World hydrology: status and prospects

Raymond L. Nace
U.S. Geological Survey
Washington, D.C., USA

SUMMARY: The broad definition of hydrology used as a guide for the IHD programme is accepted. Interpretation of the definition and of the role of hydrologists in modern problems, however, must be very liberal, because water cannot be studied realistically independently of other factors in the environment, including biological factors.

The ultimate aim of hydrological studies is to aid rational use of water for human purposes. Aspects of hydrology which need further study and research are almost limitless, and not all can be undertaken at once. Therefore, the likelihood of early payoff in practical problems will strongly influence choice of priority among activities.

Basic data are essential both for water development and for research. Basic data for all hydrological and related parameters are deficient for huge areas of the world and many development projects are being designed and constructed without an adequate base of data.

"Deficient" and "adequate" are relative terms whose use commonly is subjective. Some deficiencies and inadequacies, such as those for streamflow, are less acute than is commonly supposed. Other data, such as those for dissolved and suspended solids in rivers, are inadequate by any standard for much of the world.

Modern methods of systems simulation, data reduction, analysis and extrapolation make apparent deficiencies in some kinds of data much less serious than they were a decade or two ago. New methods for quickly obtaining synoptic and sequential data for large areas also improve the prospects for world hydrology.

1. Publication authorized by the Director, U.S. Geological Survey
HIDROLOGIA MUNDIAL: SITUACION Y PERSPECTIVAS

RESUMEN: Se acepta la amplia definición de hidrología utilizada como guía para el programa del DHI. No obstante, la interpretación que se da a esa definición y el papel que desempeñan los hidrólogos en los problemas actuales deben ser muy generosas ya que, en realidad, los recursos hidrológicos no pueden estudiarse independientemente de otros factores, tales como el medio ambiente, e incluso los factores biológicos.

El fin que se persigue con los estudios hidrológicos es racionalizar de forma más completa la utilización del agua destinada a los fines humanos. Los aspectos de la hidrología que requieren un estudio amplio más y una investigación mas detallada son casi ilimitados y no todos pueden emprenderse inmediatamente. Por lo tanto, es más que probable que al tener que decidir cuáles son las actividades más urgentes, la selección se haga en función de la rentabilidad de los proyectos escogidos.

Tanto para fomentar los recursos hidrológicos como para la investigación de los mismos, es esencial disponer de una información básica. Existen inmensas zonas del mundo para las cuales existe una carencia de datos básicos en lo que respecta a los recursos hidrológicos y a los correspondientes parámetros y muchos son los proyectos en desarrollo que se conciben y llevan a cabo sin una información adecuada.

«Carencia» y «adecuada» son términos que se utilizan a menudo en el sentido subjetivos. Ciertas carencias y faltas de adaptación, tales como las que se refieren al flujo, son menos graves de lo que, por lo general, se supone. Otros datos, tales como los relativos a las materias disueltas y en suspensión en los ríos resultan inadecuados desde el punto de vista normativo en mucha parte del globo.

Los métodos modernos que consisten en sistemas de simulación, de reducción de datos, de análisis y extrapolación de los mismos ponen de manifiesto que existe una carencia de cierto tipo de información, aún cuando de forma menos acusada que hace 10 o 20 años. Los nuevos métodos que permiten obtener rápidamente datos sinópticos y secuenciales para zonas importantes también permiten mejorar las perspectivas de la hidrología mundial.

СОВРЕМЕННОЕ СОСТОЯНИЕ И ПЕРСПЕКТИВЫ ГЛОБАЛЬНОЙ ГИДРОЛОГИИ

Аннотация: В качестве основы при разработке программы МГД было принято широкое определение гидrologии. Толкование этого определения, а также роли гидрологов в решении ряда современных проблем, однако, должно быть весьма гибким, поскольку природные воды нельзя успешно изучать и отрывать от других факторов окружающей среды, в том числе биологических. Конечной целью гидрологических исследований является обеспечение рационального использования вод для нужд человечества. Аспекты гидрологии, которые нуждаются в дальнейшей научной разработке, почти безграничны, причем мы все это можем начать разрабатывать немедленно. Очередность того или иного научного начинания определяется в значительной степени вероятностью получения быстрой отдачи при решении практических проблем.

Исходные гидрологические данные необходимы как для рационального использования водных ресурсов, так и для производства научных исследований. Однако для огромных территорий земного шара эти данные по гидрологическим и смежным с ними параметрам недостаточны, поэтому многие гидротехнические сооружения проектируются и возводятся без достаточного обоснования их исходными данными.

