NATIONAL WATER AND SOIL CONSERVATION ORGANISATION

A PRACTICAL GUIDE TO THE PREPARATION OF WATER ALLOCATION PLANS

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CONTENTS

PREAMBLE

The purpose of this document is two-fold:-

1. As an aide-memoire in conducting water resources studies;
2. More importantly, as an aid in progressing from water resources studies to the preparation of water allocation plans. It does not aim to promote a series of stereotyped plans, rather it is a guide to the preparation of a plan for a particular catchment which must be treated on its own merits.

The rationale behind its production is as follows:

Demand for water is rising, especially with substantial increases in the use of water for irrigation planned, and the resulting increases in abstractions are being drawn - and will probably continue to be drawn - from the same sources. Hence, given the time-variant nature of water flows, there will be periods when the available water in a catchment will be inadequate to meet all demands in full. The only exception to this is the case of a small demand being met from a large and reliable resource, when the total peak demand is somewhat less than the lowest known water flow. (Throughout this document, the term "demands" includes the demands of recreation, fish and wildlife).

There are two basic approaches in dealing with this situation. The simplest is to do nothing except to take emergency action in the form of the imposition of restrictions, whenever necessary, under Section 24E of the Water and Soil Conservation

Act 1967. The possibility of taking this approach as a matter of policy should not be forgotten, in some cases it would be the most suitable approach. An example is where a serious shortage of water occurs infrequently and, when it does occur, is of short duration. Under more severe conditions, however, when the resource is already inadequate for protracted periods or at some time during most years, a more sophisticated approach would be preferable. In the latter case, a plan should be prepared in advance to enable a fair and rational division of the catchment water amongst the competing demands - in short, a water allocation plan. This is more fully defined and discussed in Chapter 4.

It should be noted that development and augmentation of the resource is complementary to, not an alternative course of action to, the production of a water allocation plan, for two reasons. Firstly, a water allocation plan can be prepared and put into action more quickly than a resource can be developed or augmented. In any case, the data and information needed to assess how far to develop the resource can be used in the formulation of the water allocation plan. Secondly, it is not an economic proposition to develop a resource sufficiently to meet the very severe drought of infrequent occurrence. Therefore, although development of the resource may reduce the frequency of occurrence of water shortages and their severity, it will not eliminate them: a water allocation plan will therefore still be necessary after development. In any event a water allocation plan will form the basis of an economic study of the desirability of resource development and augmentation.

The structure of this document follows the four steps necessary to produce a water allocation plan for a catchment, one chapter being devoted to each step. These steps are:

1. Collection and presentation of water resources data. This may include both surface and underground water resources in the catchment.

2. Determination of existing use. The demands represented by recreation, fish and wildlife aspects should be included. Using the data gathered in step 1, the frequency of occasions when the resource cannot meet existing demands can be calculated and stated.

3. Assessment of future use. Again, using the data gathered in step 1, the frequency of failure of the resource to meet the estimated level of demand at any specified time in the future can be stated.

4. Formuation of a water allocation plan. Based on the results of the previous steps, a water allocation plan may be formulated. A worked example is given to indicate one possible way of preparing and presenting a water allocation plan.

In all these four steps, contact with groups and individuals with an interest on the allocation and use of water should be encouraged. Also it is desirable to obtain public discussion and comment on a preliminary allocation plan to enable all interests to make representations as is done with the water classification procedure. In this respect it would be desirable to have the results of step 1, and possibly step 2, in a published form to provide a basis for discussion in the planning stage. The objective is to arrive at an allocation plan which is publicly acceptable. From the plan intending users should be able to gauge the impact of the degree and frequency of restrictions on their proposed developments. The plan should clearly state what these restrictions will be for new users.

An appendix has been included to include future developments and flood studies in water allocation planning.

It should be constantly borne in mind that each resource will need to be dealt with on its merits. Thus, some resources will require very detailed and sophisticated water allocation plans; in other cases, a simpler approach will suffice. There is usually enough prior knowledge regarding the extent and reliability of the resource and the extent of the demands upon it to indicate how extensive and detailed the necessary investigations will need to be.

A list of references on water allocation planning is available from the Director of Water and Soil Conservation. These references are held in the Water and Soil Division and the Ministry of Works and Development Central Library and are available on request.

CHAPTER 1

COLLECTION AND PRESENTATION OF WATER RESOURCES DATA

This chapter comments on the collection of water resources data and outlines some ways in which the data might be presented in a water resources report. It does not purport to be more than a "memory-jog" for those responsible for water resources studies. Consultation with agencies other than the Ministry of Works and Development will be required (e.g. Meterological Office, Ministry of Agriculture and Fisheries, etc.)

1.1 Collection of data

The techniques of collection of water resources data have been expounded in numerous texts and further elaboration is not required here. The /object is to acquire sufficient accurate, consistent and unbiased (i.e., statistically acceptable) data to enable the total water resources to be determined and documented, and hence to enable the production of a water allocation plan. An important section of this part of the report should deal critically with the identification of gaps in the network of data-gathering stations. The establishment of any short-term stations needed to remedy such deficiences should be carefully considered at an early stage. Water resources reports may, nonetheless, have to be prepared without the data from such short-term stations. At this point correlation and statistical models could be employed to generate synthetic records where long-term data is not available. This may require the use of computer techniques.

1.2 Presentation of data

The following suggestions of ways of presenting data in a report do not claim to be an exhaustive list. For an initial study and report, only a few of them will be needed. Conversely for a complete and wide-ranging study, data not mentioned here may well be required.

1.2.1 General

Map showing catchment and sub-catchment boundaries.

Map showing topography.

Hypsometric curve(s).

Land use (present time) - map

- summary tables, by sub-catchments.

Land use capability - map.

Map showing existing water use - i.e., present-day abstractions and additions.

1.2.2 Rainfall

Map showing location of rain-gauges.

Map showing isohyets - annual rainfall, average year.

Map showing isohyets - annual rainfall, dry year of 1 in 10, chance of occurring in any one year.

Map showing isohyets - annual rainfall, dry year of 1 in 5, chance of occurring in any one year.

Map showing isohyets - irrigation season rainfall, average year.

Map showing isohyets - irrigation season rainfall, dry year of 1 in 10 chance of occurring in any one year.

Map showing isohyets - irrigation season rainfall, dry year of 1 in 5 chance of occurring in any one year.

Map showing isohyets, monthly means as % of annual means, for each month of the year.

Table of average rainfall over catchment for each month of record.

Table of lowest summer rainfalls (ranked in order).

Table of lowest winter rainfalls (ranked in order).

Graphs showing cumulative departure from irrigation season mean rainfall.

1.2.3 Evaporation

Tables of Potential Evaporation - winter (monthly figures).

Tables of Potential Evaporation - summer (monthly figures).

Open tank evaporation (month by month).

1.2.4 River flow data

Mean monthly flow - maximum.

Mean monthly flow - average.

Mean monthly flow - minimum.

Annual hydrographs for 3 driest years of record.

Unsmoothed flow duration curves - annual.

Unsmoothed flow duration curves - irrigation season.

Smoothed flow duration curves - annual.

Smoothed flow duration curves - irrigation season.

Frequency curves - lowest mean discharges for periods of 7, 15, 30 and 60 consecutive days.

Graph of durations of flows less than or equal to specified values, the recurrence intervals being stated.

Mean monthly flow, separated into surface runoff and groundwater flow.

Table of mean daily flow, for period of record.

Table of estimated groundwater component of flow.

1.2.5 Geology, hydrogeology and groundwater

Geological map.

Table of areas of outcrops of geological formations.

Maps showing aquifers and groundwater contours.

Table of aquifers and their properties.

Map showing location of wells, water supply boreholes, abstraction points on rivers and streams.

Groundwater hydrographs - selected years at selected wells.

Groundwater hydrographs - mean for year.

Table - estimated potential replenishment of each aquifer - average.

Table - estimated potential replenishment of each aquifer - year by year.

Map - areas of possible groundwater development.

1.2.6 Effluent discharges

Map showing location of any significantly large discharges, including any disposed of on to the land.

Table of quality criteria at maximum, mean and minimum flows: BOD, suspended solids, pH, and other relevant parameters.

Table: summary of conditions of water rights.

Flow rates of effluents: tables, hydrographs.

1.2.7 Existing water quality

This is required at critical points, such as at existing and possible future intake sites and just downstream of effluent discharges, but existing data should also be included.

(i) Surface waters:

Tables of B.O.D. and suspended solids at average and low flows.

Tables of dissolved oxygen at average and low flows.

Coliform counts.

Map showing water classification (final or provisional), if available.

Temperature - mean daily, maximum and minimum daily.

pH at low and average flows.

Concentrations of particular ions - e.g., Na, Fe, Cl, NO_3

A survey of bed fauna may give a good indication of the general overall health of the river.

