Australian Policy for Hydrologic Education. July 1963.

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Publication details:
Commissioning Body: Australian Academy of Science. Australia.
Report No. UNSW Water Research Laboratory Report No. 67

Publication Date:
1963

DOI:
https://doi.org/10.4225/53/5795993dcaad4

THE UNIVERSITY OF NEW SOUTH WALES

WATER RESEARCH LABORATORY

REPORT No. 67

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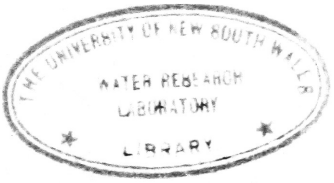
by

C. H. Munro



JULY, 1963

AUSTRALIAN ACADEMY OF SCIENCE NATIONAL SYMPOSIUM ON WATER RESOURCES, USE AND MANAGEMENT

SECTION F - EDUCATIONAL POLICY

GENERAL REVIEW OF THE AUSTRALIAN SCENE

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GENERAL REVIEW OF THE AUSTRALIAN SCENE

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SUMMARY.

Existing educational provision in Australia for the study of sciences and technologies underlying water resources development is reviewed critically, and the neglect of this field in favour of old fashioned traditional and new fangled "glamour" topics is deplored

The need for a study of the hydrologic cycle and related topics in primary and secondary schools and the inclusion of courses in hydrology as separate subjects in their own right in University undergraduate courses is stated . However, it is argued that the greatest need for the more efficient planning of Australia's water resources development is formal post-graduate courses of one year's full-time study, designed to prepare engineers and scientists for research and practice in this field. The value of hydrology as a training in scientific method is stressed. Ways and means of improving the situation are discussed, and recommendations made in regard to secondary schools and undergraduate courses, for financial assistance to formal graduate courses in water resources; and for closer liaison between Universities Commonwealth Scientific and Industrial Research Organisation and Universities in teaching and research.

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AUSTRALIAN EDUCATIONAL POLICY ESSENTIAL FOR EFFICIENT PLANNING OF USE AND MANAGEMENT OF WATER RESOURCES.

-by-

C. H. MUNRO.

1. INTRODUCTION.

As leader of the "Educational Policy" Section of the National Symposium on Water Resources Use and Management sponsored by the Academy of Science the author is charged with the task of presenting a paper as a basis for discussion. A few of the leaders of other sections of the symposium have made suggestions for improvements in the existing practice of Australian educational authorities and the essence of these have been included. However, the great bulk of the contents of this paper is based on the author's personal experience and viewpoint.

Water resource technologies depend on the basic subjects of hydrology, hydraulics, agriculture, geography, geology, forestry, meteorology, mathematical statistics and economics. The author considers that all of these subjects except hydrology are adequately catered for at all levels as individual disciplines. The weaknesses of the present situation are:-

(i) Inadequate tuition at all levels in hydrology;

(ii) Lack of co-operation between workers in the above separate disciplines;

(iii) The lack of any system of training water resources experts with an integrated knowledge of hydrology and hydraulics, and those portions of the other disciplines which are fundamental in the planning of water utilization and control.

There is a tendency nowadays to widen the term "hydrology" to embrace a training for (iii) above. The inter-university conference on hydrology at Lake Arrowhead, California, in August 1962, described by Todd, D. K. (1962) defines hydrology as "the science that treats of the waters of the Earth, their occurrence, circulation, and distribution, their chemical and physical properties, and their reaction to their environment, including their relation to living things. This conference report goes on to state that "hydrology is an interdisciplinary

science which is related to a diversity of traditional university departments, including agronomy, biology, civil engineering, forestry, geography, geology, irrigation and meteorology" but stresses that the important unifying concept is the fact that hydrology embraces the full life history of water on the Earth. For the purposes of this paper, the author will define training in hydrology as that which is necessary to enable the student to qualify as a specialist in the planning of the use and control of water.