«Недостаточные» и «достаточные» данные — это термины, которые обычно используются довольно субъективно. Некоторая недостаточность данных, например по стоку, не является настолько острой, как это обычно считается. Другие данные, как например, данные по стоку растворенных веществ и взвешенным наносам в реках, являются недостаточными для большей части территории земного шара.

Современные методы моделирования систем, приведения данных наблюдений, их анализа и экстраполяции дают возможность несколько смягчить недостаточность данных, по сравнению с тем, как это было десять-двадцать лет.
INTRODUCTION

Not quite 300 years have elapsed since Pierre Perrault, Edmé Mariotte and Edmond Halle set hydrology on its modern scientific path. During this period hydrologists have concentrated chiefly on phenomena at the relatively small and intermediate scales—the local area and the river basin. Only recently has much attention been given to the extremes of scales—the microscopic and the global.

Many problems require research at the micro-scale. Examples are the specifics of water movement through aquifers, soils and vegetation, directional variation in aquifer permeability, and osmotic processes in semi-permeable geologic materials. But many problems already on the horizon require research at the macro-scale, involving whole continents, the great icecaps, the ocean and the entire world. In accord with the title of this symposium, this paper deals only with macro-scale phenomena.

Whether large-scale water-balance studies and inventories have any great practical value has been questioned often. They are, in fact, important for several practical reasons quite beyond their scientific interest. The impact of human activity on the environment is widely recognized but poorly documented, especially at large scale. Future impact will be much greater because burgeoning population will require manipulations of the environment on an ever-growing scale. Transbasin diversions of water, for example, are not yet common, but already transcontinental diversions have been discussed. Without accurate knowledge of present large-scale water balances, it will be impossible to predict the environmental effects of future large scale manipulations of the environment, including land and water use, rain-making and other activities. All of these have international hydrological meteorological, sociological, economic, and legal implications. No nation, however, small, can afford to ignore large-scale phenomena.

TOTAL WATER

The vast basin of the world ocean contains somewhat more than 97 percent of all free water in existence. Refinement of knowledge about the topography of the ocean floor will neither change water-volume estimates appreciably nor significantly affect studies of water balances. Likewise, refinements of estimates of water in other realms, although they are important in themselves, would not noticeably affect the estimated total volume of all water, because the amounts in those realms are very small percentages of the total.

Modern calculations of the total amount of water in the atmosphere, seasonally and on the average, differ by only a few tens or hundreds of cubic kilometers. Refinement of these calculations for long-term inventory purposes does not seem to be worth much effort, because the results would add nothing to the concept of static water balances. For the study of dynamic balances, however, vapour fluxes and regional and seasonal changes in atmospheric storage have great importance. Several papers in this symposium will deal with these phenomena.

Only very crude estimates are available of water in readily accessible realms, such as channel storage in rivers and impoundments in lakes. Channel storage is insignificant as a percentage either of total water or of transient water in the land areas at any given time. Nevertheless, channel storage is important in flow routing and reservoir operation, and for many other purposes, yet it has received surprisingly little attention.
Lake-water resources in general are poorly known. The Great Lakes system of North America has been inventoried with sufficient accuracy that only minor refinements may be expected in the future. However, only rudimentary hydrometry is available for many large lakes in North America, for the huge lakes of Africa, and for some of those in Asia. The hundreds of thousands of smaller lakes in all continents have not been carefully inventoried. These are highly significant in regional water inventories, and they, in conjunction with wetlands and waterlogged areas present vast areas for evaporation. For example, about 192,000 km² of the United States is inland water area. This is far more area than that of any single lake in the world except the Caspian Sea. Inland water areas of the world probably exceed 1 million km².

Water in the icecaps of Antarctica, Greenland, and dozens of lesser icecaps generally is considered to be peripheral to the interests of hydrologists. However, if water inventories have any value, their value is incomplete without an account of snow and ice. Further, the great icecaps, ice shelves and sea ice have major roles in heat balances and hence in vapour balances and fluxes.

The volume of water in perennial snow fields and glaciers is another virtually unknown quantity, despite the importance of snow and ice as nonstructural storage reservoirs. Although snow and ice are receiving considerable attention in Europe, Soviet Asia, and North America, two important areas have received little attention and have no prospect of early regional study. These are the great snow and ice fields of the Himalaya and Andes Mountains.