(ii) Groundwaters:

As above, plus: chloride and any other ions of interest or importance - alkalinity, nitrate nitrogen, ammoniacal nitrogen, albuminoid nitrogen, oxygen absorbed, hardness, iron and manganese.

1.2.8 Net resources

Rainfall, runoff and losses - year by year.

Rainfall, runoff and losses - extreme values and averages.

Soil water deficiences - month by month for average year, dry year (10% probability of return) and dry year (20% probability of return).

CHAPTER 2

DETERMINATION OF EXISTING USE

Each catchment will have distinctive modes of use. Examples of some of the usually important modes are given.

2.1 Non-consumptive use

Industrial: table of users and quantities involved	Extracted from both surface water and ground water
Cooling water table of users and quantities involved	

Recreation: fishing, boating, etc.

Hydro-electric power generation:

Hydrographs, derived from records of power generated, of:

Daily use, i.e., throughout the day on an hourly basis	Maximum; typical day, no. of days to be stated.
Use throughout the year, on a daily basis	
Use throughout the irrigation season on a daily basis	

2.2 Consumptive use

Tables of:

Stock water	Monthly means, Maxima, Minima.
Industrial water not returned to surface water	
Public water supply	

Graphs of present-day irrigation demand: average year

: dry year, 10% probability of return

: dry year, 20% probability of return.

CHAPTER 3

ASSESSMENT OF FUTURE USE

The choice of how far into the future to take the study is to some extent arbitrary. However, for the purpose of a water allocation plan, the time-period should be no further ahead than can reasonably be foreseen - probably not more than 10 years.

A longer time-period should be used for the purpose of getting some idea of the ultimate future demand, and hence of the extent to which the resource will need to be developed or augmented. At some stage in the study, economics will be involved, and the approximate average life of certain hydraulic structures is given by Linsley and Franzini, "Water Resources Engineering", Second Edition, Wiley (1972) as:

Canals and ditches		75 years
Public water supply	- intakes	say 75 years
	- treatment works,	say 40 years
	- pipelines 50-100 years, depending on size.	
Power generation	- penstocks	50 years
	- buildings	say 75 years
	- turbines	35 years

The economic life, for the purposes of economic studies, is somewhat less than that above, so a reasonable length of time to look ahead, and which is also commonly taken to be the economic life of many engineering works would be 40 years.

The exact magnitude of the future demands will depend to some extent on the availability of water; the availability will be affected by the demands made on it. A trial calculation must, therefore, be made to start with, using some reasonable initial assumption - for example, that water is freely available without restrictions. If a shortfall is predicted as a result of sufficient seriousness to affect the growth of demand, another calculation can then be made taking this into account. A reasonably accurate forecast of the growth of demand should be the end result.

3.1 Public Water Study

Estimates of future demand for domestic purposes can be obtained from the water supply authorities.

Expected population increase can be obtained from Town and Country Planning population estimates.

3.2 Industrial Demand

3.2.1 General

Consultations with local and national Town and Country Planning authorities will identify probable and possible areas of industrial growth. The estimation of future industrial demand will necessarily be approximate; nonetheless, an estimate will have to be made.

3.2.2 Presentation of data

Table showing: type of industry, usage of water, estimated expansion, estimated future demand.

Graph showing growth of demand vs time.

Table of river flows necessary for the dilution of wastes.

Graph showing growth of demand versus time. Again, as in chapter 2, it will be necessary to distinguish between consumptive and non-consumptive uses.

The needs of mining industries and problems caused by their activities (turbidity, for example) may need special consideration, especially if considerable future expansion seems possible.

3.3 Hydro-electric generation requirements

The Electricity Department can give a forecast of future demand from this source of generating capacity. In general, water used for hydro generation can be re-used. The effect of withdrawals from storage for electricity generation on the availability of water to other users later in the dry season should be carefully considered.

Data: future growth in demand (graph) - kWh

future growth in demand (graph) - volume of water/year. (each present and projected station)

future growth in demand (graph) - volume of water/irrigation season (ditto)

The implications of possible future operating systems (such as development of pumped storage schemes) need to be considered as far as information and estimation permit.

3.4 Forestry and agriculture

3.4.1 Forestry

Although irrigated forests are unlikely in New Zealand in the foreseeable future, the possible effect of afforestation or deforestation on the quantity and quality of the water resources of the catchment may be important.

Areas of possible afforestation and likely afforestation to be shown on land use maps.

3.4.2 Agriculture

This term includes rural water-supply and irrigation water. A procedure for estimating future agricultural growth is:

(i) Determine area of farmland as at present day.

(ii) Determine area of farmland in the future - if it seems likely to be very different from (i).

(iii) Assess the area under crops, the area of pasture, and the animal population - as at present day.

(iv) Assess the area under crops, the area of pasture and the animal population - future.

Present day requirements have been discussed in Section 2.2. Future water requirements can now be assessed, taking into account climatic factors already dealt with in Section 1.

(v) Stock water requirements.

(vi) Domestic requirements.

(vii) Irrigation, water requirements for pastures
- average year
- dry year, 10% probability of return
- dry year, 20% probability of return

(viii) Irrigation water requirements for crops
- average year
- dry year, 10% return probability of return
- dry year, 20% return probability of return

(ix) Irrigation as in (vii) but assuming only high-value crops are irrigated. Steps (vi) - (viii) should initially be calculated assuming that the requisite water will be available.

The effect of peak demand of rostered irrigation as opposed to "on demand" irrigation should be examined; results could be presented as in (v) - (viii).

In such a procedure it will be necessary to consult with the Ministry of Agriculture and Fisheries and general farming interests.

3.5 <u>Recreation and ecology</u>

A river or lake that supports a large, healthy and diverse fish population is usually very satisfactory for all other purposes (water supply and bathing, for example) including preservation of scenic beauty. Sufficient flow should therefore be maintained in the river to prevent it becoming a series of stagnant pools, and to prevent irreparable damage to its ecology. This does not preclude the possibility of reducing the river flow to zero on occasions, under extreme conditions. Variable lake levels pose problems of their own which must be examined on an individual basis.

There is some guidance in the literature on minimum desirable flows, but each case must be considered in the light of local conditions.

Substantial public interest will exist in this area and there is a need to consult with all bodies and organisations who have an expressed interest in recreation and ecological aspects.

CHAPTER 4

FORMULATION OF A WATER ALLOCATION PLAN

4.1 Definition and purpose

A water allocation plan for any given resource is a published and publicly acceptable document that:

1 specifies clearly how the water available in the resource shall be allocated amongst the competing demands (including recreation, fish and wildlife) whenever the resource cannot meet the demands in full. The purpose of this is to allocate the available water in a rational and fair manner amongst those who wish to take and use water, taking into account the requirements and interests of both present and future users, including recreation, fish and wildlife.

2 indicates clearly the estimated frequency and severity of restrictions to be imposed pursuant to paragraph (1) upon different users in times of water shortage. Such restrictions would commonly be in the form of a roster which may reduce the allowed inflow rate or the time of abstraction or both. This is for the information of existing right-holders and prospective applicants for water rights

3 serves as a guide to the Regional Water Board when issuing new water rights and when varying existing water rights so that at no time does the amount of water allocated exceed the amount available. It enables the Board to write into these rights and variations such conditions as are necessary to enable the Board to implement the water allocation plan pursuant to paragraph (1).

4 serves as a guide to intending users of the resource who will wish to assess the economic impact on their proposals of the degree and frequency of restrictions they would have to face.

5 bears an expiry date. This is necessary because

(a) development and/or augmentation of the resource will change the availability of water on which the allocations considered in paragraph (1) were based; and

(b) the plan will need to be up-dated from time to time.

4.2 The necessity for producing water allocation plans

The urgency of a water allocation plan will vary from one catchment to another depending on the adequacy and reliability of the water resources to meet the existing and expected future demands. Thus, a catchment with immediate and pressing problems of water shortage will require a water allocation plan quickly, using whatever data is available. It is not necessary to delay the inception of a water allocation plan on the grounds of lack of enough data to produce very accurate results: any plan produced can be given a suitably short life-span and replaced on expiry by a more confident, up-dated one. On the other hand, if the water resources of the catchment are ample and will continue to be adequate for a few years, the preparation of a water allocation plan may be delayed until the results of the studies outlined in Chapters 1-3 start coming in.

Even when a resource has been developed, a water allocation plan will still be necessary: it is not economic to develop a resource far enough to meet the very severe drought of infrequent occurrence.

4.3 Principles and requirements

4.3.1 The relation between water use restrictions and flow duration:

This section is concerned with security of supply and frequency of restrictions. When the resource is adequate to meet all demands, including recreation and wildlife, there are no problems: all users may take up to the maximum their water rights allow. As the resource diminishes (for example, the flow in the river decreases) there comes a point where further reduction in the resource will have adverse effects on some users, and some form of rationing or allocation is necessary.

