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THE UNIVERSITY OF NEW SOUTH WALES

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by

C. H. Munro

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HYDROLOGY AND WATER RESOURCES

BY

C. H. MUNRO

SYNOPSIS

This paper argues that hydrology, as a science underlying the planning and development of water resources, has been neglected in Australia and that leaders of the profession of Civil Engineering in Australia are not sufficiently appreciative of the importance of a modern approach to engineering hydrologic problems, and do not devote sufficient resources to the investigation of projects. It reviews a number of water projects carried out in Australia in recent years, and suggests that this review supports the above arguments. It states that expenditure in research on water engineering is inadequate compared with expenditure on research in nuclear engineering, wool technology, etc.

A review is made of the efforts of various bodies over the past few years to stimulate interest in hydrology and the conclusion is reached that progress has been disappointingly slow. Methods of improving matters are discussed, such as the creation by the Commonwealth Government of a Central Water Resources Bureau, and the setting up of a Division on Water in C.S.I.R.O.

The need for research groups at various levels co-operating with water Authorities is stressed, and the suggestion is made that Universities have a role to fill in this regard.

The desirability of including engineering hydrology as an undergraduate subject in its own right in engineering curricula is emphasized, and a suggested detailed syllabus submitted. The aims and content of the University of New South Wales Master of Technology course in hydrology and hydraulics are described.

HYDROLOGY AND WATER RESOURCES

BY

C. H. MUNRO[*]

E. T. Benson, Secretary of Agriculture of U. S. A., in a recent statement (1) said that the nation needs to explore all the possibilities that natural science now offers, or there will not be sufficient water for sharply rising demands. "We have got to stop wasting water", he is reported as saying. "We have to use it more efficiently in industry, in towns and cities, in general farming, and in irrigation, which is destined to be adopted in all parts of the nation."

The wise planning of the use and control of water is undoubtedly important to U. S. A., but for Australia, with its poor endowment by Nature and its urgent need for an increase in population, this application of science is the lifeline upon which Australia must depend in the next few decades for survival as a white nation

Hydrology is the science which underlies water development and control. It deals with the occurrence and distribution of water on the earth. As a true science, it is one of the youngest. It borders on and overlaps the older sciences of hydraulics, geology, meteorology, oceanography, and agriculture, and in national affairs it should walk hand in hand with another young science - economics.

Presumably because of its youth, it is a science which is shockingly neglected in academic circles and the practical world of civil engineering. It is therefore fitting that a Congress such as A. N. Z. A. A. S. should address itself to the task of examining the reason for this neglect and considering possible remedies.

For such a discussion, with the wise development of national resources as the objective, it is desirable to widen the textbook definition of hydrology to embrace all the phenomena associated with water, from the time it evaporates from the ocean to that when it flows back from the land into that great reservoir.

This definition would embrace such fields as irrigation. When we consider the tremendous part this activity plays in our national affairs - from small farm dams and sprinkler systems to great national works -

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and the heated and inconclusive discussions which occur in scientific and practical circles on the correct techniques for different problems, and the lack of basic principles and research data to guide such discussions, it seems most odd that in no University in Australia does there exist a Chair of Irrigation. On the ten Chairs of Civil Engineering in Australia, six are held by specialists in structural design, two by specialists in Highway and Traffic Engineering, and two by persons who perhaps could be described as general practitioners. This may not be unreasonable in the Old World, but the complete absence of specialist "water" Chairs in a country such as Australia is hard to understand. As a consequence, our engineering graduates hear much of structures and materials, and little of water. This lack of balance is reflected throughout the technological community. By the very nature of things, water problems loom largely in the nation's work, but the insignificant academic interest in this field means that, broadly speaking, we attack these problems in an ill-informed and scientifically slap-dash manner.

All branches of Civil Engineering may be broadly divided into three phases:-

(i) Investigation (including research), (ii) Design, (iii) Construction.

At the risk of incurring the wrath of his many friends in water engineering, the author suggests that the great majority of water authorities of Australia are "penny wise - pound foolish" in their neglect of phase (i), and that the recognition and remedying of this weakness is the first requirement in every State of the Commonwealth. The neglect of this phase characterises many other branches of Civil Engineering. In some activities this may not matter much, but in Water Engineering it is unpardonable.

Firstly, such works usually employ hundreds of men and dozens of machines, so that a few additional engineer-months of investigation and research can usually save very large sums of money in the construction phase. Secondly, and more important, investigation and research must be considerably expanded to ensure that our limited water resources are developed in an efficient manner.

The senior officers of the Water Authorities, who are responsible for the degree of investigation carried out, will no doubt deny this charge, and point out that it is made by a Professor speaking from his ivory tower on one of his pet fads. The defence against this counter charge is threefold:-

(i) The thesis that investigation is in general inadequately carried out is based on some experience in practical civil engineering before entering the ivory tower, together with recent excursions into the hard cold world of engineering reality such as the investigation into ways and means of protecting Launceston from floods.

(ii) Senior officers of major authorities have considerable administrative work to do and little time to read and think, so that in matters of investigation and research there is a tendency for them to lag behind modern developments, particularly when the younger recruits to the departments have come from Universities where hydrology is barely mentioned, so that new ideas do not well up from below.

(iii) The training given in Universities is reflected throughout all large engineering organisations, and the lack of attention to water engineering at such seats of learning renders many water authorities unfit to pass a reasoned and informed judgment on whether their own investigation work is thorough or not.

It is admitted that in some cases senior departmental officers may be thwarted in their efforts to spend more in investigation and research, because those who control the public treasury prefer to buy concrete and carthworks rather than ideas. However, carefully reasoned representations would surely produce enlightenment in such circles.

Many water authorities seem to give an impression of self-satisfied complacency, with an absence of the spirit of enquiry and self examination. They make little if any provision for research groups, which can read, think, experiment and plan in a quiet atmosphere away from the hurly burly of a busy department. Even if such groups are set up within the various organisations, it is doubtful whether they would have a broad enough approach, or be able to resist the development of a state of affairs wherein they became engaged on day to day rather than long range problems.

More hope perhaps lies in some system of official co-operation between University research teams and the practising water authorities. The cross fertilisation of ideas and experience between the academics and practical engineers would be beneficial to both.

It is of course possible to overdo the investigations and planning phase, but many Australian engineers are quite unfamiliar with what is necessary for a really thorough investigation.

The report by the author (2) on methods of mitigating flood damage in Launceston, Tasmania, illustrates the concept of thoroughness. All four phases of the study (hydrologic, topographic, hydraulic, and economic) were given the same painstaking attention, and five possible methods of flood mitigation were evaluated by the use of a hydraulic model, which not only gave the hydraulic efficiencies of the five alternative proposals, but showed up a new and better one. Two years were spent on hydraulic data collection and analysis. The total cost of the investigation was £20,000 and the difference in the estimated cost between the recommended scheme and the original proposal is £850,000.