2. HYDROLOGIC EDUCATION IN SECONDARY SCHOOLS.

In the past, in New South Wales at least, schoolboys studied "physics" and "chemistry" and schoolgirls, say "biology" and "geology". The elements of the Carnot cycle, or the cycle of death and decay would be studied, but the hydrologic cycle, which is just as important to human existence, would not be mentioned. The secondary school system in New South Wales has recently adopted a very broad four year post primary programme leading to a "school leaving certificate" followed by two further years of relatively specialised study providing an adequate foundation for University courses. Under the new system, so far as science is concerned, the objective is to integrate the sciences into one unified concept. Judging by the pilot edition of the authorised text book, edited by Messel, H. (1963), the objective of true integration has not been achieved. Nevertheless, all students will receive a series of introductions to geology, biology physics, chemistry and meteorology. So far as this discussion is concerned, it suffices to note that the hydrologic cycle and meteorological phenomena do receive some attention. However, they appear as isolated incidents in the course. It could be argued that the unified topic of "conservation of natural resources of soil, water, plants and fauna" is surely appropriate at the school level in a modern civilization. Water is so important to Australia and the world that every citizen should be as familiar with basic hydrologic phenomena as he is with Newton's law of gravity. Teachers both in science and social studies should approach the subject with due regard to the physical, agricultural, engineering and economic points of view. The physical problems involved lend themselves readily to in-

expensive experimental study, and many applications of mathematical principles should be embodied in such a course. Student interest could readily be aroused. Human beings of all ages are interested in the weather, in the flow of water and the growth of plants.

A misleading feature of the mass media propaganda in Australia in recent years has been the glamourizing of nuclear physics, space travel, radio-astronomy, rocketry, pre-stressed concrete and the like, with the result that the youth of Australia neglects the equally interesting and rewarding - and to Australia more important - fields of conservation and utilization of natural resources. As a result the sciences underlying conservation are not receiving a fair share of the oncoming, more able, youth of the country. Hence in the new school science course in New South Wales, hydrology and conservation topics play the role of members of the chorus in the background, with the forefront of the stage and the spotlights devoted to traditional geology, biology, physics and chemistry. This is only to be expected, as the teachers have never been exposed to a systematic treatment of hydrology and conservation. Perhaps a working group, sponsored by the Academy of Science, and composed of practising experts as well as educationists, should be set up to advise on suitable courses, texts and experiments for secondary schools. At the primary school level the same comments apply, although the approach would be elementary and descriptive. Of the other States of Australia, it is understood that only in Victoria is there a four year "general science" course as an introduction to more specialised courses.

3. HYDROLOGIC EDUCATION IN UNIVERSITIES.

3.1 Importance of Hydrology.

The author concedes that the advisability of promoting hydrology and conservation from the chorus to solo parts in secondary school syllabi may well be a matter for debate. But at the University level the case for a revised attitude is surely unassailable. Action at this level is much more important than at the school level. This theme will be developed more fully later in Section 4.1 of this discussion, but it is convenient first to consider the present state of hydrologic education in Universities.

3.2 Hydrology in Australian Universities.

As far as can be ascertained, the only courses which include hydrology as a topic in its own right, with at least 10 hours of lecture time, are:-

(a) University of Melbourne Undergraduate Course Leading to Degree in Surveying.

(i) Hydrology - 13 lectures on hydraulics and 13 on hydrology covering the hydrologic cycle, general survey, precipitation, random processes, infiltration, rainfall-runoff relations, streamgauging, flood estimation, flow regulation.

(b) University of Melbourne Undergraduate Course Leading to Degree in Agricultural Engineering.

(i) Hydrology - 27 lectures on rainfall, evaporation, infiltration, runoff, groundwater, drainage.

(c) University of Melbourne Undergraduate Course Leading to Degree in Civil Engineering.

(i) Hydrology - 10 lectures as for (b)(i) but concentrating on surface hydrology, and groundwater hydraulics.

