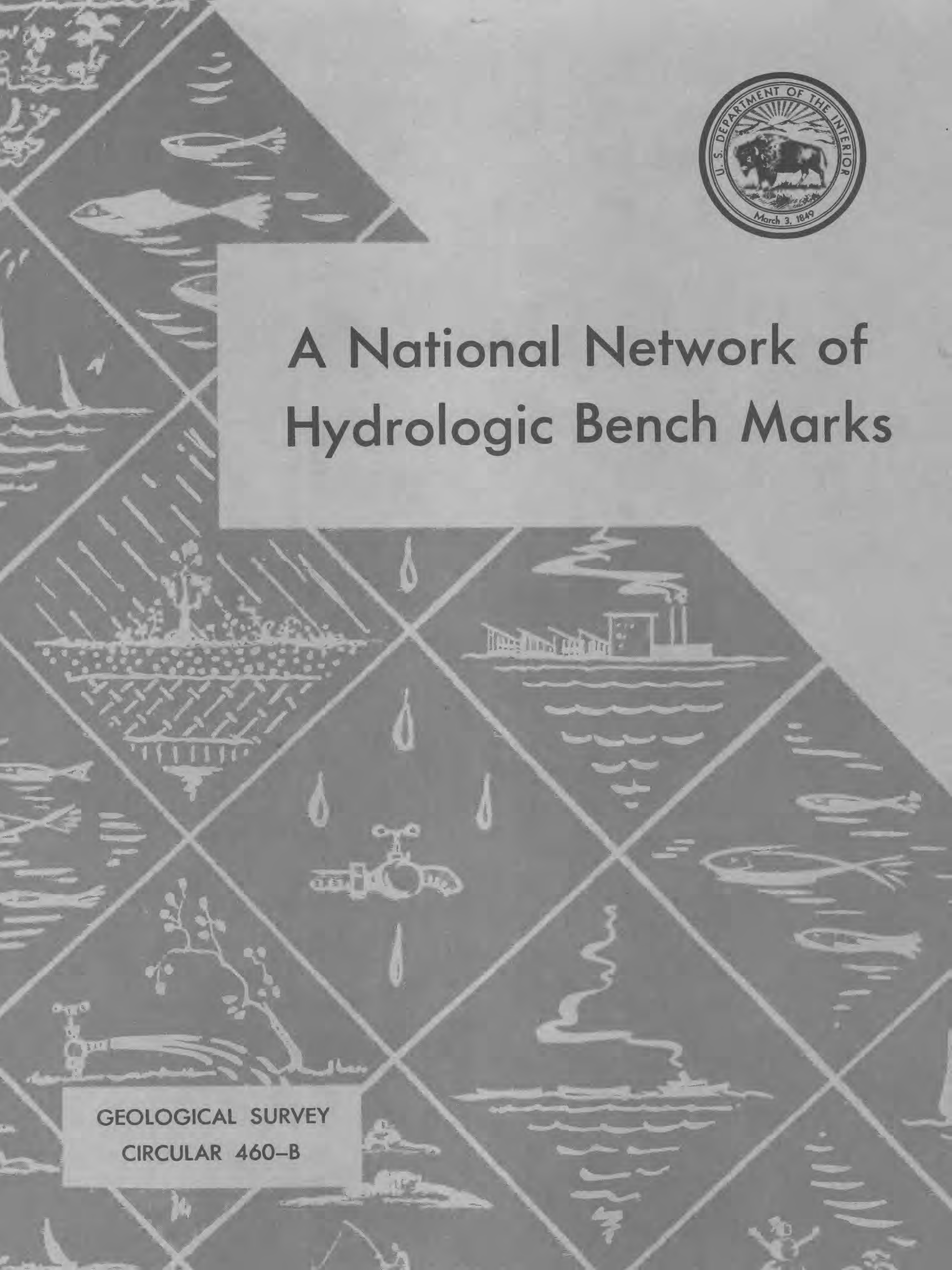

A National Network of Hydrologic Bench Marks

GEOLOGICAL SURVEY
CIRCULAR 460–B

Part B

A National Network of Hydrologic Bench Marks

By Luna B. Leopold

C O N S E R V A T I O N   N E T W O R K S

G E O L O G I C A L   S U R V E Y   C I R C U L A R   460-B

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CONSERVATION NETWORKS

PART B

A National Network of Hydrologic Bench Marks

By Luna B. Leopold

We are engaged in great national programs of water control and development. An expanding population demands ever-increasing supplies of the natural resources which are to be found in or upon the landscape—soil, water, minerals, food, timber, and fiber. By his works, by his extractions, man's mark upon his environment becomes ever deeper, his effects more indelible.

We often read that water tables are falling, that floods are increasing, that springs go dry more often now than in grandfather's time, or that rivers are muddier than before. Such changes, if true, are troublesome—but water is a fluctuating resource, responding over time to changes in the environment. A recurring question of our times, and one that we anticipate will be increasingly vexing to posterity, is to know how much of the change in our environment is caused by man and how much is natural. In trying to answer this question we immediately face the insurmountable fact that changes must be measured relative to some standard base or datum. What can we compare against?