In 1958 the author (3) made the following remarks:-

"It is often stated that a period of 20 years elapses from the date of a fundamental discovery in science to the time when that knowledge is applied to everyday technological work. This has been well exemplified in Australian practice in estimation of future floods.

Bernard in 1944 (4) pioneered maximum possible precipitation studies, Horton in 1937 (5) demonstrated the derivation of infiltration indices, and Sherman in 1932 (6), propounded the unit hydrograph principle. These three papers provided the basic concepts for the best available attack on the estimation of future floods for major works. Yet the 1949 Report of the Stormwater Standards Committee of the Sydney Division of The Institution of Engineers, Australia, recommended the use of the "rational" method for all sizes of catchments, and took no account of the more modern approach.

Such a time lag in recognition of new techniques is too long. It is due to the failure of the engineering profession in this country to keep abreast of overseas theory and practice."

After publication of these remarks the author was taken to task by some of his professional friends, who claimed that in some States at least the civil engineers were well up to date in engineering hydrology. The author is quite unrepentant. While conceding that in every State there are a few civil engineers who have read widely in this field, they are voices crying in the wilderness.

To illustrate that our hydrologic engineering investigations are inadequate Appendix A is a brief review of hydrologic aspects of a number of water engineering papers which have appeared in the last decade or so in the Journal of the Institution.

The neglect of the sciences underlying water resources development is demonstrated by the small expenditure on research. The author is prepared to hazard a guess that not more than £50,000 per annum is spent throughout Australia on hydrologic research. If hydraulics, meteorology, and some aspects of agricultural science are included with hydrology the total would not greatly exceed £200,000 per annum.

The Hon. the Minister for External Affairs, Mr. Casey (7) was reported as saying that £1,000,000 per annum is being spent on wool research, while all are aware of the large sums expended on atomic power and nuclear engineering, rockets, and the like. Surely the sciences underlying water development are as important to Australia as these more glamorous technologies.

There have been some mild stirrings of the national conscience over the last few years.

In 1951 The Institution of Engineers, Australia, convened a conference of interested parties to discuss ways and means of improving our knowledge of our available water resources. Arising out of this came the Water Resources Conference, an annual gathering of representatives of water Authorities, which submits to these Authorities various recommendations. These deal mainly with departmental techniques and procedures, with special emphasis on collection and recording of hydrologic data. There is no obligation on the various Authorities to adopt any of these recommendations. This conference has done some useful work in a rather narrow field, but one meeting a year means that it goes a short way in a long time. Until recently it was much hampered by its lack of a permanent secretariat. This has recently been overcome by the offer of the Department of National Development to provide such a service. Each Authority takes turns to act as host to the conference.

This conference is concerned with the practical implementation of lessons to be learnt from basic hydrologic research, but takes little active part in inspiring research or developing principles.

In 1957 Technical Committee No. 2 of the Institution (Stormwater Standards) completed its report on methods of flood estimation, which was published by the Institution (8). It was clear from the work of this Committee that a really satisfactory guide to the profession in this field could not be produced without some years of basic research. Partly for this reason, and partly to expand the scope of the work, the Institution in 1954 set up Technical Committee No. 6 (Hydrology) which meets annually at the same place as and a few days in advance of the Water Resources Conference, many of the members being common to both organisations. It has appointed sub-committes on yield, groundwater, floods, data, and education. Its work is hampered by its infrequent meetings, and by the fact that its sub-committees must carry on their business by correspondence as membership is spread over the various States.

In the opinion of the author, the main task of this Committee is to inspire and co-ordinate research in engineering hydrology. It has made very useful suggestions on topics for research, but these have in general been little more than pious resolutions, as it commands no research funds. The annual joint "get together" of the Water Resources Conference and Committee No. 6 has been very successful, however, in providing a most valuable and useful medium for the exchange of ideas and experience between a widely representative groups of workers in water. The 1959 symposium in Melbourne was a most pleasing success.

By 1954 the Institution had provided two legs of a tripod - firstly the 'implementation' leg in the Water Resources Conference and secondly the "research leg of Committee No. 6. However, a tripod needs three legs if it is to stand up, and in 1955 the Water Research Foundation of Australia was launched by a group of public spirited citizens, thus providing the essential third leg - money for research. So far this Foundation has aimed only to collect money for water research, in order to create Research Fellowships in Universities, Government Departments, and other appropriate institutions.

The Academy of Sciences took a hand in 1956, by setting up a Standing Committee on Hydrology. Although this committee has only met twice, it has submitted to the parent body some important recommendations.

Another forward move was the announcement by the Hon. Mr. Fairhall then Minister for the Interior in 1957, that the Commonwealth Government had created a Hydrometeorological Branch within the Bureau of Meteorology. This branch is not yet properly in action, but is doing some useful planning and thinking on what might be termed 'engineering meteorology'. The author suggests that its first objective should be:-

(i) To provide, with the minimum of delay, the meteorological data and analyses required from time to time by the engineer as distinct from the climatologist, and to make it available in a form suitable for engineering investigations.

(ii) To fill in the gaps in both rainfall and streamflow data collection throughout Australia.

In regard to streamflow data the author recognises that heretofore this has been left to the State governments. If they do the job adequately, all is well. If they do not, then the Hydrometeorological Branch must, in the national interests, step in and repair the deficiencies.

Presumably as a result of a recommendation by the Academy of Sciences, the Commonwealth Government recently re-convened the interstate Ground Water Conference, but no public statement has been made regarding its proposed activities.

An interesting new development was the creation in 1957 of the Hunter Valley Research Foundation, whose aim is to carry out hydrologic, geologic, economic, geographic and associated research directly concerned with a scientific and integrated planning of the development of the Hunter Valley. It has recently raised approximately £100,000 for this purpose. It is loosely associated with the Newcastle University College of the University of New South Wales, although administratively quite independent and separately housed. In its early stages, in the opinion of the author, it tended to belittle, by implication, the work of government engineers and scientists in planning national works for the Valley. However, this has now been set right, and all its research committees include representatives of the appropriate government departments, thus ensuring co-ordination of effort and an appreciation of the contribution by various bodies.

The very fact that a research foundation appeals to the public for funds in such matters as flood mitigation and water resources carries the suggestion that the government departments are not doing an adequate job in these fields, and that if the public will "throw in" the foundation will save the situation. Even if this is true (and the author believes there is often much truth in this suggestion) such implications are galling to the many government engineers who have done good work with inadequate resources. However, it is all in a good cause, and the vast majority of engineers in N.S.W. welcome the co-operation and assistance of such fund raising research organisations, albeit with a wry smile at some of the fund raising publicity. It is not reasonable to say that the cost of all water research should be borne by the Government. It is essential that the general public and industrial firms develop the spirit of "self help" so characteristic of the United States. On the other hand, if the public contributes funds to water research foundations, it is up to the governments to make a contribution, say on a pound for pound basis.