This point is not an unknown quantity: by adding up all present-day demands, including a residual flow in the river for recreation, fisheries and wildlife, the stage where demand begins to exceed the capacity of the resource is known. Further, in the case where the resource is a river, the total demand as calculated will correspond to a certain percentage flow duration (where the X % flow duration is a flow rate, and is defined as being the rate of flow which is exceeded or equalled for X % of the time). Therefore, the resource will not be able to satisfy the demands for the remainder of the time (i.e., for (100 - X) % of the time). As total demand increases it will be seen from the flow-duration curve that the X% of the time that the demand can be satisfied will decrease. Hence, it is possible to estimate in advance the effects that increased demand could have on the frequency and severity of restrictions on abstractions of water.

Thus, if, for example, it is proposed as part of the water allocation plan to suspend the rights of new irrigators whenever the river flow falls below a certain value, then the higher that value is, the more frequently those irrigators will have their rights suspended and the longer the restrictions will last. However, as an objective of the water allocation plan, prospective irrigators would be told in advance how often, on average, they could expect restrictions and how long they could be expected to last. They could thus decide whether it would be worthwhile setting up for irrigation.

The same argument would hold true for all other prospective abstractors.

4.3.2 Considerations of priorities

One method of allocating the available water is by the prior appropriation doctrine ("first in time is first in right") as practised in many states of the U.S.A. Under this system, as the resource decreases and becomes a progressively smaller proportion of the total demand, right-holders are compelled to suspend abstractions one by one, in the reverse order to the order in time in which the rights were originally granted. So, holders of more recently-granted rights may have to go without water completely to enable holders of longer-established rights to continue to take the maximum that their rights allow.

This system would probably not be acceptable to the majority of New Zealanders. However, it must be recognised that existing users (often with substantial investment dependent on the availability of water) should be given sufficient security of supply for them to be able to accept the allocation plan that is proposed. The mode of restriction between existing and new users must be clearly described in the water allocation plan together with estimates of the severity of proposed restrictions so that existing and prospective users can gauge the impact of the plan on their interests.

The principle that emerges is that all users suffer some restrictions when the resource falls a little below the level necessary to meet all demands. (This assumes that all users can take a modest restriction in their abstractions without significant hardship). On further diminution of the resource all holders of new rights suffer increasingly severe restrictions and eventual suspension of the exercise of their rights, while holders of existing rights continue to abstract, but at a reduced rate. With further decrease of the resource, all holders of existing rights suffer increasingly severe restrictions, and eventual suspension of their abstractions. In this latter stage, it may be useful to suspend abstractions periodically (for example, for one 24-hour day once a week) to refresh the river for the benefit of fish and wildlife.

Another case to be considered is that of an existing user who wants to take more water than he does at present. As the holder of an existing water-right, the exercise of his existing right under the water allocation plan could be restricted less often and less severely than would the exercise of the right of a new user. A fair method of allocation would be for the right for the extra water to be granted subject to the same restrictions as rights granted to new users. Restrictions on taking the extra water would therefore be more frequent and of longer duration than restrictions on his existing right, which he would still retain. Another method of dealing with this case would be to allow him to take extra water only at such time as there is sufficient water left in the resource after satisfying the demands of the new users.

In either case, at higher flows (corresponding to lower percentage durations) there will be a surplus of water in the resource. Anyone who wishes to take water at these flows should be allowed to do so, to enable maximum use to be made of the available water.

Sufficient water must be allocated for the future needs of new and existing (and any extra water for existing) users during the life of the plan. The amount to be allowed for these users during the life of the plan can be estimated from the data gathered Chapter 2, Determination of existing use, and the estimates made in Chapter 3, Assessment of future use. If a water allocation plan must be made before completing the studies suggested in chapters 2 and 3 recourse must be made to local knowledge and rules of thumb, tempered with engineering judgement. Such a plan would be of a temporary nature and would be in anticipation of the plan produced as a result of steps 2 and 3.

It is possible that publication of the water allocation plan, with its implications of a finite limit on the water available for new users, will spark off a rush of applications for water rights, the thinking being "get in now while the going's good". The basis on which applications for water rights are vetted should be made public - for example, X litres per second per hectare for irrigation, or Y litres per stock unit for a freezing works. Clearly, when the water rights are being issued, a running total must be kept of all abstractions authorised for each stage of restrictions, to ensure that at no stage does the total rate of abstractions exceed the available resource.

The frequency and severity of restrictions is related to the flow duration curve of the resource. Development and augmentation of the resource (for example, by controlled releases from dam storage or transfer from another catchment) will have the effect of altering the flow duration curve. The foregoing principles can therefore be applied both before and after the resource has been developed.

When actually employing the foregoing principles, the picture is complicated by the fact that stock water, domestic use and fire fighting do not require water rights but must be provided for. In times of water shortage,major water users (eg town water supply, irrigation) may be able to accept some immediate restrictions without a significant impact on their uses. This may not be the case for other users who will have their own characteristic requirements that affect the severity and frequency of restrictions that can be tolerated. These requirements will affect the point at which restrictions may be imposed.

For example, in a time of water shortage the abstractions for irrigation and public water supply could be cut back immediately by ten or twenty percent without seriously effecting their uses and before similar restrictions are imposed on other users of the resource. On further diminution of the resource all users would be cut back to a degree which will be largely determined by the priority of their use and the relative impact of restrictions on the various users.

4.3.3 Expiry times and review periods

Although it is reasonable to subject a new user to more frequent and severe restriction on abstractions than an existing user, it would be inequitable to continue the disparity forever. At some time in the future the resource will be developed, augmented or otherwise modified, and it will then be possible and desirable to put new and existing users on the same footing.

From this, two requirements emerge:

1. Any water allocation plan should be valid only for a limited time, after which it is reviewed and a revised plan put into operation. The logical development of this idea is that the water allocation plan should be reviewed periodically.
2. At the same time as the water allocation plan is reviewed, some or all water rights are reviewed. The best way of doing this is to put an expiry date on every right issued, the expiry date to coincide with a review (but not necessarily the next one) of the water allocation plan. Thus, every time a water allocation plan is reviewed, some or all water rights expire and are re-issued in accordance with the new water allocation plan.

Applying these two concepts, the first water allocation plan should ideally expire at a date far enough in the future to enable existing users to write-off their investments over a reasonable time period. Greater knowledge of use and resource, or positive control over the resource, may require an earlier review. Conversely a paucity of reliable information initially may dictate a short period for the first allocation plan. (The position of new right-holders in this period has been dealt with in section 4.3.2). The next water allocation plan, for the period from ten years hence until the review after that, would take into account any then-existing and expected development, augmentation or modifications of the resource as well as changes in demands and patterns of use. New water rights issued during the currency of the second water allocation plan would be dealt with in the same way as new rights issued during the currency of the first plan. (If this were not so, and new users were put on the same footing as existing users, there would be a time lag until all the water allocated to new users had been taken up. During this time existing users would suffer unnecessarily severe restrictions, and the water allocated to new users but not yet taken up would run to waste).

4.4 Implementation of the water allocation plan

4.4.1 Legal considerations

It is useful to consider what legal authority a Board would have for implementing a water allocation plan after it has been formulated. New water rights issued under the water allocation plan, and variations issued under the water allocation plan to existing water rights, present no difficulties. Such rights and variations could bear expiry dates and can have suitable conditions written into them (under subsection 3 of section 21 of the 1967 Water and Soil Conservation Act) so that the Board could impose restrictions as necessary in accordance with the water allocation plan.

It would be more difficult to impose new restrictions on existing water rights. Section 24E of the 1967 Act could be used, on the grounds of "serious temporary shortage of water." This section of the Act appears to have been written with a short duration emergency situation in mind, as it requires that any restriction order issued pursuant to it is only valid for 14 days, after which time it must be renewed if restrictions are to continue. The chronic shortage of water caused by increasing demand does not really fall into this category. Hence, the use of powers granted under this section for the purposes of implementing the water allocation plan may work, but is probably not what was intended by the Act.

As an alternative, the Board should consider using Section 24D of the Act, which gives the Board power to restrict or suspend the exercise of a water right in order to maintain minimum flows and minimum standards of water quality. Care should be exercised when considering this step.

To give the necessary authority to water allocation plans and to provide adequate powers for their implementation, the possibility of giving the plans legislative status, similar to that existing for water classifications, is to be examined.

4.4.2 Administrative procedures

A good way of processing a water allocation plan from its conception to the point where it is ready to be physically implemented would be by a process analogous to the procedure already established for water classification. A preliminary water allocation plan would be drawn up by the Board's permanent staff and discussed, perhaps modified, and approved by the Board. This preliminary plan would be published, the public notified of its publication, and comments and objections invited. As a result of these, the plan may or may not be amended. There will be many alternatives to this procedure, e.g. public participation may be sought at the resource measurement stage. The best procedure in a given situation will be evident to each Board.

