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GETTING THE FACTS THROUGH SURVEYS AND INVESTIGATIONS

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Panel Presentation

The Watershed — Using it as a Basis for Soil and Water Conservation

Getting the Facts Through Surveys and Investigations

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Collecting basic data on soil and water resources is the starting place in project design. The watershed is a natural "water handling" unit and has important advantages as a basis for collecting and analyzing facts. Recurring measurements are necessary for most hydrologic facts. Non-recurring measurements are suitable for land facts with noted exceptions. A continuing program of study of reservoir sedimentation in Illinois has shown the effect of human activities on the transport of sediment by water. Local, state and federal agencies must collaborate to insure well-rounded programs of data collection. Illinois' experience proves these people can work together effectively.

THE LAWS OF NATURE govern the effective conservation and development of our land and water resources. These laws are not limited by the boundaries of a valley authority, a conservancy district or a watershed boundary.

A watershed is generally considered to be the geographic area of overland drainage which contributes waters to the flow of a particular stream at a chosen point. It is a "water collection" and "water handling" unit, a topographic entity which is usually surrounded by other entities of the same nature.

A great river basin consisting of an entire region drained by a major continental river and its tributaries is a comprehensive mass of variable facts, but the watersheds within the basin are frequently small enough and homogeneous to let us gather all the facts, correlate them, understand the applicable laws, and intelligently design and build successful conservation developments. We cannot do an intelligent basin-wide job until we understand the functioning of the watersheds within the basin.

The drainage area is a natural unit in the important runoff phase of the hydrologic cycle. It should be noted however, that other phases such as evaporation, rainfall, and the occurrence of ground water do not necessarily follow drainage area boundaries. For instance the rainfall pattern in Illinois is affected less by the low divides which enclose the Illinois River basin than it is affected by the climatic change between northern and southern Illinois.

Water conservation programs may be aimed at conserving energy, as in reducing floods, or generating hydroelectric power, both of which generally aid in increasing the minimum stream flows; or they may be aimed at conserving materials, such as programs for reduction of pollution or reduction of silt load. Soil conservation programs are aimed primarily at conserving material through preventing physical loss of soil and fertility; and toward maintaining high crop yields.

Soil and water conservation programs that will stand the test of time require decisions based on facts on the physical situation. Getting the facts therefore is fundamental to every conservation program, and to enable good program planning, fact collection should be as complete as we can make it. The cost of gathering the basic data on water and soil resources is small in comparison to project costs but only the facts can enable design in compliance with nature's laws.

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J. B. Stall, Assistant Engineer, Illinois State Water Survey, has, since 1946, been working on the state's program of reservoir sedimentation study, and is co-author of a number of the reports on Illinois work. He is a member of the Soil Conservation Society of America.

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There are two general kinds of fact collection: Recurring, and non-recurring. For things that change rapidly we need extended programs of repeated measurements.

Water Resource Facts

Since water resources are renewable, they require extensive collection of recurring measurements. In a particular region there is need for long-time recording of intensity and duration of precipitation and for data on the character of the more intense rainstorms. These are intimately related to erosion and flood problems.

Meteorologic data are usually available over a longer period of time than other hydrologic data. The cost of collection of precipitation data is comparatively low. Frequently long-time precipitation records are highly valuable in extending stream-flow records or other records which are available in more detail but for a shorter or interrupted period of time.

Stream-gaging within the watershed is essential for estimation of sediment transport as well as for design of water projects. Closely related to stream flow gaging is the measurement of sediment transported in the streams, for sediment concentrations must be correlated with the volume of stream discharge to learn the total quantities of sediment transported. A fairly complete program of stream-flow gaging has been developed in this country since the turn of the century by the United States Geological Survey. Such gaging stations are generally operated on a matched-funds basis with the state or local agency contributing half of the cost of the work. About 170 stations are now in operation in Illinois or on its boundaries and 11,370 in the entire 48 states.

While the measurement of meteorologic and surface water phenomena progresses, there is need to gather information on ground water conditions. These include studies of the waterproducing formations, the availability of ground water, and the relationships of ground water occurrence to surface and meteorological waters. At the same time it is important to make frequent analyses of water quality, both underground and in the streams, to determine chemical characteristics.

A good deal may be learned from stream flow records. For example, recent Water Survey studies on the contributions of overland (runoff) flow to streams as compared with ground water discharge indicate that nearly two-thirds of the annual stream flow in Northern Illinois came from groundwater, while in Southern Illinois less than ten per cent of the stream flow passed through the earth.

Data on two extremely large factors in the water cycle, evaporation and transpiration, are gravely needed. Losses due to evapo-transpiration are commonly greater than the stream flow. Data on these factors are scarce due to the lack of adequate methods of measurement; yet in many cases, the success or failure of a watershed conservation program may be determined by adequate knowledge of these items.

The recurring measurement of hydrologic information requires cooperation of the state or local agency with many other agencies such as the U.S.G.S., which carries on stream-gaging work, the U.S. Weather Bureau, which does extensive climatologic data collection, as well as with many others. The Illinois Water Survey has been in this particular field of activity for some fifty-six years, and its program is therefore fairly extensive. Its present program includes studies of precipitation with radar, an extensive program of collection of ground water data, and a sizable program of water quality determination.