Similarly, except for highly technical and relatively narrow self contained topics, research foundations will have no real effect on our progress unless they work in close co-operation with the relevant government departments, all pulling together in a spirit of goodwill and co-operation, even though there must be frank and honest airing of opposing views on some matters.

Ulrich Ellis (9) and others have been asking why C.S.I.R.O. does not have a "Division of Water" instead of treating hydrology and hydraulics as an ancillary sideline. Some years ago the Executive called for a report on the need for research in hydrology, but it seems to have been pigeonholed.

The above developments betoken nothing more than an awakening to the fact that something is amiss in the State of Australia. Progress has been lamentably slow.

If it is agreed that basic and applied research is inadequate in the sciences underlying Water Resources development, the next question is what should be done to improve matters.

As far as essentially technical problems in a specified field are concerned, the answer is obvious - train more undergraduate and graduate students in the appropriate disciplines and provide more money from public and private funds for research.

However, for sound national planning of the development of our river valleys it is necessary to weld together basic and applied research and investigation in hydrology (used in a broad sense), economics, agriculture, and public administration, and this is no easy task.

It must be done at three levels:-

(i) Regional

(ii) State

(iii) Australia wide.

For the regional case, a development of the Hunter Valley Research Foundation concept may be the answer. However, the conversion of such research into tangible results such as dams, irrigation, closer settlement and the like requires legal and executive powers which are not appropriate to a research body. The author inclines to the view that the T. V. A. conception is the answer for administrative action in each region, with a Hunter Valley Research Foundation type of organisation as its forward thinking and planning mechanism.

However, the overall state-wide policy must be formulated at a higher level, and the Valley Authority must operate within an overall plan. To use an army analogy, Brigade Headquarters are in the Valley, but Divisional Headquarters must be in the capital city, with the Premier as the Divisional Commander, and the Heads of the State Water Authorities his staff officers.

At this level there exists at present a serious weakness. The Premier and his staff officers need a group of "backroom boys", representative of Universities in appropriate disciplines and of experienced civil servants from the relevant departments, whose job is to read, think, arrange experiments, and plan the principles of water development for the State, with due regard for land use, marketing, the dismal science of economics and the like.

At present there is a tendency for individual government departments to go their own sweet way without real co-ordination and getting together and asking "What are our objectives, what are the national priorities and what is the best way to achieve our aim?" Of course there are plenty of "ad hoc" and permanent committees aiming at co-ordination, comprising junior officers of the various departments. These cannot serve the function the author has in mind. The long range thinking mechanism should be in the room adjoining the Premier and Treasurer, and independent of all government departments.

If this is too ambitious, perhaps research committees of experts from government departments and Universities could direct the work of small independent groups of research fellows at a University. This arrangement, although admittedly in relatively narrow fields, has operated very well for some of the research fellowships of the Water Research Foundation of Australia.

At the Federal Cabinet level - Army Headquarters - there exists the same problem on a broader scale. Committees No. 2 and 6 and the Standing Committee on Hydrology have given some thought to the idea of a Commonwealth Bureau of Water Resources. The matter is discussed more fully in Appendix B. The ideas of its functions vary from that of merely co-ordinating and publishing hydrologic data to a group of practical thinkers studying the Australia wide scene to advise the Prime Minister in which direction to throw the powerful Commonwealth influence and finance in national water development, ignoring State boundaries, somewhat along the lines discussed by the author elsewhere. (10)

There are at least two possible criticisms of the above proposals.

The first is that they are too idealistic and are founded on a pathetic faith in the reasonableness of human beings. Hence we would do as well in the long run if we barge ahead and build dams, one by one, on all our rivers, leaving the resulting further development to take care of itself. The author feels that this is altogether too cynical a view.

The second criticism is that, so far at any rate as hydrology is concerned, the informed thinkers do not exist in adequate numbers. There is a good deal of truth in this argument. In fact, the author believes that the first essential step is for Universities and scientific circles to pay more attention to such sciences as hydrology. It is suggested that this subject should assume its rightful place in undergraduate civil engineering curricula alongside such well established veterans as Theory of Structures. A suggested syllabus is given in Appendix C.

However, for the carrying out of research work we need men who have mastered the general body of modern knowledge in hydrology. At the time he receives the Bachelor's Degree the young engineer knows "a bit about everything and not much about anything". Almost the only form of post-graduate study existing in Australia at present is the candidature for the conventional degree of Master of Engineering Science, whereby the post-graduate student "learns more and more about less and less", and puts his knowledge in a thesis. There is a need also for formal postgraduate courses of study which will cover fairly thoroughly the existing field of knowledge in some appropriate specialty of civil engineering, so that an engineer who feels that his career will lie in say structural design or water engineering can claim that he has mastered really properly his chosen field of civil engineering knowledge.

The University of New South Wales has inaugurated such courses, leading to the degree of "Master of Technology" in either "Structures" or in "Hydraulics and Hydrology". The syllabus of the hydrology subject in this course is attached in Appendix D.

All will agree that the efficient planning of our water resources development is important to Australia. It is hoped that it will also be agreed that we do not utilise adequately the aid of science in such planning. The logical corollary is that we should put more "glamour" into water engineering so that it can compete with such much-publicised activities as nuclear engineering.

Probably most engineers would also concede that a good case can be made out for more attention being paid to water sciences in engineering curricula. From this point on, however, the method whereby academic research and teaching can be used to help in national planning is, perhaps, a controversial subject. The author hopes that this paper might provoke thought in this direction, and perhaps lead to various forms of effective co-operation between academic and practical members of our profession.

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APPENDIX A TO PAPER ON "HYDROLOGY AND WATER RESOURCES" - C.H. MUNRO

Review of Hydrologic Aspects of Water Resources Projects mainly with Reference to Publications in Jl. I. E. Aust. for period 1949-59.

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1. "The World's Water Supply and Australia's Portion." Nimmo - Jl. I.E. Aust., March, 1949.

The statement is made in this paper that the average depth of runoff from the whole of Australia is 1-1/3 inches per annum, compared with 9 inches for U.S.A.

While there is no doubt that the runoff of Australia is considerably less than U.S.A., the presentation of a figure of 1-1/3 inches must be the result of a good deal of intelligent guesswork, because inadequate measurements have been made of streamflow throughout Australia. One would expect rather a statement such as "a rough estimate of Australia's runoff is somewhere between 3/4 and 3 inches per annum."

Nimmo recognises this in his statement that "actual measurements of streamflow are good in Victoria; fair in N.S.W.; less satisfactory in Queensland, and almost entirely lacking elsewhere."