The result, after approval by the Board, would be published as the final water allocation plan, and the Water Resources Council informed. If Crown water-rights are involved, the National Water and Soil Conservation Authority would need to be informed and asked for comment before the preliminary plan is published. The Authority's approval of the proposed restrictions on Crown water-rights would be necessary before publication of the inal water allocation plan.

4.4.3 Physical implementation of the water allocation plan

It is envisaged that eventually every water right will carry a list of restrictions to be applied at various stages and times of the day as the resource decreases. The right will not state the method of implementing the restrictions: the implementation would probably be via a roster system which can be modified frequently as more and more water rights are issued.

To implement the water allocation plan, at least one gauging station on the river is necessary, with gauging sites as necessary on major tributaries. It will be necessary for the Regional Water Board to read the gauge (by telemetry or direct reading) and to deduce the actual river flow from the rating curve: after making allowance for estimated abstractions above the gauging site, the natural flow of the river can be estimated. Alternatively, the readings from one or more gauges sited above all abstractions can be used to obtain by correlation an estimate of the natural flow at a specified point.

Either way, the result is an estimate that may be termed the "official flow of the stream", and is the flow available for allocation to all users, both upstream and downstream of the gauging site. This figure can be notified to all right-holders - for example, by publishing it in the local press and broadcasting it from the local radio station. All right-holders may then exercise their water-rights only in accordance with the restrictions set out in the documents comprising their water-rights.

To implement and police the restrictions, it is probably easiest to put irrigators on a roster system, which would include the times and days for which a particular abstraction is allowed. Most industrial users and water supply undertakings will have flow meters to enable them to control their abstractions and processes, but few irrigators will. A practical system is to allow each irrigator to operate at maximum rate for part of the time, and to roster irrigators so that at no time is the total abstraction more than the river can stand.

Calculations should be in terms of the average daily flow as used in Section 3.2.5 of the technical part of the National Water and Soil Conservation Organisation Manual. Thus if a water right entitled the holder to 1 m^3/s for 16 hours per day for 5 days each week then the "cycle time" would be one week and the average daily value would be $1X\ 16/24 \times 5/7 = 0.476\ m^3/s$.

4.5 Worked example of the production of a water allocation plan

This example concerns a fictitious river and fictitious demands, although it is based on a real-life situation:

4.5.1 Background

The river in this example has a mean flow during the irrigation season (September to April inclusive) of 24.4 m^3/s and a minimum recorded flow of 1.2 m^3/s based on 8 years of continuous flow gaugings. There are no lakes in the catchment, either natural or man-made. The river rises in the foothills of the Southern Alps and flows more or less straight to the sea, with no major tributaries but several minor ones. About halfway along its length the river flows through a gorge, at the lower end of which is the gauging station. There are a few small abstractions above the gorge for township and rural water supplies, but the bulk of the present-day abstractions are below the gorge.

The irrigation season flow duration curve is presented in Fig. 1, and low flow duration vs. recurrence interval curves in Fig. 2. These graphs relate to the natural flow that would occur at the gauging site were there no abstract-

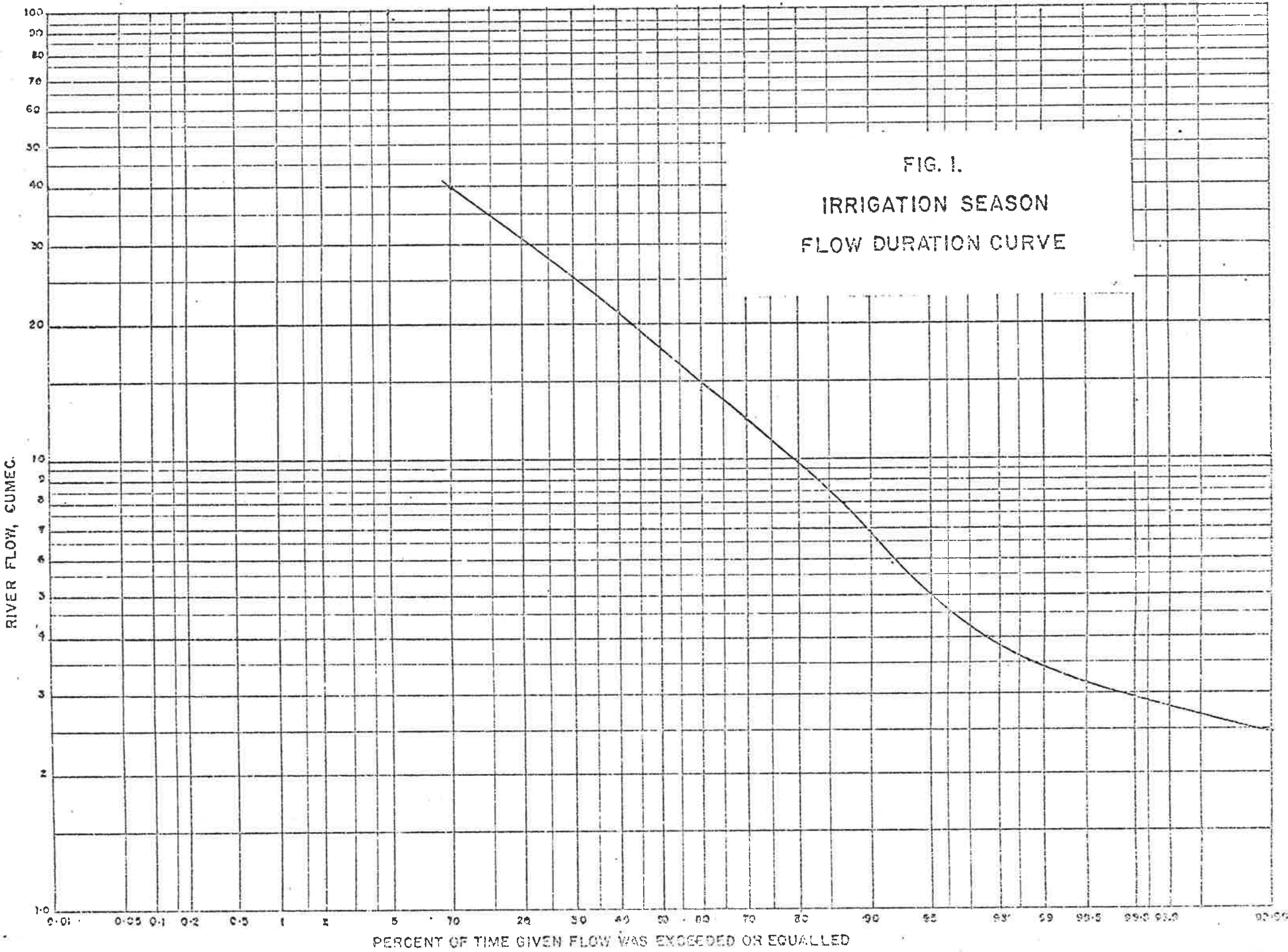
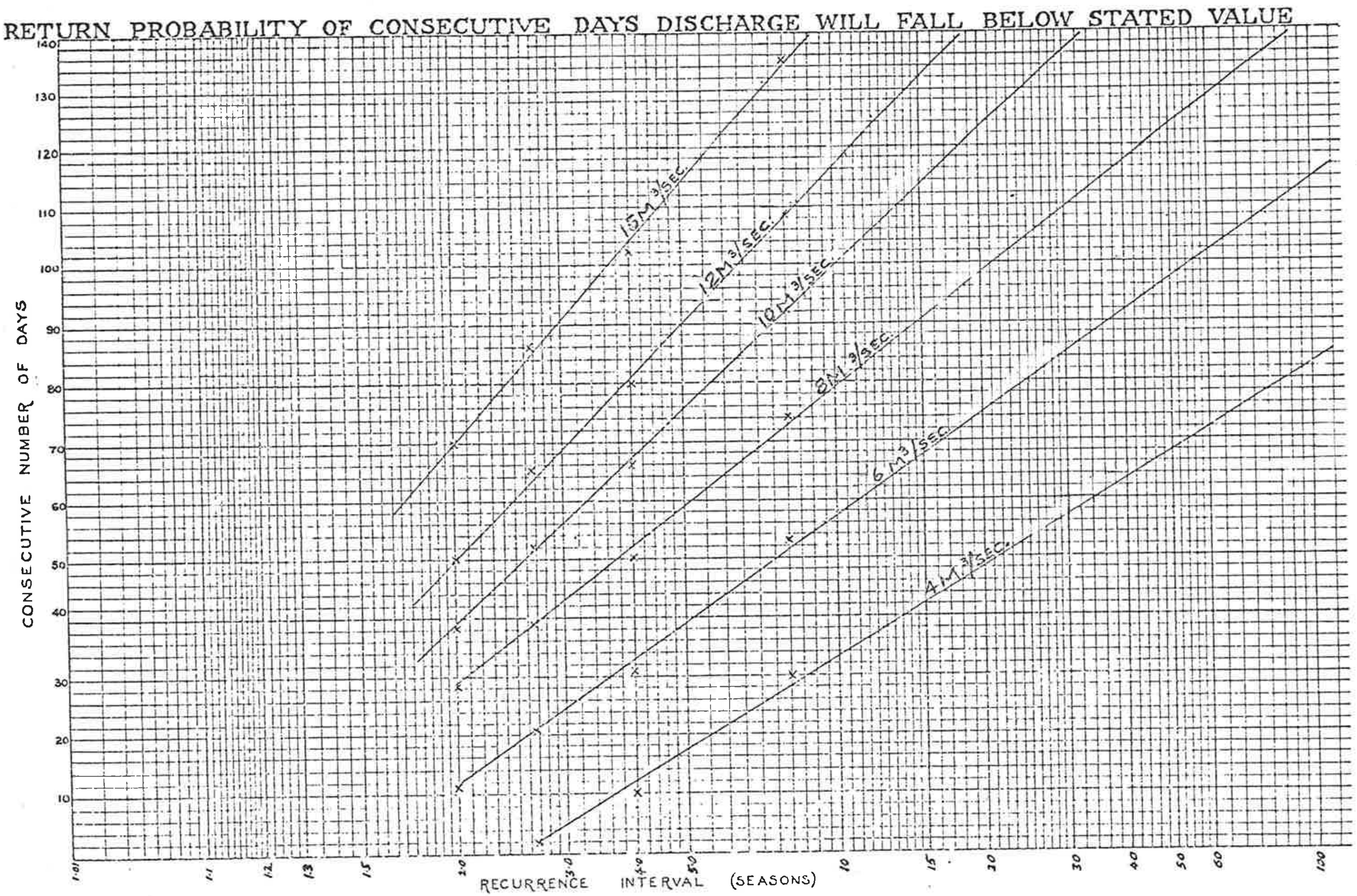