(d) University of New South Wales Undergraduate Course Leading to Degree of Bachelor of Civil Engineering.

(i) Full-time Course.

Engineering hydrology (part B of "Civil Engineering") 36 hours.

(ii) Part-time Course.

Engineering hydrology (part B of "Civil Engineering") 15 hours.

(e) University of New South Wales, Undergraduate Course Leading to Degree of Bachelor of Science (Technology) in Civil Engineering (part-time Course)

(i) Engineering hydrology (part B of "Civil Engineering") 36 hours.

(f) University of New South Wales Undergraduate Course Leading to Degree of Bachelor of Surveying.

(i) Engineering Hydrology (Part B of "Civil Engineering") 36 hours

(g) University of New South Wales Post-graduate Courses Leading to Degree of Master of Technology in Hydrology and Hydraulics.

The M. Tech. courses provide for one year of full-time or two to three years of part-time study.

Hydrodynamics	60 hours
Advanced Hydraulics	75 "
Hydraulic Design	45 "
Laboratory Practice	60 "
Hydrology I	90 "
Hydrology II	90 "
Irrigation and Drainage	90 "

Project - which may be of a hydraulic or hydrologic nature, involving a specific investigation or design.

(h) University of New South Wales Post-graduate Course Leading to Degree of Master of Technology in Public Health Engineering.

(i) Hydrology I of (g) above.

(i) University of New South Wales Special Post-graduate Course.

(i) A 12 weeks' special full-time day course of 400 hours class tuition in engineering hydrology.

(ii) A 30 weeks special part-time evening course of 60 hours of class tuition in Water Resources Development.

One difficulty experienced by lecturers in these courses is the fact that rarely, if ever, have the students a good grounding in mathematical statistics. So far as the University of New South Wales is concerned, an outstanding weakness is the comparative neglect of geohydrology in all of its courses.

Possibly some other Universities provide tuition in hydrology or related water resources topics as elements of courses with broad titles such as "civil engineering" or "economic geography", but it seems probable that any such treatment would be sketchy.

When the number of hours of formal instruction in hydrology listed above for undergraduate courses are compared with those allocated to structures and other traditional civil engineering subjects, it is clear that hydrology occupies an insignificant place in the scheme of things.

Some thirty years ago the subject of "soil mechanics" was unheard of as far as the average civil engineering undergraduate was concerned, but almost as soon as the subject reached the text book stage practically all civil engineering schools included it as a subject in its own right in their curricula. Why this did not occur with hydrology is a mystery. Perhaps the reason is that even the most antiquated of civil engineering professors had been brought up in their undergraduate days on Rankine's theory of earth pressure, whereas the term "hydrology" was quite unfamiliar.

At the postgraduate level, the list of courses at the University of New South Wales may appear impressive, but in actual fact geo-hydrology, hydro-economics, and mathematical statistics are not yet catered for adequately. The course listed in (g) above is overweighted with traditional hydraulics with consequent neglect of the broader concept discussed in Section 3. 4 below.

3. 3 Hydrology in United Kingdom Universities.

In the United Kingdom, the only case where engineering hydrology appears as a distinct discipline is in the post-graduate Diploma Course in Hydrology of the Imperial College of the University of London. However, it is surprising how many civil engineering schools provide introductory courses in engineering hydrology as sections of all embracing subjects with such titles as "Civil Engineering". The University of Durham (King's College, Newcastle) provides a number of elective specialties in the final years of the Bachelor's course, and one is "Hydrology and Hydraulic Engineering".

In every school of civil engineering there seems to be at least one member of the academic staff who is well read in engineering hydrology, although few are researching in this field.

It has often been said that the United Kingdom is in the van of progress in fundamental research, but dragging behind in the rear as far as practical application of this research is concerned. This is certainly true of hydrology. In practical engineering hydrology the civil engineering profession lags behind Australia, to say nothing of U. S. A. But the fundamental approaches exemplified by such engineers as Dooge, J. C. I. (1959), Nash, J. E. (1957) (1958) and Appleby (1954) and Dawson, E. E. (1958) are of high merit.