If Nimmo means "fair for the purposes of establishing total flow from each river system", this statement may be reasonable. If he meant "fair for designing water resources projects then he is much in error. The position in N.S.W. in 1946 from this point of view is better described as "very poor". As far as Queensland is concerned, McCutchan (1) describes a case as late as 1958 in Queensland where 9,000 square miles of catchment was not provided with any pluviographs until late 1955 (and then only two), while only two automatic streamheight recorders were available, being installed in 1956.

Nimmo and other eminent engineers at the 1949 Institution of Engineers" Conference in Perth accused many of the general public of being "ill-informed visionaries" who do not dream quantitatively.

Apparently, however, Nimmo and the rest of the eminent engineers (who thus belaboured the public in 1949 (2) did not practice what they preached, and measure rainfall and streamflow in accordance with principles well established in 1949, in spite of the fact that Butters (3) in 1926 stressed the need to collect data.

Perhaps the governments of the day begrudged the funds for such unglamorous and seemingly unproductive tasks as data collection. Whatever the reason, this neglect has led to much waste in subsequent years.

2. "A Survey of Water Conservation and Supply in Australia"
T.H. Upton Jl. I.E. Aust. March, 1949.

Upton states: "One of the most valuable though silent services being performed and extended by the various State Authorities is the establishment of gauging stations."

The hydrologic design of Warragamba Dam, referred to by Dr Upton in this paper has not been described in the technical press. It is known, however that no pluviographs were installed in the catchment nor were sufficient streamgauging stations in operation to enable unitgraphs to be derived in accordance with practice well established in 1949.

The reader is forced to the conclusion that Dr. Upton was under the impression that streamgauging stations are only used for the type of analysis described by Waitt (4) and was unaware of the work of Sherman, Bernard and Horton. He would no doubt have been well aware of the work of, for example, Abrams in the concrete field. This anomaly arises from the fact that Sherman, Horton and Bernard were never mentioned in University engineering courses whereas the work of Abrams would be well discussed.

3. "Potential Water Power Resources"
Galbraith Jl. I.E. Aust., Dec. 1949.

This writer points out that when the Snowy Mountains investigation began, the only streamgaugings available were those from a daily read staff gauge at Jindabyne, the furthest point downstream at which water could be utilized.

This astonishing state of affairs existed in spite of the fact that the Snowy Scheme in one form or another had been talked about for the previous 50 years.

Even in 1954, when Jamieson (5) was working on the hydrologic design of Adaminaby, the data collection network was quite inadequate (see (Section 9 below).

Galbraith, in the same paper, states that when investigations started on the Kiewa project, there were no meteorological records in existence for any place within the catchment, "as it was uninhabited". It is hoped that he does not regard lack of habitation as an excuse for not collecting data.

Galbraith, in discussing peak flood discharges in this paper, does not even mention storm maximization, although much had been written in this field in U. S. A. at that time.

4. "Flood Mitigation in N. S. W."
Reddoch and Milston, Jl. I. E. Aust., Dec. 1953.

These authors state "As far as is known, there has never been a comprehensive detailed investigation of loss and damage caused by floods in N. S. W."

The economic phase of a flood mitigation investigation is a twin brother of the hydrologic phase. The statement by these authors is therefore a clear criticism of the engineering profession, which is responsible for flood mitigation investigations.

5. "Dams and Reservoirs (Big Eildon Dam)"
R. G. Knight, Proc. Eng. Conference Melbourne, 1953.

This paper is interesting as being the first which refers to modern engineering hydrology, and yet it also contains very considerable discussion of obsolete methods. The Bernard-Sherman technique, although apparently the basis for design of the Big Eildon spillway, is not described in detail. Burns (6) states "nothing is known of Collins' method" This was at that time a well documented method of unitgraph derivation, e.g. (7).

It would seem, therefore, that the standard hydrology text books were not in the library of the State Rivers Commission at this time. There can be no doubt that the standard text books on, say, concrete, were in the library - why not those on hydrology? The fault lies with the Universities.

Burns also says: "The conditions which produced each unit hydrograph are not known because of the absence of continuous recording pluviographs, and the lack of rainfall gauging stations on a large part of the catchment." As the estimated cost of the dam was many millions, it seems strange that the small expenditure necessary to obtain adequate hydrologic data was not incurred. Although the catchment was 5,000 sq. miles in extent, it was apparently not "zoned", and multi-period storms not considered for unitgraph derivation. However, Burns' work is notable as being apparently the first application in Australia of modern techniques in flood estimation.

6. "Upper Yarra Dam"
Caine, Proc. 1953 Melbourne Conference.

Although the spillway and river diversion costs amounted to £2,500,000 out of a total cost of £12,600,000, it was found that a satisfactory unit hydrograph could not be deduced from the records, and synthetic unitgraph methods were perforce adopted. Synthetic procedures are adequate for minor rural structures, but not for a major dam. Surely the dam was conceived a good many years before designs were finalised, and a determined effort would have collected enough data for deriving reliable unitgraphs. Probably the importance of such data was not realized, which is not surprising in view of the neglect of hydrology by Universities.

7. "Availability of Hydrologic Data in Victoria "
K. Green, Jl. I.E. Aust., Sept., 1956.

This author states "There are only 34 recording rain gauges in the State, 16 of which are in the metropolitan area. - The installation of automatic recording streamgauges began in 1935 and today there are 33 station."

This is an inadequate number, if a modern approach to engineering hydrology is to be used for the design of projects.

8. "Development of Unit Hydrographs under Australian Conditions."
P.H. FeKete Jl. I.E. Aust. Oct. Nov., 1954.

The author has examined 16 catchments in N.S.W. to ascertain whether data existed which was adequate for deriving unit hydrographs. Of 16 catchments only 6 were rated at high flows. One of the 6 catchments was unsuitable because of questionable accuracy of the rating curve. Of the five remaining, four were equipped only with staff gauges, while the remaining one had installed on it a "Bristol" pressure recorder. The network of daily read raingauges was good on three of the four catchments and poor on the other, which was eliminated. This one incidentally had the Bristol recorder. The remaining three catchments were reasonably equipped with pluviographs, i.e. 3 catchments out of 16 were adequately instrumented.

9. "Hydrologic Studies for Adaminaby Dam."
L. N. Jamieson, Jl. I. E. Aust., Oct. Nov. 1954.

This author had one reliable streamgauging station, established in 1944, and two daily read rain gauges on the catchment of 260 sq. miles, with four stations just outside the catchment, and two pluviographs since 1951.

In view of the fact that the Snowy Scheme had been under discussion in a general way since the turn of the century, and in a detailed way from 1946, these data are surprisingly inadequate.

10. "Pine Tier Dam"
L. S. Whitehouse, Jl. I E. Aust., Ap. May, 1955.

For estimation of spillway design flood enveloping curve and synthetic unitgraph methods were used. A pneumatic streamheight recorder and a couple of pluviographs could have been installed for a cost of £400 to £600, and a few years of record should have permitted the derivation of reliable unitgraphs. Surely this is not an unreasonable expenditure on investigation for a dam costing 1-1/2 million pounds.