FIG. 1.

IRRIGATION SEASON

FLOW DURATION CURVE



From "The Resources and Usage of Water in the Opihi Catchment"
South Canterbury Catchment Board, February, 1973

FIG. 2

ions above the gorge: tributaries entering below the gorge are negligible compared with the flow in the main stream.

Even at the present time, total demands exceed the low flows of the river. A water allocation plan is therefore needed immediately to share out the available water.

It is intended to develop the resource, either by dam-building or by using ground-water. The programme is expected to be roughly: consideration of alternatives and preliminary calculations, two years: investigations leading to recommendation, three years; design period, one year; construction period, two to three years; total 8-9 years, plus a year's float time, say ten years. The water allocation plan will therefore be given a ten-year life-span, to 30 June 1985, after which it will be reviewed and revised as necessary.

4.5.2 Demands - (a) present day

Even at the present time, total demands exceed the low flows of the river. The greatest demand is for water for irrigation, the demand being greatest at times of lowest flow in the river. Restrictions are enforced at some time during most irrigation seasons.

Recreation is important on this river, mainly trout fishing and boating; the fishing is beginning to deteriorate as abstractions continue to increase. Industrial demand is small, and is confined mainly to a small area near the river mouth. Abstractions for water supplies are small and widely scattered. There is no hydro-electricity generation.

Water quality is generally good, and there are no significant sources of pollution. Most of the small amount of pollution that does occur is agriculturally caused, by run-off from fields and effluent from cow-sheds.

Demands - (b) Future

The main expansion of demand is expected to be for irrigation, with lesser expansion due to increasing industry. Demand for water supply is expected to decrease as a result of a change to using groundwater for this purpose. It is not expected that the river will be used for hydro-electricity generation, certainly not in the next 10 years, the life of the first water allocation plan. Industrial non-consumptive demand is expected to remain compatible as regards quality and quantity with the low flows of the river, as at present. Special provision for effluent dilution will therefore not be necessary.

It is known that recreation will continue to be very important, and discussions were held with local interests to establish a desirable minimum flow to be maintained if possible. This was finally fixed as 3.6 m^3/s. Should it be impossible to maintain this flow, it was agreed that abstractions would be suspended for one day a week (a day being defined as 24 hours) to allow the river to be refreshed.

Demands - Summary

Demands, both present and future, were estimated to be as follows, in cubic metres per second:

Demand	Present-day	10 years estimated	Ultimate, estimated
Water Supply	1.04	0.8	0.8
Recreation, Fish and Wild-life	3.6	3.6	3.6
Industrial consumptive	0.16	0.3	0.5
Irrigation	6.0	10.0	14.5
Total	10.8	14.7	19.4

4.5.3 Formulation of the water allocation plan

The total demand of 10.8 m^3/s corresponds to the 78% flow duration; therefore, restrictions on existing users will need to be imposed for 22% of the time. It is necessary to know what restrictions can be imposed without causing significant hardship; this information can be used to impose the first restrictions where they will do least harm. In this example, it is assumed that water supplies can be cut by 5% by economies in use; that industrial use can be cut by 20% without affecting production (although extra costs will be incurred by the companies); that irrigation demand can be cut by up to 1/4 with only slight loss of yield. A series of trial calculations can be made, at gradually reducing river flows, to give an allocation plan covering present-day demands:

At 80% flow duration, flow	=	9.68 m^3/s
Therefore, reduction in demand	=	1.12 m^3/s
Water supply		= 0.92 (- 0.12)
Fish and wildlife		= 3.60
Industrial		= 0.16
Irrigation = balance		= 5.0 (- 1.00)
		9.68

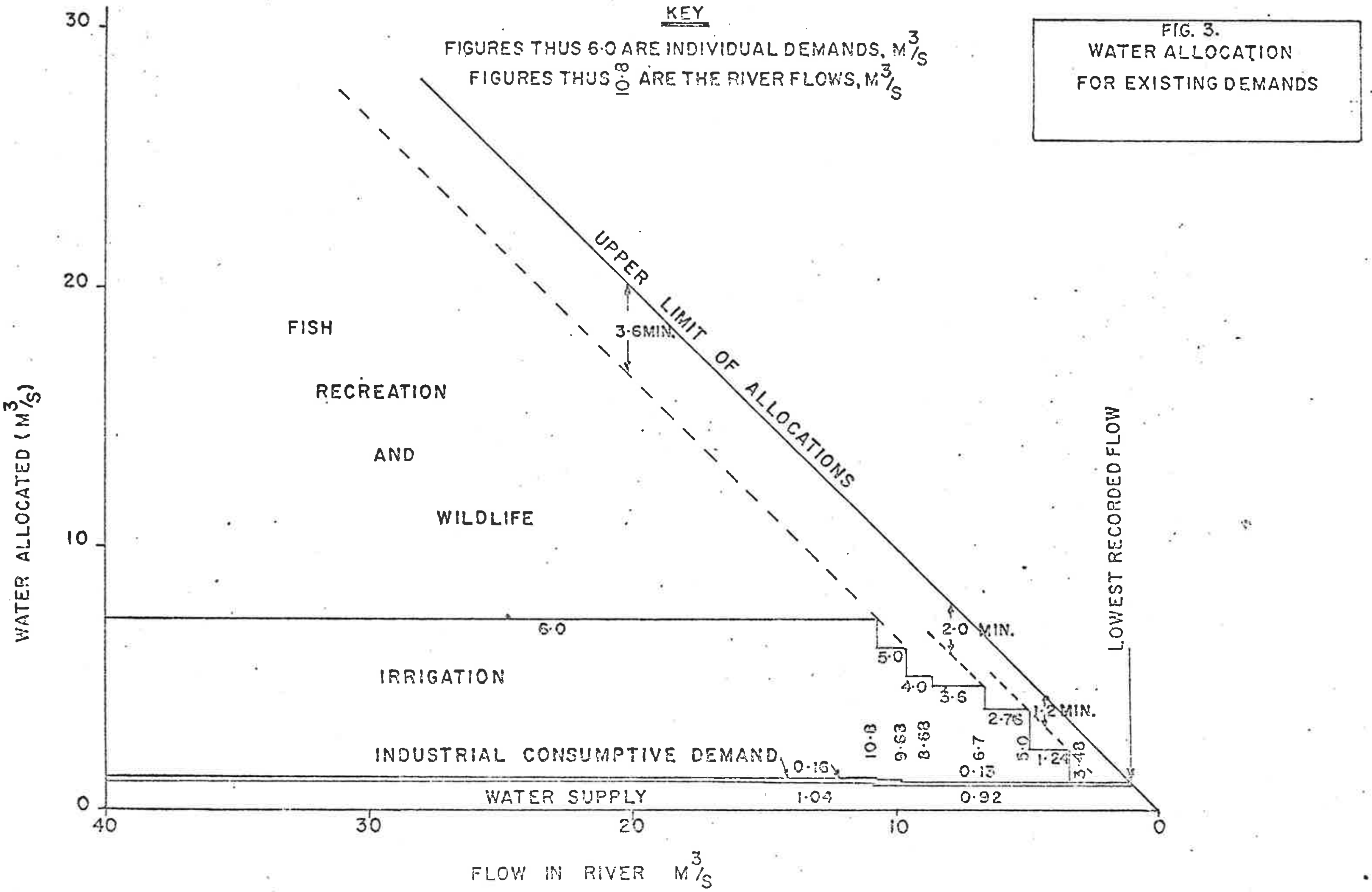
At 84% flow duration, flow	=	8.68 m^3/s
Therefore, reduction in demand	=	2.12 m^3/s
Water supply		= 0.92 (-0.12)
Fish, wildlife and recreation		= 3.60
Industrial		= 0.13 (-0.03)
Irrigation = balance		= 4.0 (-2.00)
		8.65 - near enough