Despite studies of soil moisture and ground water during many years in all parts of the world, virtually no data are available on the absolute quantity of subterranean water. Estimates have been made for a few isolated areas, but only the crudest of estimates are available for the land areas as a whole. Whatever their amounts may be, they may be considered as constants for long-term averages in large areas. But for short periods or small areas they are variables and must be accounted for in dynamic terms.

**VAPOUR AND WATER FLUXES**

Storage and residence times of water in various realms are important for water inventories, but they imply a steady-state balance, whereas the hydrological cycle is a system of processes which both upset and tend to restore balances. Fluxes, changes of state, and changes in storage have importance in the study of water balances.

Vertically integrated horizontal vapour fluxes need much more attention. Aerological observations of vapour-flux divergences permit indirect determination of evaporation and precipitation, and the method is especially useful for large areas. Existing observation networks should be greatly extended and their density increased. This method, although not new, is in its infancy. So far it has depended on airborne, and rocketborne sensors which, unfortunately, sample only slender columns of the atmosphere. Orbiting sensors probably will provide essential supplemental or primary data in the future, and this technique should be fully exploited.

**EVAPORATION**

Evaporation data are very deficient for large areas of the world, especially for the vast areas of the world ocean. Calculated values for world evaporation, based on theory, require extensive extrapolations and interpolations from sparse observational data. The poor state of knowledge about evaporation is well known and need not be belaboured here. The world water balance study requires more basic data for bare and vegetated land,
wetlands of all kinds, for free water surfaces of ponds, lakes, inland seas and the world ocean, and for areas of snow and ice.

PRECIPITATION

Most precipitation, like most evaporation, occurs in oceanic areas, and no prospect is in sight for accurate direct measurement in that vast area. In land areas the problem is less formidable but, even so, no economically feasible density of stations could give a precise measure of precipitation. For all but small local areas special studies, therefore, estimates of gross precipitation will continue to be made. These approximations must be improved by refinement of theory and by improved technology and observation.

RUNOFF

I will deal with runoff in some detail because for this factor we have sufficient data to make a crude evaluation of the state of knowledge. It is commonly believed that runoff from land areas to the world ocean is quantitatively known with sufficient accuracy for most broad-scale hydrological studies. Classical studies treat all continental water yield as runoff. This may be unimportant if ground-water discharge is insignificant. Data on ground-water discharge (which I shall call runout) are so deficient that no valid estimate of its magnitude is possible. However, some simple estimates and calculations point to its probable magnitude.

In coastal areas in general, one of the following conditions prevails: (a) dense rock having very low permeability; (b) permeable rock or sediments in which, however, the hydraulic gradients are low and the runout cross-section is thin. Runout per kilometer of shoreline probably is small except in special areas such as Hawaii, Florida, some Mediterranean countries, and a few other areas.

The total shoreline length of world areas is about 370 000 km. Permanently frozen land areas such as Antarctica, Greenland and Arctic lands probably have no significant runout. Suppose, however, that runout occurs along 200 000 km of shoreline and that it is at the rate of 33 l s⁻¹ km⁻¹, based on assumption of 25 percent porosity of the aquifer, vertical discharge zone 4 m thick, and an underflow rate of 3 m d⁻¹. The average total runout then would be about 7 000 m³ s⁻¹. This is less than 1 percent of estimated surface runoff. While the calculation is wholly hypothetical, it is based on liberal assumptions. In order to be significantly large the value would have to be greater by a factor of 5. Evidently, runout is negligible in relation to the world water balance, though it is significant within some regions.

A more significant matter is that classical estimates of total runoff do not seem to be verified by analysis of data for rivers whose discharge is known within reasonable limits. Such an analysis discloses some interesting facts, using data for rivers that discharge to the sea.

Table I and figure I show the estimated discharges of several hundred rivers, grouped by orders of magnitude of discharge (see footnote to table I). It is believed that the data include all rivers of Orders I and II and most rivers of Order III, but they include only a non-systematic sampling of lesser rivers that discharge to the sea. The data include 68 great rivers (those whose average discharge is 1 000 m³ s⁻¹ or more).