3. 4 Hydrology in U. S. A. Universities.

Langbein, W. (1958) stated that "because hydrology is an overlapping and relatively new science, there are no established courses of study for hydrologists" and goes on to deplore that practising hydrologists must acquire their knowledge "on the job" after a basic training in civil engineering (often largely directed to materials and structures), geology, or meteorology. Langbein extols the virtues of a study of hydrology as a basic professional discipline. Lenz, A. T. (1950) reports that only 41 engineering schools out of 119 in U. S. A. included at least one undergraduate course in hydrologic subjects. Enquiries in U. S. A. in 1960 revealed that the situation described by Langbein had not changed materially, and his discontent was widely shared by engineers and scientists. Eventually the United States Geological Survey (1961) issued a statement of the problem as follows -

> "Despite the vast programs to develop the water resource, at present there are no schools which include in their curriculum a comprehensive program of instruction in the basic sciences that govern the development of this resource.
>
> The physical and social sciences, which are the foundations of the study of water either as an aspect of earth history or as a

resource, include a wide range of subjects such as physics, chemistry, hydrology, meteorology, geology, resource economics, political economy. These disciplines are integral parts of any study of water, but the field in general demands particular concern with the synthesis of these disciplines.

There is need therefore for educational centers in this country, staffed by earth scientists and social scientists, devoted to education and research throughout the range of disciplines that can contribute to a coherent and rational approach to the study of water.

The present statement is a brief analysis of the need for improved educational facilities, and suggests some of the ways this need may be approached." .....

" Many public decisions concerning development, control, and management of water depend, in one or more ways, on interpretations of knowledge within more than one of these sciences. In fact, most practicing hydrologists acquired their professional training in hydraulics, geology, or meteorology. A sample list of affiliates of the Section of Hydrology of the American Geophysical Union indicates basic training as follows:

	Percent.
Civil or hydraulic engineering	49
Geology	28
Meteorology	10
Silviculture, agronomy, soil science	8
Chemistry and physics	5

None report their training to have been in hydrology, because there are no curricula in that subject. There are relatively few astronomers, yet there are several recognized schools of astronomy. Despite the vast contrast between astronomy and hydrology in the economic life of our society, no schools give thorough training in hydrology as a distinct earth-science discipline." .....

"Many schools offer general hydrology in one- or two-semester courses or as part of courses in water supply, irrigation or waterpower engineering. Some schools offer courses in groundwater hydrology, and agricultural schools may provide instruction in watershed hydrology. A few schools offer degrees in hydraulic engineering with intensive instruction in applied hydrology.

> The available instruction is too narrow. Limitations on training tend to restrict breadth of research and to compartmentalize the study of what is a single substance. The literature is composed largely of papers on surface-water hydrology, flood hydrology, ground-water hydrology, water chemistry, and so on. Almost no papers bridge the traditional divisions that reflect the limited training of the authors."

This report suggested that the U. S. G. S. should assist in the establishment of a graduate school of hydrology that can offer:-

> "A competent university staff in such collateral subjects as geology, meteorology, and fluid mechanics, and possibly also in oceanography and limnology.
>
> A curriculum in hydrology with major emphasis on the earth sciences, as defined in the attached statement prepared by the Panel on Hydrology of the Federal Council on Science and Technology. Because water has universal importance, the curriculum should include instruction in such subjects as water law and resource economics."

It goes on to say - "Some universities already are taking steps to improve their curricula in hydrology, but in most instances, the steps consist of adding one or two new courses in applied or engineering hydrology. The results probably will fall short of the goal here visualized.

Rather, what appears to be needed is a program within which all or nearly all individual courses are, at least to some extent, reoriented toward the broad problems of water on the earth. The design of such a program is probably simpler at the graduate level than at the undergraduate, because present college training in civil engineering, meteorology, soil science, or chemistry tends to be directed towards specialization in those disciplines."

