IAHS/UNESCO, Paris, France, 1974.
Vol. 3, 1974, pp 1283-1299.

15. HALL, W.A.
"Risk and uncertainty as objectives in water resources".
Stochastic approaches to water resources, vol. 1.
Edited and published by H.W. Shen, Colorado State University, Fort Collins, Col., CH8 p 8.1-8.13, 1976.

16. HAIMES, Y.Y., HALL, W.A.
"Sensitivity, responsivity, stability and irreversibility as multiple objectives in civil systems".
Advances in water resources, Vol. 1., No. 2., December 1977, pp 71-81.

17. NAZAR, A.M., HALL, W.A., ALBERTSON, M.L.
"Risk avoidance objective in Water Resources".
Journal of the water resources planning and management division (ASCE). Vol. 107. No. WR1 March 1981, pp 201-209.

18. MOREL-SEYTOUX, H.J.
"Optimisation and Uncertainty:
Stochastic approaches to water resources. Vol. 1
Edited and published by H.W. Shen, Colorado State University, Fort Collins, Col., CH9, p 9.1-9.37 1976.

19. HAITH, D.A., LOUCKS, D.P.
"Multi-objective water resources planning"
Systems approach to Water Management
McGraw-Hill. New York. 1976 (Ed: Asit K. Biswas)
p 365-397 (chapter 10).

20. BEESON, R.M., MEISEL, W.S.
"The Optimisation of complex systems with respect to Multiple Criteria"
1971 IEEE SYSTEMS, MAN & CYBERNETICS GROUP Annual Symposium Record, p 144-149. October 1971.

21. CROLEY, T.E., RAJA RAO, K.N.
"Multi-purpose reservoir operation using stochastic trade-off analysis"
Stochastic processes in water resources engineering. Proceedings, 2nd international IAHR Symposium on Stochastic hydraulics, Lund Institute of Technology, Sweden, August 1976. Ed: Lars Gottschalk et al. Water Resources Publications, Fort Collins, Colorado, 1977, p 483-513 (chapter 24).

22. NEUMAN, S.P., KRZYSZTOFOWICZ, R.
"An iterative algorithm for interactive multi-objective programming".
Advances in Water Resources Vol. 1 No. 1, September 1977, pp 1-14.

23. COHON, J.L., MARKS, D.H.
"A review and evaluation of multi-objective programming techniques".
Water resources research, Vol. 11, No. 2, p 208-20 April 1975.

24. HAIMES, Y.Y., MACKO, D.
"Hierarchical Structures in water resources systems management".
I.E.E.E. Trans, Syst., Man & Cybern. (USA) Vol. smc-3, No. 4, p 396-402. July 1973.

25. HAIMES, Y.
"Hierarchical modelling of regional total water resources".
Automatica (GB), Vol. 11, No. 1, p 25-36.
January 1975.

26. BONAZOUNTAS, M., CAMBOULIVES, J.M.
"Multi-decision analysis for large-scale river basin reservoir systems".
L.R. Beard (Guest Ed.) Water for survival.
Journal of Hydrology, Vol. 51, 1981. p 139-149.

27. NAMIS, W.S., HAIMES, Y.Y.
"A multi-level approach to planning for capacity expansion in water resources systems".
International Conference on Cybernetics and Society, Washington, D.C. Proceedings. New York. USA
I.E.E.E. 1972. October 9-12. 1972. pp 311-318.

28. HERATH, A.F., CHONG, P.S.
"Security and augmentation decision criteria in a complex water resources system".
Pre-print, Civil Engineering Transactions 1980
Institution of Engineers, Australia.

29. MAIDMENT, D.R.
"Water resources control through systems analysis".
Water supply and management, Vol. 2, pp 243-251.
Pergamon Press Ltd. 1978.

30. COLE, J.A.
"Optimal seasonal and short term operation of a reservoir used for flood control and water supply".
Mathematical models in hydrology, proceedings of the Warsaw symposium, Poland, July, 1971
IAHS/UNESCO, Paris, France, 1974, p 978-988.

31. WILKINSON, J.C., SMITH, D.K.
"Designing simulation models for optimisation studies".
Modelling and Simulation of Water Resources Systems.
Computer Simulation of Water Resources Systems,
Proceedings of the IFID working conference 1974.
G.C. Vansteenkiste (Ed.)
North-Holland 1975. pp 167-175.

32. HYDROLOGIC ENGINEERING CENTRE
"Reservoir system analysis for conservation".
Hydrologic Engineering Methods for Water Resources Development. Vol. 9. June 1977.
Hydrologic Engineering Centre, Corps of Engineers, US Army.

33. TOEBES, G.H., RUKVICHAI, C.
"Reservoir system operating policy - Case Study".
Journal of the water resources planning and management division (ASCE) Vol. 104, No. WR1,
P 175-191, November 1978.