Other water resource information must be collected on a non-recurring basis. This includes some of the ground water data for, except where the works of man intervene, ground water situations change slowly and may be studied on a non-recurring basis, or with a recurrence interval of many years. There is need for mapping of stream channels, reservoir volumes, land slopes, and of other slowly-changing things. In general, these latter measurements may be carried on at intervals not more frequent than once in ten years, if that often. For example the first survey of Lake Decatur was made in 1931. Subsequently a detailed survey was made in 1936, and another detailed survey in 1946.

Land Resource Facts

Changes in the land are less rapid than those that take place in streams, and data need not be obtained so often. For example, the frequency of soil mapping may be determined by the development of improved classifications rather than by changes in the soils. Measurements of the soil resources that are necessary to the planning of any watershed program include mapping of the distribution of soils, slopes and erosion, studies of the character of the soils in the basin, investigation of subsoil conditions, and identification of sediment sources, either by inspection of the land or by analyses of accumulated sediments.

One method of determining the rate of erosion and the amount of sediment which is being transferred from the land into the river waterways is by measurement of sediment deposits in reservoirs. The Illinois State Water Survey has been active in this field for more than 20 years. All its work is carried out under a cooperative program involving all the major agencies which have information of value in relation to sedimentation.

The Illinois program of sedimentation study includes field work in measuring the actual amount of sediment

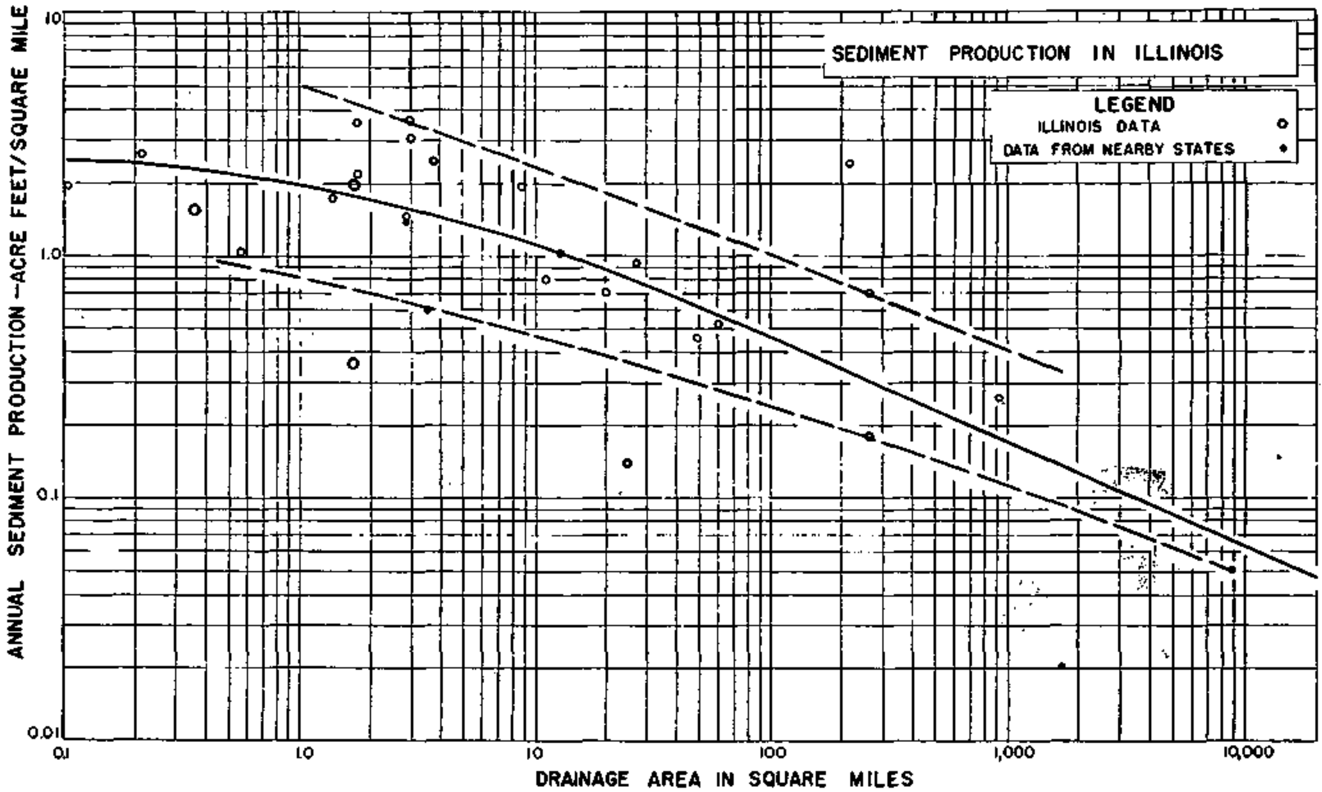

Figure 1. Sediment Production in Illinois.

accumulated in reservoirs, and in compiling the hydrologic and engineering facts relative to each of the reservoirs. The lake owners provide records of construction, modifications, and use, and furnish labor to aid in the actual surveys. The Office of Research, Soil Conservation Service, contributes technical advice and guidance and furnishes equipment for some of the work.