The report goes on to list the subjects of study which are desirable for a graduate school.

Further evidence of dissatisfaction and ideas for remedial action are found in the proceedings of the conference reported by Todd, D. K. (1962). This conference was attended by academics and representatives of Government departments, and took as its starting point the following quotation of the Federal Council for Science and Technology (1962):-

> "The water development and management problems of the last few years have created a need for scientific hydrology that exceeds the capacity of the relatively few individuals who have come into the

> field from bordering disciplines. The time has come to encourage colleges and universities to make a conscious effort to develop scientists trained to work on hydrologic problems from a broad base in the fundamental sciences."
>
> (Federal Council 1962)

(This prior report is of considerable importance. It discusses hydrology as a science, the status of hydrologic research, education in hydrology, and international co-operation, and the proposed "hydrologic decade".)

The report of this conference deserves serious study by Australian academics and governmental and private engineers and scientists. The final resolutions are worthy of quotation in full:-

"(1) That particular efforts should be directed to attracting talented students into graduate programs in hydrology.

(2) That a comprehensive evaluation of present educational programs and their relation to future manpower needs in hydrology should be made.

(3) That universities should assume responsibility for the promotion of interdisciplinary offerings and for the development of new programs in hydrology.

(4) That all avenues for increased support of university education and research in hydrology should be explored and that steps should be taken to provide for an immediate and a greatly increased level of support.

(5) That the federal agencies be authorized to assign federal personnel to universities, on their request, to assist in the development and expansion of academic and research programs in the field of water resources.

(6) That the Government Employees Training Act be amended to increase the permissible number of personnel that may be assigned to extramural training.

(7) That the Civil Service Commission be requested to establish a classification of hydrologist.

(8) That the Director of the Office of Science and Technology should be urged to request the National Academy of Sciences to establish a Committee on Hydrology with which the university community may work toward developing a program for rapid progress in education and research in hydrology.

(9) That a Universities Council on Hydrology should be established in accordance with the accompanying 'Memorandum of Understanding'".

If American engineers and scientists are dissatisfied with the standards of water resources development planning in their country, then the plight of Australia is serious indeed. If we could even approach the standard of investigation and planning of water projects which is taken for granted in U. S. A. we would have made tremendous advances.

Apparently U. S. authorities are dissatisfied with the part Universities have played in hydrologic education and research, in spite of the many able textbooks produced by American professors. If this is correct, it is interesting to enquire why U. S. A. is so advanced in the practice of hydrology. Perhaps the reason lies in the active part played by major U. S. water authorities in research and in the dissemination of hydrologic knowledge basic to practice.

3.5 Hydrology in the Soviet Union.

For some years past English speaking hydrologists have become aware through translations of the high standard of work in Russia in many aspects of hydrology. A valuable review of hydrology in the Soviet Union has been provided by Sweet J.(1962).

3.6 Hydrology in Japan.

The work of Sugawara M. and Maruyama F. (1956) and of Kimura T. (1960) reminds us of the benefit which would accrue to Australian hydrologists

from a closer liaison with workers in Japan.

4. FUTURE AUSTRALIAN POLICY

4.1 Undergraduate Study

The author is convinced that urgent action should be taken to include "Hydrology" (broadly defined) as a subject in its own right in undergraduate courses in all Australian Universities, with a status and time allocation greater than that now allocated to such subjects as "soil mechanics". Some will debate this and perhaps bring forward arguments on the following lines:-

(i) The main functions of an undergraduate course is to teach the student to read, think, delve for himself and learn how to teach himself, and this can be done just as well with traditional subjects as with some new-fangled topic such as hydrology.

(ii) "Hydrology" is an interdisciplinary science which is related to a diversity of traditional university departments, including agronomy, biology, civil engineering, forestry, geography, geology, irrigation and meteorology" (Todd, D. K. (1962)) and is therefore not suitable for inclusion in existing degree courses.