At 90% flow duration, flow	=	6.7 m^3/s
Therefore, reduction in demand	=	4.1 m^3/s
Water supply		= 0.92 (-0.12)
Fish, wildlife and recreation		= 2.00 (-1.60)
Industrial		= 0.13 (-0.03)
Irrigation = balance		= 3.60 (-2.40)
		6.65 - near enough

At 95% flow duration, flow	= 5.0 m^3/s	
Therefore, reduction in demand	= 5.8 m^3/s	
Water supply	= 0.92	(-0.12)
Fish, wildlife and recreation	= 1.20	(-2.40)
Industry	= 0.13	(-0.03)
Irrigation = balance	= 2.76	(-3.24)
	5.01	

At 99% flow duration, flow	= 3.48 m^3/s	
Therefore, reduction in demand	= 7.32 m^3/s	
Water supply	= 0.92	(-0.12)
Fish, wildlife and recreation	= 1.20	(-2.40)
Industry	= 0.13	(-0.03)
Irrigation = balance	= 1.24	(-4.56)
	3.49	

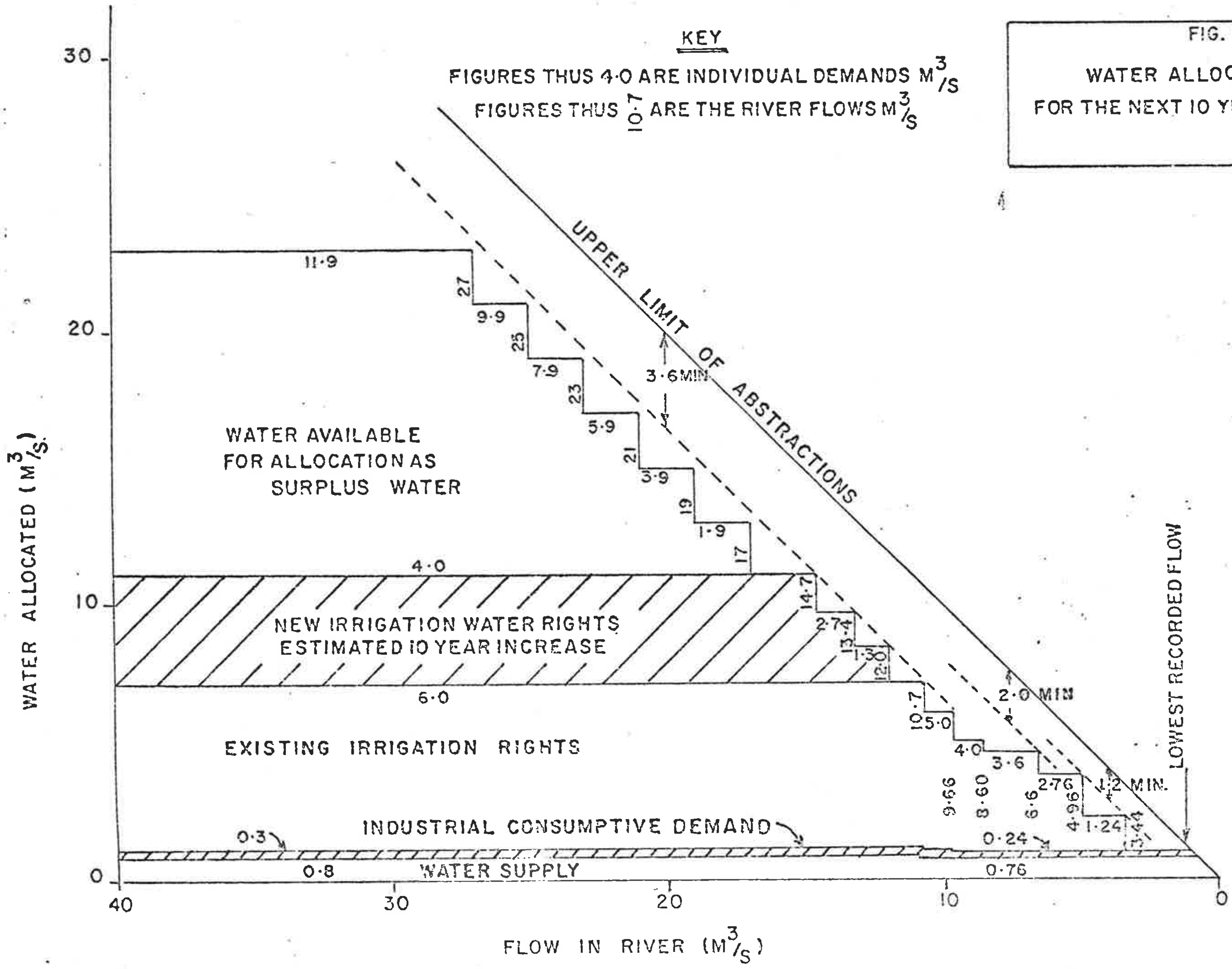
At minimum recorded flow, flow	= 1.2 m^3/s
Water supply	= 0.92
Fish, wildlife and recreation	= 0.15
Industry	= 0.13
Irrigation	= 0
	1.20



KEY
FIGURES THUS 6·0 ARE INDIVIDUAL DEMANDS, M3/S
FIGURES THUS 10·8 ARE THE RIVER FLOWS, M3/S
FIG. 3.
WATER ALLOCATION
FOR EXISTING DEMANDS
UPPER LIMIT OF ALLOCATIONS
3·6MIN.
2·0 MIN.
1·2 MIN.
FISH
RECREATION
AND
WILDLIFE
IRRIGATION
INDUSTRIAL CONSUMPTIVE DEMAND
WATER SUPPLY
LOWEST RECORDED FLOW
6·0
5·0
4·0
3·6
2·76
1·24
10·8
9·63
8·68
6·7
5·0
3·48
0·16
0·13
1·04
0·92
WATER ALLOCATED (M3/S)
FLOW IN RIVER M3/S
30
20
10
0
40
30
20
10
0

FIG. 4.

WATER ALLOCATION PLAN
FOR THE NEXT 10 YEARS - FIRST DRAFT



These figures are put on to a graph of water allocated versus water available in the river - see Fig. 3. This is the first trial water allocation plan. The largest demand is for irrigation water: it is obvious that increases in demands other than irrigation can be accommodated, but the increase in the demand for irrigation water will need special consideration and should be dealt with according to the principles expounded in Section 4.3. A second trial calculation, on the lines of the one above, for the 10-year demands excluding the increase in irrigation demand, can be summarised thus:

Water Supply	Fish Wildlife & recreation	Industry	Irrigation - existing users	Total	Percent duration (from Fig. 1)
0.8	3.6	0.3	6.0	10.7	76%
0.76	3.6	0.3	5.0	9.66	80%
0.76	3.6	0.24	4.0	8.60	84%
0.76	2.0	0.24	3.6	6.60	91%
0.76	1.2	0.24	2.76	4.96	96.5%
0.76	1.2	0.24	1.24	3.44	99.1%
0.76	0.20	0.24	-	1.20	100%

These results are plotted in the same way as before - see Fig. 4. The increase in irrigation demand ("New users") is added, and then minor adjustments are made to get an equitable allocation within the framework of the general principles set out in Section 4.3 and the assumptions made when drawing up the water allocation plan. The step sizes used for the allocation of surplus water need not be as small as those shown on the figure. The actual size is unimportant as allocation will be on a "first in time, first in right" basis.