34. FORD, R.
"Simulation and optimisation oif water resource development".
Institution of Engineers, Australia.
National Conference Publication No. 74/1.
(Computers in Engineering, Sydney) 16-17 May 1974
pp 64-68.

35. ASHKANASY, N.M.
"Recursive programming, a practical application".
6th Australian Computer Conference, Sydney,
(Australian computer society 1975) 20-24 May 1974,
Vol. 1, pp 192-202.

36. BEARD, L.R.
"Models for optimising the multi-purpose operation of a reservoir system".
Application of mathematical models in hydrology and water resources systems, Proceedings of the Bratislava symposium, Czechoslovakia, September, 1975.
IAHS-AISH publication No. 115 1975, pp 13-21.

37. HYDROLOGIC ENGINEERING CENTRE
"HEC-3. Reservoir System Analysis".
Hydrologic Engineering Centre Computer Program
723-X6-L2030.
Hydrologic Engineering Methods for Water Resources Development. Volume 1.
Requirements and General Procedures, October 1971.

38. McMAHON, G., BONNER, V., EICHERT, W.
"Operational simulation of a reservoir system with a pumped storage".
United States Army Corps of Engineers
Hydrologic Engineering Centre
Technical Paper No. 60.
February 1979.

39. LENTON, R.L., STRZEPEK, K.M.
"Theoretical and practical characteristics of the M.I.T. River Basin simulation model".
Ralph M. Parsons laboratory for water resources and hydrodynamics.
Department of Civil Engineering
Massachusets Institute of Technology Report 225,
August 1977.

40. FRANKHAUSER, C.G., KIDWELL, R.H.
"Interactive computer graphics, a simulation tool"
1971, I.E.E.E. Systems, Man and Cybernetics group annual symposium record, p 174-179. October 1971.

41. HURRION, R.D., SECKER, R.J.R.
"Visual interactive simulation. An aid to decision making". Omega (GB), vol. 6, No. 5, p 419-26. 1978.

42. MILLER, G.A.
"The magical number seven, plus or minus two: Some limits on our capacity for processing information".
The Psychological Review, Vol. 63, No. 2, March 1956 pp 81-97.

43. DAVID, E.E.
"Physiological and psychological considerations".
On-line computing. Editor: W.J. Karplus
McGraw-Hill 1967, pp 107-128.

44. MILLER, R.B.
"Response time in Man-Computer Conversational Transactions".
Fall Joint Computer Conference, 1968. Proceedings, AFIPS Vol. 33, part 1, pp 267-277.

45. HANSON, W.J.
"User engineering principles for interactive systems".
Fall Joint Computer Conference, 1971. Proceedings, AFIPS, Vol. 39, pp 523-532.

46. MARTIN, J.
"Design of Man-Computer Dialogues".
Englewood Cliffs N.J.: Prentice Hall, 1973.

47. FOLLEY, J.D., WALLACE, V.L.
"The art of natural graphic Man-Machine Conversation".
Proceedings of the I.E.E.E. Vol. 62, No. 4, April 1974, pp 462-471.

48. SPENCE, R.
"Human factors in interactive graphics".
Computer Aided Design. Vol. 8, No. 1, January 1976. pp 49-53.

49. SIMANIS, A.
"Human factors at the graphics interface".
10th Annual symposium on the interface, Gaithersburg, MD, USA.
Computer Science and Statistics.
(Washington, D.C., USA : Nat. Bur. Standards 1978), 14-15 April 1977, pp 122-130.

50. HERDA, S., DZIDA, W., ITZFELDT, W.D.
"User perceived quality of Interactive Systems".
Software Engineering.
PPS. Pres. At the 3rd INTL Conference, I.E.E.E. Computer Soc.
Ca. USA. 10-12 May, 1978, pp 188-195.

51. SCHNEIDERMAN, B.
"Human factors experiments in designing interactive systems".
Computer : December 1979, pp 9-19.

52. NEWMAN, W.M., SPROULL, R.F.
"Principles of Interactive Computer Graphics".
McGraw-Hill 1979. 2nd Edition.

53. LOUCKS, D.P., HAITH, D.A.
"Multi-objective water resources planning".
Systems approach to Water Management.
McGraw-Hill. New York, 1976. (Ed: Asit. K. Biswas) p 365-397 (chapter 10).

54. FRENCH, P.N., JOHNSON, L.E., LOUCKS, D.P., GREENBERG, D.P.
"Water Resources planning using Computer Graphics".
Journal of the Water Resources planning and Management division A.S.C.E. WR1. March 1980.
p 21-42.

55. SHAFER, J.M.,
"An interactive river basin water management model: synthesis and application".
Colorado Water Resources Research Inst., Fort Collins.
August 1979.

56. ABRAHAM, C.E.
"Computer use for river regulation".
Journal of the hydraulics division (ASCE).
Vol. 101, No. 2, February 1975, pp 291-297.