The author's reply to (i) is that, if we follow this reasoning, such subjects as soil mechanics could be eliminated from civil engineering courses, and such subjects as Astronomy, or perhaps even Latin, substituted. In speaking of graduate courses, Todd, D. K. (1962) answers (ii) thus:-

"Although graduate education in hydrology must cut across departmental lines to cover all aspects of water, the fact that hydrology embraces the full life history of water on the earth is a unifying concept". The author's answer to (ii) is that a start can be made with "engineering hydrology" anyway, and the sooner civil engineers learn to mix with geographers, economists, geologists, meteorologists, agriculturalists and foresters, the better.

The identification of "civil engineering" with "structural engineering" is a strange feature of the Australian scene. Of the eleven chairs of civil

engineering in Australia, seven are occupied by men whose specialty is structural design, two by specialists in highway and traffic engineering and only two by persons who are personally interested in research in water. Several Associate Chairs or Readerships are held by specialists in hydraulics, but none by specialists in hydrology or conservation engineering. When one considers the importance of water to a dry continent such as Australia, it is strange that there does not exist at least one Full Chair in Irrigation Engineering, and several Chairs or Associate Chairs in such subjects as hydrology, water resources, and hydro-economics.

Hydrology is a good medium for educating the undergraduate engineer. The use of conventional and more or less idealized mathematical approaches to such subjects as structural design, based on years of traditional teaching, breeds in the mind of the student the idea that civil engineering is a nice neat collection of straightforward, well-established principles, procedures and formulae. Hydrology, being a new science still in its formative stages, is an excellent medium to illustrate how natural phenomena must be studied, measured, and analysed to build up engineering techniques, to understand the importance of established facts as compared with wishful assumptions, and to apply some original thinking and delving to the mastery of the subject rather than to absorb parrot fashion a series of procedures. A study of hydrology provides a training in methods of attack on any future problem which is off the beaten track. A healthy cynicism and disrespect for authoritative text book statements is an essential part of undergraduate training and in no field can this be better acquired than in a study of hydrology.

There are several important ancillary subjects, of which mathematical statistics and data processing and computer techniques are two. Courses in statistical methods appear in all Australian University handbooks, but computer techniques in only five. This does not mean, however, that they

are included in the regular civil engineering undergraduate course. It seems probable that few if any civil engineering courses include the subject of mathematical statistics. This is sometimes partly the fault of the mathematicians, who make themselves unpopular with engineers by stressing too much the philosophy and derivation of their theorems, rather than their application. A strong case can even be made out for the teaching of statistical methods in secondary schools, concentrating on description of them rather than on discussion of their mathematical basis. The absence of any treatment of basic "engineering economics" from most Australian civil engineering undergraduate courses is as puzzling as the absence of "mathematical statistics".

A feature of Australia is the almost complete divorce of C.S.I.R.O. scientists from any teaching responsibility, and the relatively small use of practising engineers and scientists as part-time or visiting lecturers in Universities. The late Professor D.W. Phillips advocated "industrial fellowships", whereby University staff exchanged places with government specialists in the same field for an academic year. This concept is particularly applicable to water resources teaching and research.

Assuming that it were agreed that there should be some reform of University teaching in the direction of greater emphasis on the proper development and use of water resources and its ramifications into other resources, such as land use, soils, forests and wildlife, the question arises as to the nature of such reforms.

In view of the interdisciplinary nature of the subject, it could be argued that there should be created undergraduate courses of three or four years' duration leading to some such degree as B.Sc.(Conservation). Such a course could include all the subjects which have been advocated as essential for a worker specialising in water development and management fields. However, in the present climate of public opinion, it would probably fail for lack of students. Schoolboys planning their careers will "play safe" and enrol in the recognized courses in civil engineering and science. A more practical programme at the undergraduate level would

be to include a 40 to 60 hour course in basic hydrology in all civil engineering degree courses, and corresponding courses, with perhaps different subject matter, in courses in geography, agriculture and similar disciplines. Further work might be provided in those courses which allow for "elective" subjects at the undergraduate level. As far as civil engineering is concerned, the raising of hydrology to at least the same status as soil mechanics is essential if any real improvement of the present situation is to be achieved.