11. "Trevallyn Power Development."
Thomas, Jl. I.E. Aust., Jan. Feb. 1957.

Although a staff gauge has been read and recorded in the lower reaches of the S. Esk river since 1900, no attempt was made to "rate" the station until a few years before Trevallyn Dam was due to be completed, and of course Nature turned obstinate and provided only low discharges until the dam was complete. Incidentally, no attempt at all was made to measure discharges in the lower reaches of the N. Esk until 1957.

It could be argued that the fault here lies with the legislators, but surely it is the task of the engineering profession to press for the necessary legislation.

The spillway design was based on an enveloping curve method. It is most surprising that a unit hydrograph was not derived.

12. "Mareeba - Dimbulah Irrigation Project"
G. E. McDowell and F. J. Calvert. Jl. I. E. Aust. Sept., 1957.

The following extracts are relevant:-

"The nearest station for which evaporation records were available was at Home Hill on the Burdekin River about 200 miles south, on the coast".

"No streamflow statistics were available at Tynaroo Falls, and it was necessary to estimate the discharge at the site from two gauging stations," one 20 miles downstream and one 20 miles upstream.

"The lack of reliable information on water requirements of the irrigated crops necessitated an estimation of the likely irrigation demand".

"It is considered that the investigations were as complete as can normally be afforded up to the stage of ..... actual commencement of construction."

The concept of thorough preliminary investigation is well recognised by these writers, but their idea of what "can normally be afforded" sounds more like the ideas of a State Treasurer than those of an investigating engineer.

13. "Flood Mitigation in the Lower Hunter River"
E. W. Harrison. Jl. I. E. Aust., Dec. 1957.

Hydrologic data collection and analysis is barely mentioned in this paper.

14. "Design of Glenbawn Dam"
N. A. Wilson and H. S. Scott.

Hydrologic data collection and analysis is barely mentioned in this paper. Why not? Is the hydrologic design of a dam not just as important as the structural design?

REFERENCES FOR APPENDIX A

1. McCutcheon - "Flood Studies for Dawson River" cyclostyled publication - Symposium of Hydrology Committee and Water Resources Conference, Melbourne, April, 1959.

2. Jl. I.E. Aust. Apl-May, 1949, p. 78.

3. Butters - Trans. Inst. Eng. Aust. Vol. VII, 1926.

4. Waitt - Jl. I.E. Aust. Apl. -May, 1925.

5. Jamieson - Jl. I.E. Aust. Oct. -Nov. 1954.

6. Burns - Jl. I.E. Aust. Jan. -Feb. 1954 p. 24.

7. Johnstone - Cross "Elements of Applied Hydrology" 1949 (Ronald Press N.Y.)

APPENDIX B TO PAPER ON "HYDROLOGY AND WATER RESOURCES" by C. H. MUNRO

Since the end of World War II there has been a growing body of thought which feels that on account of the great importance of water resources development to Australia the Commonwealth Government should play a more active part in this field.

Some argue that if a Commonwealth "Bureau of Mineral Resources is justified then a Commonwealth "Bureau of Water Resources" is even more justified.

Early thoughts on the matter had reference to the relatively limited field of collection of data, and this concept implies a Commonwealth Bureau responsible for activities somewhat along the following lines:-

(a) To organise the collection, collation, centralised recording and filing, co-ordination and publication of data relating to streamflow, both surface and underground, and to the water resources of the Commonwealth generally;

(b) To initiate action to fill in the gaps in hydrologic data collection throughout the Commonwealth;

(c) To provide facilities for standard testing of hydrologic instruments, and issue appropriate certificates.

(d) To encourage hydrologic research and the publication of technical reports, and to disseminate in a standard manner the results of data collection.

More recently a somewhat broader conception of the part to be played by the Commonwealth Government has been put forward.

The water Resources Policy Commission of the President of the U.S.A., in 1950 reported as follows:-

> "The Nation should have comprehensive, multiple-purpose, and co-ordinated plans for.... regions.... Each of the plans should be carefully adapted to the potentialities of the region as well as to regional needs and should include local and State as well as Federal undertakings. Such a plan need not initially be in complete detail, but it should constitute a framework into which can be fitted, in proper relation to all other activities the projects and programs as they are further developed."

It also said:-

"Planning for water resources cannot be dissociated from planning for all resources. Nor can it be dissociated from those fields of economic activity which give rise to the needs to be met by water developments. This leads to the further conclusion that water developments should be planned as integral parts of basin programmes."

As a result of this report the whole question was re-examined by various bodies in U.S.A., and in 1956 the Presidential Advisory Committee on Water Resources Policy recommended the setting up of a permanent inter-agency Committee to advise the President regarding programmes for basin or regional water resources programmes. President Eisenhower has endorsed this and other recommendations of the Committee, and has indicated his intention of recommending legislation to make them effective.

Moreell (1), Hathaway (2), Hoak (3) and Cook (4) have also discussed the U.S.A. scene.

It is considered that the above comments regarding U. S.A. apply with equal force to Australia, although it is recognised that because of the great differences in the administrative pattern in the two countries it would be foolish to attempt to base Australian planning directly on any established procedure in U.S.A.

It is surely reasonable that at the Federal Cabinet level there should be a group of practical thinkers who are arranging for the covering of overall Australia wide hydrologic and economic data, and studying the comprehensive nation-wide picture in the light of this data, without regard to State boundaries, in order that they may advise the Federal Government of the manner in which its influence and finance should be directed in the development of Australia's Water resources.

While most Australians would agree that something should be done in this matter, it is not so easy to specify just exactly what should be done and how it should be done. The question of State and Commonwealth rights and responsibilities, the varying types of organisations already existing amongst the States, and similar matters, present any planners of the functions of a Commonwealth-wide Bureau with a rather confused picture. In the Agricultural field this problem of State and Commonwealth co-operation was tackled in 1934 by Sir Earle Page, and as a result the Australian Agricultural Council was set up, its functions and methods of operation being well discussed by Grogan (5).

It is doubtful whether this approach would quite fill the bill for the water problem.

It is therefore considered by many that the first step in this important national problem is to appoint a Committee of Enquiry consisting of three senior and experienced officers, one at least of whom shall be an eminent water engineer, to report to the Commonwealth Government on whether or not a Bureau of Water Resources or some similar body should be set up at the Commonwealth level, and if such a Bureau is recommended, to specify its functions and the manner in which it should carry out this work with particular reference to co-ordination of the activities of existing Commonwealth and State instrumentalities.

REFERENCES FOR APPENDIX B

1. Moreell - Civil Eng. 26th May, 1956.
2. Hathaway - " " 26th Sept., 1956.
3. Hoak " " 27th May, 1957 - Report of E. J. C. Board of Review.
4. Cook - Agric. Eng. March, 1957.
5. Grogan - Jl. of Public Administration (Australian Regional Group) Vol. XVII No. 1 March, 1958.