The single first-order river discharges an average of 175 000 m³ s⁻¹ from a drainage area of 6.3 x 10⁶ km². The 15 second order-streams discharge at an aggregate average rate of 285 700 m³ s⁻¹ from an area of 27.5 x 10⁶ km². The 52 third-order rivers discharge about 148 000 m³ s⁻¹ from an area of about 19.6 x 10⁶ km². The aggregate average
TABLE 1. Estimated discharge to the sea of principal rivers of the world and a sample of smaller rivers

<table>
<thead>
<tr>
<th>Rank (a)</th>
<th>Number of rivers</th>
<th>Drainage area (km² x 10^-3)</th>
<th>Average annual discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>m³ s⁻¹</td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td>6 300</td>
<td>175 000</td>
</tr>
<tr>
<td>II</td>
<td>15</td>
<td>27 485</td>
<td>285 730</td>
</tr>
<tr>
<td>III</td>
<td>52</td>
<td>19 558</td>
<td>148 286</td>
</tr>
<tr>
<td>IV</td>
<td>133</td>
<td>7 205</td>
<td>49 030</td>
</tr>
<tr>
<td>V</td>
<td>103</td>
<td>1 382</td>
<td>3 914</td>
</tr>
<tr>
<td>Totals</td>
<td>304</td>
<td>61 930</td>
<td>661 960</td>
</tr>
</tbody>
</table>

Average unit-area yield 10.7

(a) Ranked by orders of magnitude of discharge as follows:
I. ≥ 100 000 m³ s⁻¹
II. ≥ 10 000 but < 100 000
III. ≥ 1 000 but < 10 000
IV. ≥ 100 but < 1 000
V. ≥ 10 but < 100

(b) Here and at some places in the text, the values shown are for bookkeeping purposes. They do not imply accuracy within 1 m³ s⁻¹.

![Figure 1](image_url)

**Figure 1. Comparison of aggregate discharges and drainage areas of rivers, by order of magnitude**

discharge of all 68 rivers is 609 000 m³ s⁻¹ from an area of about 53.4 x 10⁶ km². A non-systematic sample of 133 fourth-order rivers of the world (100 to 999 m³ s⁻¹) has an aggregate discharge of about 49 000 m³ s⁻¹ from an area of about 7.2 x 10⁶ km². A similar sample of 103 fifth-order rivers discharges about 3 900 m³ s⁻¹ from an area of about 1.4 x 10⁶ km².
As a basic for the graphic presentation in figure 2, river-discharge data were tabulated with the rivers ranked numerically in decreasing order of magnitude of average discharge. Using numerical rank, discharge of the Amazon River was plotted as number 1. The discharge of the Amazon plus that of the Congo is number 2. The Amazon plus the Congo plus the Yangtze is number 3, and so on to number 68, which represents all the great rivers of the world. Beyond number 68 the additional increment at number 100 includes 32 streams of Order IV. Points beyond that represent increments for groups of 50 to a total of 300 rivers.

![Figure 2. Semi-logarithmic graph of discharge of 300 rivers of the world](image)

The smoothness of the sinusoidal curve has no special significance. It is built in by the method of plotting. The significance of the curve is that it seems to be approaching a limit below the value of 700 000 m$^3$ s$^{-1}$.

Based on some classical studies, modified by unpublished data, the estimated aggregate oceanic discharge of all rivers of the world is about 924 000 m$^3$ s$^{-1}$. Large areas of some continents, chiefly deserts and endorheic basins, contribute no runoff to the sea. Excluding these and icecap areas, the actual runoff-contributing area is about $103 \times 10^6$ km$^2$. The aggregate discharge of the 68 principal rivers of the world is about $608 000$ m$^3$ s$^{-1}$ from $53.3 \times 10^6$ km$^2$. These are 66 percent of estimated total discharge and 52 percent of the contributing area.

Great rivers are great because their basins have high unit-area yields, are very large, or both. Excluding the Nile, whose unit yield is low because of the large desert part of its basin, the unit-area yields of great rivers (Orders I to III) range from 2.7 to 32 ls$^{-1}$ km$^2$ and they average about 12 ls$^{-1}$ km$^2$.

Many lesser rivers have high unit yields (up to 40 ls$^{-1}$ km$^{-2}$), but their basins are small and they add little to total discharge. The average yield of the sample of 133 IVth-Order rivers is 6.8 ls$^{-1}$ km$^{-2}$.

In summary, the 300 rivers treated in the accompanying graphs and table drain about 63 percent of the world’s runoff-contributing area and yield about 72 percent of estimated
total world runoff. Is it reasonable to expect that the remaining contributing area of $38.1 \times 10^6 \text{km}^2$ produces the additional yield of $260 435 \text{m}^3 \text{s}^{-1}$? The fact that the right limb of the line in figure 1 is approaching a limit does not necessarily mean that the answer is "no". The facts and estimates presented thus far raise several possibilities:

1. aggregate oceanic discharge of all rivers is considerably less than has been estimated;
2. the total discharge of the larger rivers is considerably underestimated; or
3. some large areas of high yield are not represented.