4.2 Post Graduate Courses.

However, no matter how valuable an undergraduate course may be in inculcating in students sound attitudes to their life and work, it must be realised that at the Bachelor's level the student, as far as the more specialised science and technology of his profession is concerned, "knows a bit about everything and not much about anything".

If the graduate civil engineer proposes to practice or research efficiently in structural, water, or transport engineering he requires at least a further full year of specialised study aimed at mastering the basic technology of his chosen field. Hence the greatest need, in the Australian scene, is a series of formal post-graduate courses leading to a Master's degree, with some of the students proceeding further to the research Ph.D. degree. In the author's experience, graduates need a year of formal post-graduate study before they are properly prepared for work towards a higher degree of the research type (M.E. or Ph.D. in the University of New South Wales). More important than training in research, for Australia's problems, is the need to supply major governmental water authorities with a "corps d'elite" for practical investigation and planning. In view of the inter-disciplinary nature of water resources planning, it is desirable that these post-graduate courses should be so planned that graduates in various science specialties, as well as graduates in engineering, should be eligible to enter such courses. This presents

some difficulties, which can only be met by planning the programme in such a way that scientists first fill in the gaps in their knowledge of such basic subjects as hydraulics, while engineers must undergo some preparation in biological and agricultural aspects, and probably also in geo-hydrology. Even if these formal post-graduate courses were restricted to civil engineering graduates, some elective choice of subjects should be provided, to allow for a degree of specialization within the specialty, as water engineering is a broad field. A course of, say, two compulsory subjects, and a choice of four more from a total of eight, might be a typical pattern.

The School of Civil Engineering of the University of New South Wales has made an attempt at developing this kind of graduate school, although aiming more at pure civil engineering objectives rather than the broader concept of conservation generally. Progress has been disappointing. The number of students in the classes range from four to eight, sometimes rising as high as a dozen for the shorter special courses. The majority of the students are Asians. If the support from Australian students does not improve, this University, which must have regard for the relative economies of various courses, may have to discontinue its efforts to serve Australia in this matter. (It is perhaps significant that Professor J. P. Baxter, the Vice-Chancellor, is Head of the Atomic Energy Commission, and yet has been one of the most powerful supporters of teaching and research related to water resources development). The only incentive for academic staff to carry on these courses is that arising from a spirit of service and technical interest. If their efforts were deemed to be of no value, they must devote their energies instead to research instead of post-graduate teaching. Only in research, in the academic world, does there exist the added incentive of promotion and material reward in due course.

One must of course expect difficulties in fostering such courses, firstly because the concept of formal post-graduate training is a new one in Australia, and secondly because young engineers have little incentive to carry on

with study beyond the Bachelor's degree. An engineer, on graduation, commands a salary of £1,600 p. a. or more, and the prospect of spending a further year at the University at a sacrifice of £1,600 plus fees, is not attractive, particularly as, in Australia, he receives little if any reward for his additional qualifications when applying for an appointment. For graduate courses in highway engineering, liberal sponsored scholarships overcome this problem. It is essential that similar scholarships be made available in water engineering, and the newly created Water Resources Council should provide them.

Admittedly, a period of two or three years of part-time study can achieve substantially the same result as one year of full-time work, but such a long period is not attractive to young graduates. From an educational point of view it is not as efficient.

Theoretically raw graduates in engineering and science should first have two years of practical experience with large conservation authorities before returning to the University for a year of formal graduate training. In engineering this is impracticable. The heavier financial sacrifice and the involvement of the graduate in the promotional system of his employer means that few would return. Hence the major proportion of graduate students is likely to consist of students who proceed straight on from a Bachelor's to a Master's degree (formal course).