APPENDIX C TO PAPER ON "HYDROLOGY AND WATER RESOURCES" by C.H. MUNRO

THE UNIVERSITY OF NEW SOUTH WALES

School of Civil Engineering

SUBJECT	:	8.63B Hydrology
DATE	:	January, 1959
COURSE	:	Civil Engineering Degree
DURATION	:	18 hours lectures
REFERENCE BOOKS	:	Wisler and Brater - Hydrology Johnstone and Cross - Elements of Applied Hydrology Linsley, Kohler and Paulhus - Applied Hydrology.

SYLLABUS

Scope and importance of hydrology - applications and history - Australia's water resources - Hydrologic cycle - Hydrologic design - Data collection.

Elementary meteorology - terrestrial heat balance - circulation of atmosphere - pressure systems - Australian applications.

Elementary climatology - variations of climate in Australia Climatic systems - Koeppen Thornthwaite.

Analysis of hydrologic data - bar charts, hyetographs, moving averages, mass curves, cumulative frequency curves, rainfall variability, water year storage period variation of rainfall with altitude and area - isohyetal maps, thiessen polygons. Depth-duration-area data. Frequency of occurrence of intense rainfalls. Correction of precipitation records - double mass curves, interpolation - frequency and cumulative frequency curves of streamflow - mass curves and residual mass curves of streamflow.

Streamgauging - Requirements of gauging section - current meter measurements - recording and calculations - float gaugings - stage-discharge relations - artificial controls - rating curve extrapolation - stage measurement and recording - siting of gauges and records - slope - stage discharge relations - slope-area method - accuracy of streamflow records.

The Runoff Process - The runoff cycle, general description, and discussion of its component phenomena - components of the flood hydrograph - base flow separation - algebraic analysis of hydrograph shape - channel storage - parts of the hydrograph - types of streams - effect of storms on streamflow.

Infiltration - Description of process factors affecting infiltration rate - variation of infiltration capacity during storms - measurement of infiltration capacity - infiltration indices and loss rates - types of indices - derivation of Ø index - effects of partial area storms and time period used on the derivation.

Flood Estimation - The problem and analysis required factors affecting flood magnitude - empirical formulae for flood estimation - enveloping curve method - flood frequency studies preparation of frequency curves - sampling errors - applications - Rational method - time of concentration - runoff coefficient defects and applications of the method - loss rate - unitgraph method - unitgraph theory - derivation of unitgraphs from single period storms - application of unitgraphs - distribution graphs - summary of methods of flood estimation and their application.

Yield - The problem - water balance of a catchment - rainfall - runoff relations - factors affecting losses - streamflow correlations - factors affecting required storage - mass curve analysis and residual mass curve analysis - storage yield curve - behaviour diagram - artificial droughts - mention of probability approach to storage determination - empirical formulae for storage determination.

APPENDIX D TO PAPER ON "HYDROLOGY AND WATER RESOURCES" by C.H. MUNRO

THE UNIVERSITY OF NEW SOUTH WALES

School of Civil Engineering

SUBJECT	:	8.519 Hydrology I.
DATE	:	June, 1959.
COURSE	:	Master of Technology (Hydrology and Hydraulics).
DURATION	:	51 hours lectures and 34 hours tutorial.

REFERENCE BOOKS:-

Butler	-	"Engineering Hydrology"
Wisler and Brater	-	"Hydrology"
Johnstone and Cross	-	"Elements of Applied Hydrology"
Linsley, Kohler and Paulhus	-	"Applied Hydrology" "Hydrology for Engineers"
Linsley and Franzini	-	"Elements of Hydraulic Engineering"
Rouse (Ed.)	-	"Engineering Hydraulics"
American Society of Civil Engineers	-	"Hydrology Handbook" (Manual of Engineering Practice No. 28)
Institution of Engrs., Australia	-	"Australian Rainfall and Runoff" (Report of the Stormwater Standards Committee)

SYLLABUS

1. INTRODUCTION - SCOPE OF HYDROLOGY.

Definition and history of Hydrology. Related subjects. Hydrology in Australia - importance, development and scope. Water resources of Australia. Hydrologic Design - need for scientific approach. Design of Urban, small and large rural drainage systems, irrigation and water supply, flood control water storages (flood and yield), navigation, recreation, flora and fauna, erosion control, soil conservation, pollution, sediment transportation and siltation, operation of water schemes.

2. CLIMATOLOGY FOR ENGINEERS.

Definitions, the Atmosphere motions of the earth, Solar radiation and terrestrial heat balance, General circulation of atmosphere, Influences of land masses and sea on climate, Influences of topography, vegetation and human activity on climate, climate changes, classifications of climate - Thornthwaite, Koeppen, Comfort zones, Climate of Australia. Applied Climatology - agricultural and industrial uses of climatic data.

3. METEOROLOGY FOR ENGINEERS.

Meteorological measurements - temperature humidity, pressure, wind geostrophic and cyclostrophic, gradient wind, precipitation types orographic, frontal convergent. The circulation of the atmosphere and pressure systems, anticyclones. Physical properties of the atmosphere, gas equation, altimetry equation, isothermal atmosphere, constant lapse rate atmosphere. I. O. A. N. atmosphere. thermodynamics of atmosphere. Dry adiabatic lapse rate, Wet adiabatic lapse rate, stability of atmosphere, adiabatic charts and thermo dynamic diagrams, conditional instability. Weather forecasting for engineering - flood forecasts.

4. THE COLLECTION OF HYDROLOGIC DATA.

Importance of data collection, Meteorological data, telegraphic reports, monthly returns, punch cards, unofficial recorders, extrapolation, climatological records, weather maps. Meteorological measurements and instruments, siting, pluviometers, telemeters, storage gauges, special networks, errors, snow surveys and courses, phenological observations. Rain gauge networks -

4. THE COLLECTION OF HYDROLOGIC DATA (Cont'd.)

factors, errors. Records of stream flow, authorities, historical, special reports. Data from other countries. Required network density for hydrologic measurements.

5. STREAM GAUGING.

5.1 Measurement of Discharge. Equation of continuity, $Q = \Sigma (V. \Delta A)$ Measurement of ΔA by graduated lines and sounding equipment. Measurement of V. by current meters - types and design differences, advantages and disadvantages of types. Auxiliary equipment - rods cables, bridges, travellers, etc. Rating of current meters - types of rating base, rating methods, graphs, tables. Gauging procedures - methods adopted for low and high flows, measurements at a few depths, multiple point measurements, velocity integrations techniques used with floats, velocity rods, flumes, weirs. Other methods of measuring V - volumetric methods, contracted opening and slope-area methods.