So, the first adjustment is to introduce restrictions on water supply authorities' abstractions at an earlier stage. The purpose of this is to encourage the water supply authorities to apply restrictions on non-essential uses and to check waste of water before introducing restrictions on better uses. The major adjustment is to take steps to improve the availability of water for new irrigators. The allocation of water to existing irrigators is reduced by a quarter, and the water thus freed is allocated to new irrigators. Some trial-and-error is then used to get a reasonable series of staged reductions in the allocation to the new irrigators. The end result - see Fig. 5 - is: first stage reduction, new irrigators and existing irrigators suffer a 15% reduction in allocation, second stage reduction, all irrigators suffer a 25% reduction in allocation. In the third and fourth stages of reduction, the reduction to existing irrigators is held at 25% while the allocation to new irrigators is reduced to 37½% and then to zero. The reduction of allocations to existing irrigators as the river flow decreases is then tidied up, the number of steps being reduced to three, i.e., the reductions are from 75% to 50%, then to 25% and finally to zero.

Finally, the total suspension of abstractions for short periods of time - in this example, for one 24 hour day per week - are put on to the figure. These sorts of restrictions are necessary on many rivers because losses to groundwater through the river bed can cause an intended small residual river flow to fall to zero. In these circumstances a periodic "flushing" is needed to prevent stagnation and excessive temperatures in pools in the river bed, for the benefit of wildlife and fish; and

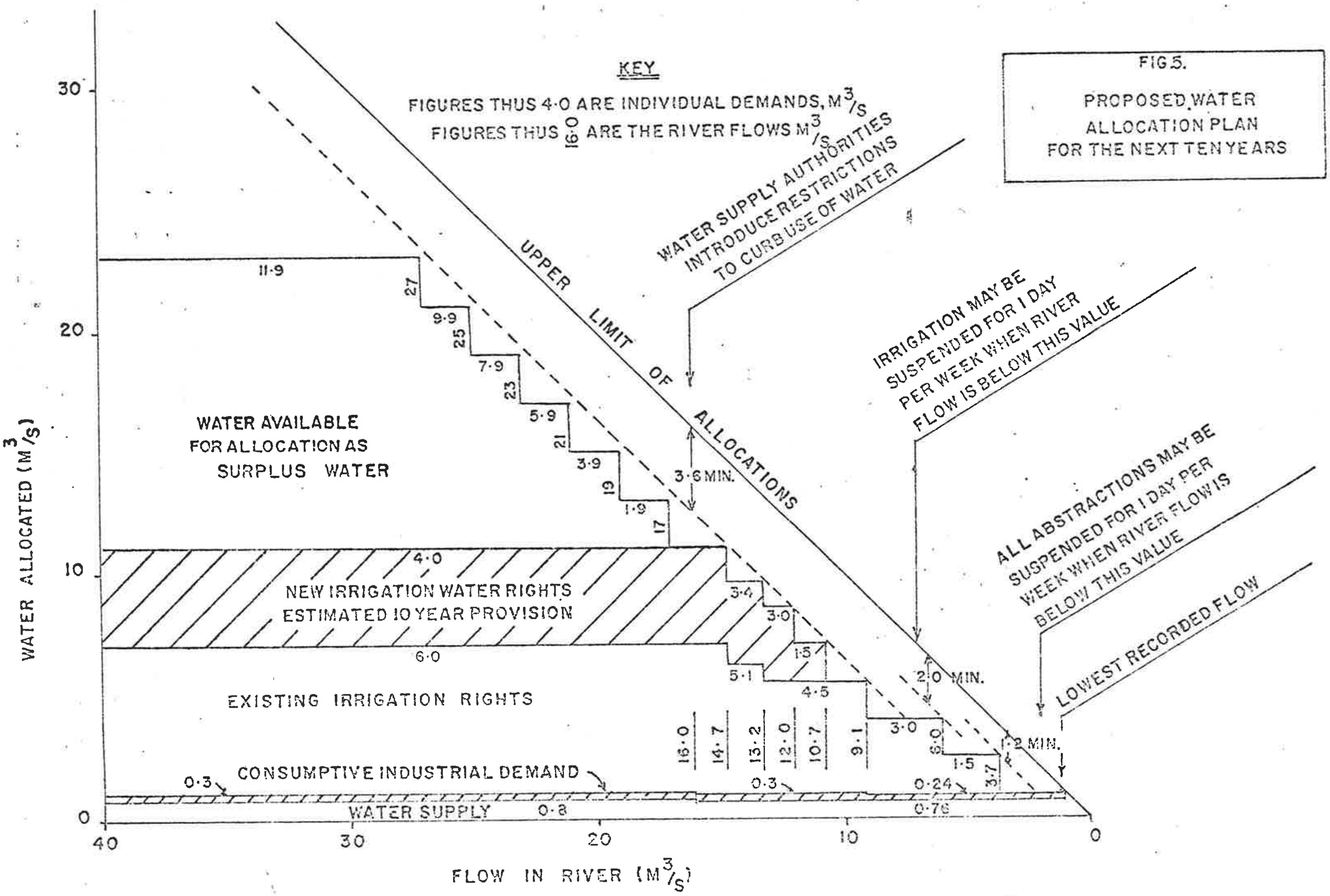


FIG 5.
PROPOSED WATER ALLOCATION PLAN FOR THE NEXT TEN YEARS
KEY
FIGURES THUS 4·0 ARE INDIVIDUAL DEMANDS, M3/S
FIGURES THUS 16·0 ARE THE RIVER FLOWS M3/S
UPPER LIMIT OF ALLOCATIONS
WATER SUPPLY AUTHORITIES INTRODUCE RESTRICTIONS TO CURB USE OF WATER
IRRIGATION MAY BE SUSPENDED FOR 1 DAY PER WEEK WHEN RIVER FLOW IS BELOW THIS VALUE
ALL ABSTRACTIONS MAY BE SUSPENDED FOR 1 DAY PER WEEK WHEN RIVER FLOW IS BELOW THIS VALUE
LOWEST RECORDED FLOW
WATER AVAILABLE FOR ALLOCATION AS SURPLUS WATER
NEW IRRIGATION WATER RIGHTS ESTIMATED 10 YEAR PROVISION
EXISTING IRRIGATION RIGHTS
CONSUMPTIVE INDUSTRIAL DEMAND
WATER SUPPLY
3·6 MIN.
2·0 MIN.
1·2 MIN.
11·9
27
9·9
25
7·9
23
5·9
21
3·9
19
1·9
17
4·0
3·4
3·0
1·5
6·0
5·1
4·5
3·0
1·5
6·0
3·7
16·0
14·7
13·2
12·0
10·7
9·1
0·3
0·3
0·24
0·8
0·76
WATER ALLOCATED (M3/S)
FLOW IN RIVER (M3/S)
0
10
20
30
40
30
20
10
0

also to replenish the water in gravels in the river bed.

It is now possible to spell out to users, both existing and prospective, how severely and how often the proposed restrictions are likely to bear upon them. This is easily done by referring to Figs. 5 and 2, and then presenting the results in an easily-grasped form. For example, from Fig. 5, a new irrigator will suffer a 15% reduction in his permitted take when the river falls below 14.7 cumec. From Fig. 2, once in 5 years (on average) the river flow will be below this for 109 consecutive days. The new irrigator will suffer more severe restrictions when the flow falls below 13.2 cumecs: from Fig. 2, once in 5 years (on average) the river flow will be below this for 98 consecutive days. The new irrigator will therefore be restricted to 85% of his allocation for 109-98=11 days, once in 5 years. These 11 days could be split, some coming before the severest part of the drought and some coming after. However, the rise of a river after a dry spell tends to be much more rapid than the recession of the river as the drought gets more severe, so as a practical approximation it can be assumed that these 11 days are consecutive and occur before the most severe part of the drought.

In this manner the probable durations of restriction can be worked out for each category of use. A convenient summary of the results is displayed in the tables on the following two pages. Thus, for example, a new irrigator will suffer restrictions in his supply of <u>at least</u> 15% on 86 consecutive days once every three years.