The most pervasive—and probably the most important—of the slow and subtle changes result directly or indirectly from variations in climate. Over a shorter or longer period of time, pulsations in precipitation and temperature change the amounts of water that are evaporated or transpired by the soil and vegetation, the amount of water that replenishes soil water, the quantity of water for recharge to ground water and for riverflow. Climatic variations also cause changes in the pattern of erosion, of which some spectacular consequences can be observed in the arid zones. Changes in climatic pattern, through their effects on the hydrologic cycle, on soil, and on vegetation, can produce results remarkably similar to those effected by the works of man.

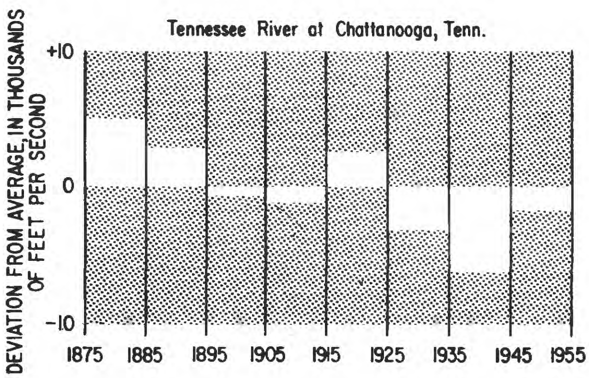
Oraibi Wash, Navajo County, Ariz., July 1960.

About 20 miles upstream from Oraibi Village. The gully is about 20 feet deep, 30 feet wide, and tens of miles in length. Like many others in the Southwest, this gully was formed in the 1880's.

These are direct practical reasons for our concern. The division of water of highly developed streams between bordering States is often based on the so-called virgin flow. What constitutes the flow unvexed by the hand of man cannot be determined at the council tables of negotiation, or even in the halls of justice, without essential hydrologic facts.

It therefore becomes a matter of practical concern, as well as a matter of scientific interest, that the specific causes of given observed effects be identified. The chain of events—the linkage of interrelated factors—must be known in far more detail than is possible at present. Attainment of this objective requires a means for dissociating the direct and indirect effects of man's use from similar effects which are brought about by natural variations in climatic factors.

Determination of these changes is often sought in the analysis of records of streamflow, but the answer usually is neither simple nor unequivocal. Natural daily, seasonal, and secular changes in precipitation cause changes



Example of downward trend in a record of riverflow.

in the rate of replenishment to streams, to the soil, and to ground-water storage which do not show up immediately, but are mingled with the effects of previous changes. Water levels, soil moisture, and streamflow are constantly changing; add the complication of manmade changes and the problem of resolution of the separable effects becomes exceedingly complex.

BENCH MARKS

There is a vital need for a series of measurements of water discharge, ground-water levels, and other hydrologic parameters at selected places representing various environments, unchanged by and permanently protected from the effects of man's activities.

It should be no surprise that, out of the 7,000 stream-gaging stations and the thousands of wells for observation of the levels of ground water now maintained in the United States, only a few fit the requirement. As Langbein and Hoyt[1] show, the vast national program of hydrologic measurements is motivated by the occurrence of hydrologic events—water shortage, flood control, and river regulation, to name a few. Hydrologic measurements, such as streamflow, ground-water levels, and water quality have been made in those areas where there is maximum potential for development and control of water, and for this reason, such information has least potential for observing the long-term operation of natural processes apart from the artificial.

A lengthening of the period of record can be of little help. When the total period of record of streamflow and other hydrologic elements becomes much longer, say twice its present 60-odd years, statistical variance could be better defined. Meanwhile, man's effects and pressures on the enviroment will grow, and so the records become what hydrologists call "inconsistent." The early part of the record measures conditions which differ from those in the latter part. Consequently, increasingly long records can never, by themselves, be analyzed hydrologically or statistically to demonstrate what part of the measured variations in hydrologic conditions is natural and what part is induced by man.

If an answer is to be found it must come from a planned network of observations that include measurements of the natural hydrologic regimen: the flow of streams, the quality of water, and the levels and temperature of ground water, unaffected by man.

For long-term observations of the natural hydrologic regimen, the Geological Survey proposes to establish a network of "hydrologic bench marks" in areas which are as free as possible from man-induced changes.

SCOPE OF THE BENCH MARK NETWORK

Obviously, the establishment and operation of a nationwide network of hydrologic bench marks entails many difficult scientific and technologic problems. The right kinds of observations must be made at the right places. The areas selected must be representative of different climates and terrains. The areas must be as safe from development and disturbance as this generation can assure. Wilderness areas will be especially suited. Because they can help us to understand and to measure the quantities and qualities of water in their native state, wilderness areas to this extent will have direct value to society as hydrologic bench marks. For the same reasons, National and State parks would rank high in the selection of sites for hydrologic bench marks.