Possibility (1) may be tested by use of data for European rivers. Forty-one large European rivers for which records have been assembled have an aggregate drainage area of $4 850 850 \text{km}^2$. Their aggregate average discharge is $36 000 \text{m}^3 \text{s}^{-1}$, and their average unit-area yield is $7.42 \text{Is}^{-1} \text{km}^2$. The total European area that contributes runoff to the sea (excluding Iceland and the endorheic Caspian basin) is about $7 857 000 \text{km}^2$. The residual area not represented by the 41 rivers is $3 006 150 \text{km}^2$. If the water yield of this area is equal to the average for the 41 rivers, then the additional yield is $22 500 \text{m}^3 \text{s}^{-1}$ and the total for Europe as a whole is $58 500 \text{m}^3 \text{s}^{-1}$. This is considerably less than $75 000 \text{m}^3 \text{s}^{-1}$ which is one widely used estimate for European water yield. The deficiency is $16 500 \text{m}^3 \text{s}^{-1}$, or 22 percent of the larger value. It seems possible that European water yield has been overestimated.

Concerning possibility (2), that the total discharge of individual large rivers has been underestimated, it will be recalled that the Amazon, when systematically measured in 1963-1964, was found to have a discharge nearly twice as large as was previously estimated. It now ranks nearly $4\frac{1}{2}$ times the discharge of the Congo, but the latter also may be considerably underestimated. Moreover for certain large rivers such as the Brahmaputra, Ganges, and Orinoco data are poor, especially for high and flood discharges. However, if we double the discharge of the Congo and increase the discharge of all other Second-Order rivers by 10 percent, we add only $70 000 \text{m}^3 \text{s}^{-1}$ to the total and the curve in figure 2 seems to approach a limit of about $734 000 \text{m}^3 \text{s}^{-1}$. It seems unlikely that underestimation of individual river discharges is great enough to account for the discrepancy.

Concerning possibility (3), it is a fact that some areas of high yield are not represented in the data used. No data have been obtained for individual rivers of Taiwan, for instance, but the total discharge from its $35 700 \text{km}^2$ of area reportedly is $1 744 \text{m}^3 \text{s}^{-1}$, or $49 \text{Is}^{-1} \text{km}^2$. Malaysia and Indonesia, with an aggregate land area of $2 183 000 \text{km}^2$ are high yield areas (ignoring the fact that the eastern part of Indonesia is comparatively dry). If their yield is comparable to that of Taiwan, they may add about $107 000 \text{m}^3 \text{s}^{-1}$ to the world total. This would raise the right limb of the line in figure 2 to about $770 000 \text{m}^3 \text{s}^{-1}$, but the line would still seem to be nearing a limit below the classical estimate of $924 000 \text{m}^3 \text{s}^{-1}$.

The number of rivers, by itself, may have no significance as used in the foregoing discussion. The compilation, however, does include all or nearly all large rivers. If the compilation were carried out to the $n$-th order of measurable streams, their number would be very large, but the area drained is limited, not infinite. The question remains therefore, whether this would significantly change the apparent total discharge indicated by figure 2.

A plot on logarithmic paper of the data for stream Orders I-IV, using cumulative discharge on one ordinate and cumulative area on the other, yields a straight line and, if this is projected to the full contributing area it indicates a yield of $880 000 \text{m}^3 \text{s}^{-1}$. This is about 5 percent below the classical estimate. On the other hand, it seems to me that the data for fifth-order rivers cannot be ignored. In contrast to an earlier statement about large rivers, small streams are small because their basins are small, or their unit yields are small, or both. It seems unlikely that a sample of 100 rivers of Order V from many parts of the world be so atypical or biased on the low-yield direction that they must be regarded as extraordinary and the data ignored. For example, some small streams have unit discharge as high as $100 \text{ls}^{-1}$, but their drainage areas are on the order of a few hundred
square miles. Others with yields of a small fraction of a liter per second have drainage areas of several hundred thousand square kilometers. The latter type of streams causes the very low over-all average yield.

SUMMARY AND CONCLUSIONS

The most important of all parameters from the standpoint of global water balance is the sea-air interface. Meteorological data for most oceanic areas are sufficient to give only a crude picture of conditions on any given day. Gaps in data will shrink with the establishment of more and better drifting and fixed weather buoys and use of communications satellites, if plans for the World Weather Watch come to fruition. The oceanographic counterpart, the Integrated Global Ocean Station System of the Intergovernmental Oceanographic Commission also will add to the store of information. These are vital to world hydrology and should be encouraged by the hydrological community.