5.2 Relation between Stage and Discharge. The control - low and high water controls, permanence, stability and sensitivity of controls. The Gauging Site - description of ideal site Instrumentation - staff gauges, peak level indicators, stream level recorders - Advantages and disadvantages of different types of recorders. Types of recorders - description and comments on suitability for different purposes. Telemetering Instruments. Stage-discharge (or rating) curves - simple and complex; plotting the curve. Effect of shifting control and corrections to rating curves. Effect of unsteady flow on rating curve - corrections to Q depend on $\partial h/\partial x$, $\partial h/\partial t$, Q and $\partial Q/\partial t$; simplified corrections for surface slope; use of auxiliary gauge; plotting of normal-fall correction curve; simplified corrections for rate of rise and fall; loop rating curves and their uses.

5.3 Office Work. Computation of discharge by average daily stage. Discharge integrator - description, advantages and disadvantages. Electronic computers - at present used for current meter rating tables; possible future use in calculation of stream discharge.

6. ANALYSIS OF HYDROLOGIC DATA.

6.1 Presentation of Hydrologic Data.

Rainfall - bar charts, moving average, hyetograph, mass curve synthesis of mass curves, analysis of pluviometer charts.
Streamflow - hydrograph, mass curve, residual mass curve.
Wind - wind roses for frequency and velocity.

6.2 Areal distribution of Precipitation.

Determination of areal average precipitation - arithmetic mean, Thiessen method, isohyetal method, inclined plane method.
Depth - area - duration studies.
Relation of areal average to local storm rainfall.
Variation of Precipitation with Elevation.
Meteorological Homogeneity.
Isopercental maps.

6.3 Temporal Distribution of Precipitation.

Variations of annual and seasonal precipitation.
Duration of storm rainfall.
Storm intensity pattern.
Water year, storage period.

6.4 Consistency and Correction of Hydrologic Data.

Method of ratios.
Double mass curves.

6.5 Frequency Analysis of Hydrologic Data.

Types of long term variation - trends, cycles.
Frequency curves, cumulative frequency curves (duration curves).
Point depth-duration-frequency studies.
Depth-duration-frequency-area relations.
Station year method.
Relation between storm frequency and flood frequency.
Relation between design recurrence interval and economic life of structure.

7. THE RUNOFF PROCESS.

7.1 The Runoff Cycle

7.11 General description of Runoff Cycle, and detailed discussion of the following phenomena, including, where possible, notes on rates and magnitudes - channel precipitation, interception, depression storage, surface runoff, infiltration, rainfall-excess, soil moisture, interflow, percolation, groundwater.

7.12 Discussion of initial, supply, and residual periods, and initial loss.

7.2 Analysis of Hydrograph Shape.

7.21 Factors affecting hydrograph shape

a. Storm factors.

b. Catchment characteristics.

(i) Infiltration do.

(ii) Physiographic factors.

This section to include discussion of the time-area diagram, and channel storage.

7.22 Separation of Hydrograph into its four components, surface runoff, interflow, groundwater flow, and channel precipitation.

7.3 Overland Flow Theory
(Brief Treatment)

8. INFILTRATION

8.1 The Infiltration Process

Description of Process.
Infiltration Capacity.
Factors affecting Infiltration Rate.
Temporal variation of infiltration rate and infiltration capacity.
Measurement of infiltration rate and capacity.

8.2 Introduction to Mathematical Theories of Soil Water Movement.

Soil moisture-energy relationships.
Soil water movement.
Infiltration rate theories.

8.3 Infiltration Indices and Loss Rates.

Types of Indices - ϕ, f_{av}, W, W_{min}.
Derivation of Indices.
Dependence on Temporal pattern of storm.
Effect of Partial Area storms.
Temporal variation of ϕ - index.
Variability of Loss Rates.
Sources of Design Values.

9. FLOOD ESTIMATION.

9.1 Introduction

The problem.
Analysis required.
Illustrative Magnitudes.
Factors affecting flood magnitudes.

9.2 The Rational Method.

Simple Rational Formula.
Time of Concentration.
Rainfall Intensity.
Runoff coefficient.
Defects of Method.
Applications of Method.
Refinements of Method.
Use of formula $q = A (p - f)$

9.3 Loss Rate - Unitgraph Method.

Definition of Unitgraph.
Unitgraph Theory.
Derivation of Unitgraphs from single period storms.
Selection of unit period.
Changing the unit period.
Application of unitgraphs.
Distribution graphs.

9.4 Flood Frequency Studies.

Preparation of Frequency Curves.
Sampling Errors.
Confidence Limits
Applications.

9.5 Empirical Formulae.

9.6 Enveloping Curves.

10. EVAPORATION AND TRANSPIRATION.

Evaporation as portion of the hydrologic cycle.
Process of evaporation, theory and relationships between elements.
Empirical Formulae.
Calculation of evaporation - surface energy balance, vapour flow, combination of energy balance and vapour flow, water balance methods. Instruments for measuring evaporation, lysimeters - tank factors.
Potential evapo-transpiration (evaporation opportunity).
The estimation of evaporation and consumptive use, - Irrigation need - work of Blaney, Criddle, Van Bavel, Penman, Lowryt and Johnson, Thornthwaite.
Evaporation in Australia - its value and variations.
The Manfield process.
Summary of Factors affecting total losses for a catchment.

11 YIELD.

11.1 Introduction

The Problem.
Definitions.
Water Balance of a catchment.

11.2 Rainfall-runoff Relations.

Factors affecting losses.
Form of Relationship.
Simple correlations - examples.
Multiple correlations.

11.3 Streamflow Correlations.

Examples.

11.4 Storage Required.

Factors affecting required storage - demand, compensation, flow, variability of streamflow, reliability of supply required.
Mass Curve Analysis.
Residual Mass Curve Analysis.
Storage-yield curve.
Behaviour diagram.
Artificial droughts.
Empirical formulae for storage capacity.

APPENDIX E TO PAPER ON "HYDROLOGY AND WATER RESOURCES" by C.H. MUNRO.

THE UNIVERSITY OF NEW SOUTH WALES

School of Civil Engineering

SUBJECT	:	8 520 Hydrology II
DATE	:	June, 1959
COURSE	:	Master of Technology (Hydrology and Hydraulics)
DURATION	:	51 hours lectures, 17 hours tutorial, and approximately 100 hours project time.
REFERENCE BOOKS	:	As for 8.519 Hydrology I.

SYLLABUS:

A. FLOOD ESTIMATION

1. HYDROMETEOROLOGY.

The precipitation process - storm models frontal, topographic and convectional precipitation. Moisture charge of a storm - basin constants, wind velocities - dew point persistence.
Determination of precipitable water, Effective precipitable water, Meteorological homogeneity - Australian regions. Physical upper limits of precipitation - maximisation of storms, consideration of efficiency, moisture charge, inflow velocities and storm model. Maximum possible studies in Australia. Depth duration area analyses and their maximisations - Australian data and curves - Data from other countries. The thunderstorm model and maximum values. Transposition of storms. Generalised values - formulae maximum possible and frequency.
Snowmelt - its computation.