Duration of restrictions, of given frequency and severity, on existing irrigators

Severity of restriction	River flow (cumec)	Duration of restriction, consecutive days			
		Every other year	Once in 3 years	Once in 5 years	Once in 10 years
15% reduction	between 14.7 and 13.2	66	86	109	137
25% "	between 13.2 and 9.1	56	76	98	125
50% "	between 9.1 and 6.0	34	50	68	90
75%	between 6.0 and 3.7	12	25	39	57
taking suspended	below 3.7	0	2	10	26
Total number of consecutive days of restriction equal to or greater than 15%		66	86	109	137

Duration of restrictions, of given frequency and severity, on water supply abstractions

Severity of restriction	River flow (cumec)	Duration of restriction, consecutive days			
		Every other year	Once in 3 years	Once in 5 years	Once in 10 years
5% reduction	below 16.0	77	98	123	150

Duration of restrictions, of given frequency and severity, on industrial users

Severity of restriction	River flow (cumec)	Duration of restriction, consecutive days			
		Every other year	Once in 3 years	Once in 5 years	Once in 10 years
20% reduction	between 9.1 and 1.0	34	50	68	90
taking suspended	below 1.0	0	0	0	0

Duration of restrictions, of given frequency and severity, on new irrigations

Severity of restriction	River flow (cumec)	Duration of restriction, consecutive days			
		Every other year	Once in 3 years	Once in 5 years	Once in 10 years
15% reduction	between 14.7 and 13.2	66	86	109	137
25% "	between 13.2 and 12.0	56	76	98	125
62½% "	between 12.0 and 10.7	50	69	90	116
taking suspended	below 10.7	44	62	82	107
Total number of consecutive days of restriction equal to or greater than 15%		66	86	109	137

Duration of restrictions, of given frequency and severity, on a user of the first stage of surplus water

Severity of restriction	River flow (cumec)	Duration of restriction, consecutive days			
		Every other year	Once in 3 years	Once in 5 years	Once in 10 years
taking suspended	below 17.0	84	106	132	160

4.5.4 Conditions attached to water rights granted under the water allocation plan

Every water right granted under the water allocation plan needs to have a definite expiry date and conditions written into it setting out the restrictions that may be imposed on the exercise of the right in accordance with the water allocation plan. This is best illustrated by some hypothetical examples.

1. Granting a water right for industrial use

A company applied for a water right to take 5 l/s for industrial purposes.

The Board granted the water right, subject to the Board's standard conditions and to a set of special conditions which allow the right to be exercised only in accordance with the Water Allocation Plan:

(1) The right will expire on 30 June 1995.

(2) The maximum rate at which water is taken will be reduced by 20% (to four l/s) at all times when the official flow of the river at the Gorge gauging station is less than 9.1 m^3/s.

(3) The exercise of the right must be suspended at all times when the official flow of the river at the Gorge gauging station is less than 1.0 m^3/s.

(4) The exercise of the right must be totally suspended for one day per week at all times when the official flow of the river at the Gorge gauging station is less than 2.0 m^3/s.

2. Granting a water right to a local authority for abstractions for rural water supply

The local County Council applied for a right to take 220 l/s for rural water supply. In this case, the special conditions were:

(1) The right will expire on 30 June 2004.

(2) The maximum rate at which water will be taken shall be reduced by 5% to 210 l/s at all times when the official flow of the river at the Gorge gauging station is less than 16.0 m^3/s.

(3) The exercise of the right will be suspended for one day per week at all times when the official flow of the river at the Gorge gauging station is less than 2.0 m^3/s.

3. <u>Granting of a water right to a new irrigator</u>

In this example, a dry-land farmer will convert 150 acres (60 ha) of his 500 acre (200 ha) farm to irrigated pasture, and applies for a water right for 42 litres/second based on a rate of 0.7 litres/second per hectare (equivalent to 1 cusec/100 acres). The special conditions attached to his water right are:

(1) The water right will expire on 30 June 1985.

(2) At times of low flow in the river, as measured at the Gorge gauging station, the taking of water under the right will be reduced as follows:

Official flow at Gorge gauging station; in cubic metres per second	Average daily rate of taking must not exceed:
More than 14.7	42 litres/second
13.2 to 14.69	36 " "
12.0 to 13.19	31½ " "
10.7 to 11.99	16 " "
Less than 10.7	Nil

4. Granting of a water right to a new irrigator who also wants to use some surplus water

In this example, the farmer wants to irrigate 150 acres (60 ha) of pasture and to grow several acres of crops. The pasture requires a maximum of 42 litres/second (based on 0.7 litres/second per hectare) and this should be available at all times during the season. The crops are estimated to require a further 40 litres/second during the period up to mid-January. The farmer has been told that "surplus water" is usually available in this period, and accordingly has applied for a water right for 42 l/s of irrigation water and 40 l/s of surplus water. The special conditions attached to his water right are the same as in the previous example, except that the table reads:

Official flow at Gorge Gauging station, cubic metres per second	Average daily rate of taking must not exceed:
More than 17	82 litres/second
14.7 to 17	42 " "
13.2 to 14.69	36 " "
12.0 to 13.19	31½ " "
10.7 to 11.99	16 " "
Less than 10.7	Nil

5. Variation of an existing water right to allow an existing irrigator to use surplus water

The farmer in this example has a water right to take 1½ cusec. He wants to be able to take extra water early in the season to water several acres of crops during the growing season. He has been advised that "surplus water" would be adequate for this needs, and has lodged an application for 40 litres per second of surplus water.

In varying the existing water right, the Board takes the opportunity, with the farmer's agreement, to convert the right to metric units and to add to the right the same sort of special conditions - including an expiry date - that are written into new rights granted under the water allocation plan. The special conditions attached to the modified water right are:

(1) The right will expire on 30 June 1985.

(2) At times of low flow in the river, as measured at the Gorge Gauging station, the taking of water under this right will be reduced as follows:

Official flow at Gorge gauging station, cubic metres/second	Average daily rate of taking must not exceed:
More than 17.00	82 litres/second
14.7 to 17.0	42 " "
13.2 to 14.69	36 " "
9.1 to 13.19	31½ " "
6.0 to 9.09	21 " "
3.7 to 5.99	10½ " "
Less than 3.7	Nil

(3) The exercise of the right will be suspended for one day per week at all times when the official flow of the river at the Gorge gauging station is less than 7.0 cubic metres/second.

APPENDIX

A FUTURE DEVELOPMENTS

A.1 Development and augmentation of water resources

Future developments of water resources - including advanced management techniques such as the conjunctive use of surface water and underground water resources - are a longer-term measure than the water allocation plan. They are aimed at improving the reliability of the resource, so that either abstractors suffer restrictions less severely and less frequently than at present or more abstractions are possible with the same frequency of restrictions.

Initially, all possibilities for augmenting and developing water resources can be examined, and some preliminary designs and costs worked out: schemes that are obviously uneconomical or not technically feasible can then be discarded. Possibilities for meeting the demand should include as wide a variety of methods as possible. Some examples with type of information required are:

A.1.1 Surface water reservoirs:

Map showing location.

Table giving dam heights, types and lengths, approximate cost, volume impounded, and surface area.

Stage/storage graphs.

Yield studies - probability of failure to meet demand.

A.1.2 Groundwater development:

This has been covered in chapter 1 for natural recharge.

For artificial recharge:

Map showing location of recharge sites.

Table of estimated recharge rates, site by site.

A.1.3 Importation of water into the area:

Sources and possible amounts.

A.1.4 Economies in usage

Economy in the use of water should be encouraged; in particular, efficient use of irrigation water should be promoted wherever possible.

A.2 Drought considerations

There are two possible approaches to the problem of how far to take development of water resources:-

1. A benefit-cost analysis relating the frequency and severity of losses due to shortages of water to the costs of works to reduce the frequency with which restrictions are imposed.
2. Design works to meet a "design drought" obtained by analysing available flow records and meteorological records.

Examples: Thames Conservancy Water Resources Report (U.K.):- used a "standard drought", which was the worst historic drought as shown by the flow in the River Thames, but no attempt was made to calculate the return period. This drought (1943/4) lasted for 20 months; and thus covered the dry periods of two water years.

Devon River Authority (U.K.): defined the "reliable yield" of a source (stream, spring, etc.) as being the water available in a 6-month drought of 2% return probability. They also mentioned but did not define, a "critical drought".

For New Zealand conditions, where long streamflow records are sparse or non-existent a possible method could be: use such rainfall records as are available to get the worst 20-month (say) drought and the worst 6-month or 8-month drought and obtain the corresponding streamflows by unit hydrograph methods. This would give a two season drought and a single season very severe drought to form the basis for studies. The return probability of the drought should be indicated.

B FLOOD STUDIES

Any reservoir proposed will be for the purpose of improving the availability of water, but an incidental benefit should be the reduction of flood peaks and, possibly, flood volumes. Note the use of the conditional: it is essential to check that the delaying effect of the reservoir will not cause worse flooding downstream then occurred before. This could happen if the delaying effect of the reservoir caused the peak flow in the river to arrive at some point downstream later than it would otherwise have done, and thereby to coincide at a junction with the peak inflow from another river, causing excessively high river levels and consequent flooding.

The results of this study could be presented as:

Map showing isohyets of design storm (duration of storm to be stated).

Hydrographs - inflow to and outflow from reservoir.

Hydrographs at junction of streams for both streams, individually and combined: before the proposed reservoir is built: after the proposed reservoir is built.

NATIONAL WATER AND SOIL CONSERVATION ORGANISATION

A PRACTICAL GUIDE TO THE PREPARATION OF WATER ALLOCATION PLANS