Some of the bench marks should be arranged in the pattern of a transect across various geologic and climatic provinces as well as a wide variety in vegetation and soils. One transect would extend east to west across the continent to include mountains and plains. Another would extend north to south through the central regions where the terrain is relatively flat, thus giving a representation of the

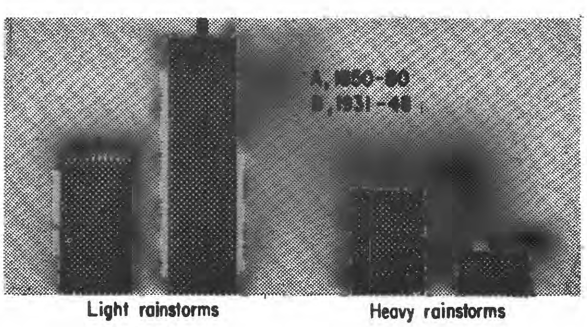
[1] Water Facts for the Nation's Future, The Ronald Press, 1959.

effects of latitude uninfluenced by major differences in topography. The ranges of landscapes that can be included will be severely limited at first because funds now available for this purpose are small. However, we hope that as many as a hundred hydrologic bench marks can be established among the 50 States of the Union.

KINDS OF OBSERVATIONS

Several kinds of observations would be carried out at the hydrologic bench marks. At most sites, autographic records will measure runoff—the flow from a watershed in a stream—and observations may be made of the movement of salts and sediments transported in runoff. Measurements may be made of fluctuations in the level and temperature of ground water, and precipitation and other climatologic phenomena may be observed. Because channel stability is a problem of growing concern, consideration will be given to the inclusion of observations of changes in cross-sectional shapes of streams. There is also the possibility of installing traps for the collection of windblown pollen—useful because the species composition of pollen is a clue to vegetal changes in an area.

Apart from these kinds of observations, which are made periodically or seasonally, a survey would be made of the drainage basin above the bench-mark measuring points to record the soil, geology, topography, and vegetation. in some areas, particularly in the arid zones, quadrants or transects will be established to give quantitative estimates of gradual changes, if any, in plant growth or species.



Change in character of rainfall at Las Cruces, N. Mex.

Light rains promote vegetal growth; heavy rains produce runoff and create erosion. Hence, there was in the 1850–80 period a climatologic condition that led to a modern epicycle of erosion that began with the 1880's. Climatologic conditions in the 1931–42 period lessened the erosion.

HOW HYDROLOGIC BENCH MARKS ARE TO BE USED

The powerful tools of statistical inference cannot do what bench-mark observations can do—distinguish man's effects from those of nature in the records. Bench marks, as simple measures of the time trend in the secular march of hydrologic events unaffected by the works of man, have been mentioned already. Direct comparison with other records is a more sophisticated use. For example, if the record of flow at a regular gaging station shows a downward trend relative to that at a nearby hydrologic bench mark, there is direct evidence of depletion of streamflow. Hydrologic bench marks can resolve the interrelations between climatic and hydrologic variables with confidence that the results are not clouded by the effects of the works of man. The interrelationships thus demonstrated at proven hydrologic bench marks can provide the base or datum for separating natural from artificial effects.

THE VIGIL OBSERVATION AREAS

A second kind of observation is needed for the study of time trends. We must also begin now to observe changes in various phenomena related to land-water relations that change with time. The established network of gaging stations and temperature stations furnishes a record of variations of streamflow and rainfall through time. Both streamflow and (to a lesser extent) water temperature may be affected by man and his activities. Even precipitation may be indirectly affected by, for example, changes in the carbon dioxide content of the atmosphere and by atmospheric pollutants. Records of streamflow, temperature, and precipitation indicate time trends, whether caused by natural processes or induced by man's activities. No comparable records are being kept on the shape and character of river channels, the density of vegetation and its species composition, the amounts and character of dust, pollen, and other particulate matter carried by and deposited from the air.

In addition, then, to the establishment of bench marks which will provide a record of observations of hydrologic phenomena uninfluenced by man's activities, observations of phenomena which might be affected by man's activities should be extended to include many other parameters not now being measured.

The network of such observations might be thought of as observational areas or points where the hydrologic phenomena as they change with time would be recorded. This is the nature of the Vigil Observation Network I earlier proposed as one aspect of our international program for hydrologic investigations.[2]

INTERNATIONAL COOPERATION

The program of the Geological Survey for a network of hydrologic bench marks and the Vigil network will become part of a proposed international program of cooperation in hydrologic research. By this means, American scientists will have direct access to information on a far wider range of variations of soils, vegetation, and climate than are represented in this country. These measurements on diverse types of landscape in different parts of the world will greatly enhance our opportunity to distinguish between the effects of man and of nature on the environment.

[2] Leopold, L. B., 1961, The man and the hill: opening address to the Symposium on climatic change, UNESCO and WMO, Rome, Italy, Oct. 3, 1961; U.S. Geol. Survey Circ. 460-A. 1962.

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