Remote-sensing experiments with instruments in the Nimbus 3 satellite (launched 14 April 1969) indicate that it is possible to sense the vertical distribution in the atmosphere of temperature and water vapour. It may also be possible to measure ocean-surface temperatures. The promise from studies of hemispheric and global atmospheric vapour fluxes should be exploited fully, as this is one of the very few possibilities for determining regional evaporation and precipitation.

Soil moisture and ground water are two of the most difficult parameters to evaluate. Were they not difficult the task would have been accomplished long ago.

Global water budgets may be made to balance nicely on paper on the basis of theory and by adjustment of the several components to force a balance. Estimates of individual parameters, however, when independently derived from real data, do not fit these balances. The fact that it is necessary to juggle data, for example, those for streamflow, in an effort to reach agreement with classical estimates is symptomatic of the unsatisfactory state of knowledge. If this is true of streamflow, one of the most readily measurable parameters, how much more true must it be of other parameters of the hydrological cycle!

Nearly all large rivers of the world probably need restudy, including measurement at the head of tidewater and estimates by standard methods of unaged increments of runoff and runout into tidal reaches below gaging stations. Flood discharge of most rivers needs increased attention. Meantime, more complete compilations should be made of existing data. These data should receive more careful and sophisticated analysis than the simple treatment in the present paper.

It is evident that new or improved measurements of small rivers would not have much effect on estimated total discharge of all rivers to the sea. The total amount of water discharged by these rivers would be less than the probable error in measurements of large rivers. For example, the error in estimated flow of the Amazon probably is about 10 percent or about $17,500$ m$^3$ s$^{-1}$. Only nine rivers in the world discharge more than that amount.

On the other hand, lesser rivers have great practical importance in local and regional economies. Relatively speaking, major rivers such as the Amazon and Congo are scarcely used at all except for navigation. On the other hand, a minor river such as the Colorado of the United States is completely used and it is the figurative lifeblood of an area of hundreds of thousands of square kilometers. In much of the world, therefore, hydrological study of rivers has great potential value for human interests and for study of local or regional water balances.

Studies of hydrology in its large-scale and ecological contexts are essential. Man has already affected and, in many ways, unfavourably affected the world environment. With human activity increasing on an exponential scale, it is imperative that extensive
and intensive studies be made, lest further activity causes incalculable damage to the environment.

ACKNOWLEDGEMENTS

I wish to acknowledge with sincere thanks, many helpful suggestions and constructive criticisms from my colleagues M.A. Benson, S.M. Lang, Allen Sinnott, T.E.A. Van Hylckama, and Alfonso Wilson.

Principal problems of modern hydrology

A. A. Sokolov,
State Hydrological Institute, Leningrad, USSR

SUMMARY: The water balance of reservoirs, the interrelation of surface and ground water, the water and salt balance of irrigated land, the water balance of swamp areas and the influence of man on runoff, are discussed as illustrations of some of the most important problems of modern hydrology.

PROBLÈME PRINCIPAUX DE L'HYDROLOGIE MODERNE

résumé : Le bilan d'eau de réservoirs, les relations réciproques entre l'eau de surface et l'eau souterraine, le bilan d'eau et de salinité des surfaces irriguées, le bilan d'eau de zones marécageuses et l'influence de l'homme sur l'écoulement sont discutés en les considérant comme des illustrations de quelques-uns des plus importants problèmes de l'hydrologie moderne.

PROBLEMAS SABRE EL PRINCIPIO DE LA EVAPOTRANSPIRACIÓN EN LOS BOSQUES

resumen: Como ejemplo de alguno de los problemas más importantes que plantea la hidrología moderna, en este documento se estudia el balance hídrológico de los embalses, la relación existente entre las aguas de superficie y las subterráneas, el balance hídrológico y salino de las tierras irrigadas, el balance dihrológico de las sonas pantanosas y la influencia del hombre en los fenómenos de la escorventía.

ОСНОВНЫЕ ПРОБЛЕМЫ СОВРЕМЕННОЙ ГИДРОЛОГИИ

Аннотация: Рассматривая историю развития гидрологии, автор приходит к выводу, что современный её период характеризуется все более широким внедрением методов водного и связанного с ним теплового балансов в практику гидрологических исследований, расчетов и прогнозов. При этом характерной особенностью современного периода в развитии гидро-