Even if the financial and professional climate changed in such a manner as to make graduate schools attractive, the meagre population of Australia means that classes would be wastefully small if every University offered every type of course. Either the two larger centres - Sydney and Melbourne - should provide the water resources post-graduate teaching for the whole of Australia, or various specialties within this field should be allocated to appropriate Universities. The great disadvantage of the latter course is the inter-disciplinary nature of water resources studies. The courses at the University of New South Wales suffer from the predominately civil engineering approach, and

liaison with the University of Sydney is desirable if geographic, economic and agricultural viewpoints are to be adequately presented, as is essential for properly integrated study.

5. CONCLUSIONS.

As a basis for discussion, the following suggestions are made as to future policy:-

(a) At the primary school level, the hydrologic cycle and associated biological concepts in their relation to the development of civilization should be embodied in the syllabi of appropriate subjects, and appropriate text books and teaching aids acquired or produced.

(b) Similar action should be taken at the secondary school level at greater depth introducing the applications of mathematics, physics, chemistry and experimental methods in relation to appropriate hydrologic phenomena.

(c) The Academy of Sciences should sponsor a committee representative of Universities and practicing water resources engineers and scientists to prepare recommendations for the consideration of the Australian Universities' Vice Chancellors' Committee, the Water Resources Council, C.S.I.R.O. and similar bodies on:-

(i) Desirable undergraduate studies related to hydrology and water resources development;

(ii) The nature and location of formal post-graduate courses of instruction necessary to service Australia in the broad field of water resources development;

(iii) The provision of scholarships for formal post-graduate study;

(iv) Grants necessary for equipment and staff to establish graduate schools on a sound footing;

(v) Closer liaison between Universities, C.S.I.R.O., and Conservation authorities in teaching and research.

LIST OF REFERENCES.

Appleby F. V. "Runoff Dynamics - A Heat Conduction Analogue of Storage Flow in Channel Networks." Proc. Inter. Assn. Sci. Hydrology, Int. Un. Geodesy and Geophysics, Rome Gen. Ass. 1954. Vol. III pp. 338-348.

Dooge, J. C. I. "A General Theory of the Unit Hydrograph" J. Geophys. Res. 64 241-256 (1959).

Dawson, E. E. "Discharge from Heavy Rainfall", Inst. Civ. Engrs. Proc. 10 453-472 (1958).

Federal Council for Science and Technology U. S. A. Report of Ad. Hoc. Panel in Hydrology - Scientific Hydrology, June 1962.

Kimura, T. "Research on the Estimation of Flood Runoff - A Study of the Storage Function", Jl. of Research, Public Works Res. Inst. Construction Ministry, Japan. Vol. 4, Res. Paper No. 5, Dec. 1960.

Langbein, W. "Hydrologic Education", Bull. No. 11 Int. Assn. Scientific Hydrology, pp. 27-30 Sept. 1958.

Lenz, A. T. "Educational Facilities for Hydrology" Trans. Am. Geo. Union pp. 27-30 Sept. 1958.

Messel, H. (ed.) "Science for High School Students" Pilot Edition, New South Wales Govt. Printer 1963.

Nash, J. E. "The Form of the Instantaneous Unit Hydrograph", Intn. Assn. Scientific Hydrology, Int. Un. Geodesy and Geophysics Proc. Toronto Gen. Ass., Vol. III pp. 114-121 (1957).

Nash J. E. "Determining Runoff from Rainfall", Inst. Civ. Engrs. Proc. 10 163-184(1958).

Todd, D. K. "Report of Inter-University Conference in Hydrology", Trans. Am. Geo. Union 43 No. 4 pp. 491-494, Dec. 1962.

United States Geol. Survey "A Statement on Hydrologic Education" pp. 1-7 mimeographed Jan. 1961.