2. DESIGN STORM SYNTHESIS

Choice of Method.
Security against surcharging.
Determination of mean intensity.
Reduction of point intensity for area.
Temporal pattern.

3. UNITGRAPHS.

Historical review - Sherman's basic theory - relation to "rational method" - theory of unitgraph derivation - practical substantiation of theory - preparation of unitgraphs for multi-period storms - data preparation - graphical analyses, Fort Belveir method and the McCarthy method - mathematical analysis, Collin's method, least squares solution - use of UTECOM to derive unitgraphs - advantages and disadvantages of the derivation of unitgraphs from single period and multi-period storms - application of unitgraph theory - selection of the unit period - variation of unitgraph ordinates with magnitude of flood - effect of temporal and areal distributions of rainfall pattern - selection of unitgraph for the design storm - unitgraph research being undertaken - further research required.

4. FLOOD ROUTING.

4.1 Introduction.

The Problem.
Applications.

4.2 Storage Equation.

4.3 Determination of Storage.

By Survey.
By hydrograph analysis.
Intermediate inflow or outflow.

4.4 Storage-discharge Relationships.

Storage as a function of outflow.
Prism storage and wedge storage.
Storage as a function of inflow and outflow.
Linear and non-linear storage-discharge relations, examples.
Mathematical form of relation.
Storage-discharge relations in long reaches.

4.5 Storage Routing.

Muskingum Method.
Graphical Methods (Representative types).
Mechanical Analogues.
Electronic do.
Use of electronic digital and analogue computers.

Use of hydraulic models.
Lag method.
Lag and route (x = 0) method.
Exact solution in terms of the energy equation as well as the equation of continuity.

4.6 Non-storage Routing.

Stage relations.
Time of travel relations.
Complex relations involving intermediate inflow.

5. CATCHMENT CHARACTERISTICS.

Introduction

Numerical and graphical measures of -
Area
Shape
Stream pattern
Stream density
Drainage density
Overland slope
Stream slope
Elevation
Size of channel
Condition of channel

6. SYNTHETIC UNITGRAPHS.

6.1 Introduction

The Problem.
Method of solution.
Methods proposed.
Status of synthetic unitgraph procedures.

6.2 Procedures based on the Routing of a Time-Area Diagram through Channel Storage.

Basis of Procedures.
Determination of the Time-Area Diagram.
Approximations to the Time-Area Diagram.
Determination of Storage Effect.
Routing Procedure.
Summary and Example.

6.3 Snyder's Method and its Development.

Snyder's Method.
Taylor and Schwarz' method.
Other Developments - U.S. Corps of Engineers, U.S. Bureau of Reclamation, Loden, Reilly, and Minette.

6.4 Other Methods.

Sherman, Bernard, McCarthy, Morgan and Hullinghorst.

7. FLOOD FREQUENCY STUDIES.

7.1 Review of first year work, basic principles, frequency curves, plotting position.
Historical review of development of method.
Curve fitting - methods of Hazen, Goodrich, Slade, Gumbel, Chow, Jenkinson and Moran.

7.2 Errors

Uncertainty as to form of distribution.
Sampling errors.
Confidence limits.
Non-homogeneity of record.

7.3 Regional Frequency Studies.

Station-year method.
Flood peak-area-frequency relations.
Correlation of flood peak with rainfall and topographic features as well as frequency.

7.4 Extending the Flood Record.

Use of historic floods.
Estimation of past floods from rainfall by ordinary flood estimation procedures.

7.5 Conclusion and applications of Method.

8. URBAN DRAINAGE DESIGN.

Methods - rational, overland flow, synthetic unitgraph methods.

Coefficient of runoff - definition, weakness of concept, determination, sources of values.

Time of concentration - overland flow time, gutter flow time, drain flow time.

Lloyd-Davies method - algebraic illustration of principles for drains fed continuously and intermittently along their length. Theoretical objection to method.

Trial and error method.

Partial area storms.

The tangent check, S-line method.

Temporal variation in rainfall intensity.

Overland Flow method. Johns Hopkins, D. S. I. R. methods.

9. COLLATION, REVIEW, SUMMARY OF FLOOD ESTIMATION.

9.1 Procedure for loss rate - unitgraph method - Design storm, critical duration, mean intensity (design frequency or max. possible), temporal pattern, Loss rate, Snowmelt, Unitgraph or synthetic unitgraph, Application of rainfall-excess to unitgraph, Groundwater flow, Flood routing.

9.2 Review and summary of methods of flood estimation and their applications. Rational method, overland flow method, empirical formulae, enveloping curves, probability method, loss rate unitgraph method.

B. YIELD

10. RAINFALL-RUNOFF RELATIONS.

10.1 Short-Period Relations.

Multi-variable correlations, with their applicability to Australian conditions. Possible ways of applying electronic computers to multi-variable correlations.

10.2 Long-Period Relations.

General comments on Q-P graphs - scales, scatter of points. Index of seasonal wetness. Differences between Q-P relations for arid, semi-arid and humid basins. Brief reference to historical formulae such as that of Justin Meyer's hydrophysical method, including discussion on effects of evapo-transpiration. McDonald's "recession from storage" method. Brief reference to certain empirical methods - Khosla, Parker, Olsen's method for a poorly gauged catchment using data from nearby catchments. Penman's "water balance" method involving estimates of evapo-transpiration. Application of "yield lines" in Snowy Mountains area. Comparison of various methods. Effect of snowfall on Q-P relations. Discussion of actual Q-P relations which have been measured, with particular reference to Australian catchments.

11. PROBABILITY METHODS OF STORAGE DETERMINATION.

11.1 Mathematical Introduction.

Homogeneity. Correlation in time-series. Sampling errors. Theory of distribution of extreme values. Queuing theory. Monte Carlo methods. Types of flow distribution and linearization. Control curves. Extension of duration curves. Trends.

11.2 Application to Storages.

Reasons for probability approach. Comparison with other methods. Reference to history of probability methods, explaining the techniques used by Hazen, Sudler, Hurst, Thomson and Thompson, Barnes, Moran, Law (including his revised method of 1955), and Gould. The "ideal" method. Comments on the above methods in relation to the "ideal".

C. GROUNDWATER AND ENGINEERING APPLICATIONS OF HYDROLOGY.

12. GROUNDWATER.

(Detailed Syllabus to be determined).

13. ENGINEERING APPLICATIONS.

Economic studies, flood control, flood mitigation, flood forecasting, telemetry, hydro-electric engineering, dam design, water supply, water conservation, multi-purpose schemes, data collection planning, review of major Australian water projects.