Cooperating in the studies, the Soil Conservation Districts within the counties, and State and Soil Conservation Service soils surveyors work on the collection of data on the erosion on the land. The data include a complete or sample conservation survey of the watershed for each reservoir surveyed, involving location of eroding areas, extent and degree of erosion, slopes of land, and soil groups involved in the erosion process. The Agricultural Experiment Station of the University of Illinois analyses samples of sediment taken during the engineering survey of the lake to determine the character of the sediment.

Under the cooperative program, data are now available on 41 reservoirs in Illinois. Detailed surveys have been made on 18 reservoirs; reconnaissance surveys on 17. Preliminary cross-sections have been taken on six new reservoirs during construction.

The Illinois reservoir sedimentation program has not yet determined all the separate effects of the . many physical factors involved in soil erosion and sediment movement. Certain general relations have evolved, however, as shown in Figure 1, which summarizes the Illinois data. From this graph it is seen that the contribution of sediment into reservoirs from small watersheds is greater per square mile than the amount of sediment that arrives in reservoirs which receive the flow from large watersheds. Large watersheds do cause more reservoir silting than small ones, but the silting is not in direct proportion to the area. Part of the sediment drops out of the flow of water enroute from the point of erosion to the reservoir. The average annual rate of sediment production on the smallest watershed studies is in the neighborhood of three acre feet per square mile, which checks reasonably well with a mean figure of seven tons of sediment per acre, estimated by studies on the land.

Certain facts in connection with the soil do need to be measured fairly frequently. Land use changes rapidly at times and frequently brings about changes in erosion rates. The Agricultural Experiment Station, in cooperation with the Soil Conservation Service, has collected information on the land use history of each basin. The latter has undergone marked changes with resulting changes in erosion rates.

At Lake Decatur, the intensive war-time cultivation of corn and soybeans apparently increased erosion rates. A survey of this lake showed that during 1922-1936 the lake had lost capacity to sediment deposits at a rate of

1.0 per cent per year. A later survey showed that during 1936-1946 this rate had increased 20 per cent to a loss of 1.2 per cent per year. Analysis of stream flow data indicated that the difference was not due to climatic or hydrologic factors. A study of land use data in the watershed showed a 29 per cent increase in the acerage of clean-tilled crops—corn and soybeans. The higher erosion rate on such fields was concluded to be the chief factor in causing the increased lake sedimentation.

From Figure 1 we have estimated the sediment load reaching the Illinois River. The sewage and waste suspended solids discharged by the population and industries along the river add up to about only one-thousandth of the sediment load caused by erosion.

Facts on Human Activities

Collecting data on human activities in the watershed is much like market research. It is necessary to determine present and future demands that may be placed on the resources available, such as demands for food and fiber, and for industrial products. If for example it were anticipated that population would dwindle, it would follow that less intensive cultivation would be required, and less intensive development within any particular watershed would be expected except where the local conditions were exceptional.

Many economic and human aspects need to be evaluated. Do the people in the basin have the capital necessary for the completion of the proposed development? Have they learned to desire the contemplated developments? Is there desire or need for immediate cash crops greater than their desire for long term improvements of their conditions? What proportion of the farms in the basin are occupied by owners? What are the customs of the area that may make it difficult to initiate the projects under consideration?

The avowed purpose of the soil conservation movement is the "most productive use of each acre of land in accordance with its capabilities." In the arid regions of this country it has become equally important to "make the most productive use of each gallon of water." Here the presence of water is the major controlling factor in the capability of the land.

In states like Illinois where water is not yet the controlling factor in agricultural production, it may nevertheless become critically important. Furthermore, a development plan for water resources is necessary that municipalities and industries, supported by agriculture, may thrive. Table 1 gives the story of demands that are placed on water in Illinois. This method can be applied in any watershed.

Notice the importance of industry as a producer of wealth and as a water user. Agriculture generally uses water that does not appear as stream flow; in Illinois this is 76 billion gallons daily, of which agriculture is using about 33 billion gallons daily. Industry and the cities use only the "available" water that appears as stream flow, and they are using nearly half of that. These latter uses can be reduced by effective conservation measures, but Illinois is much closer to the danger point in municipal and industrial uses than in agricultural ones.

Table 1. Status of water resources and water use in Illinois—1948.

Item	Billion Gallons Per Day	Annual Value Millions of Dollars
Atmospheric Moisture passing over Illinois	2,000	----
Precipitation	99	----
Transpiration by Crops	33	1,983
Evaporation losses, etc	43	0
Stream Flow	23	----
Industrial Use	8	6,675
Municipal Use	1	40

Erosion has a serious effect on the industrial potentialities of any watershed. High concentration of turbidity in the river makes the water undesirable for use in industrial processes through increased fouling of condensers and through making the water less suitable for other uses. In addition, the deposition of sediments along the valleys beneath the flowing streams have created a situation where recharge of water from the river into depleted ground water formations adjoining is much reduced.

Such a situation has developed at Peoria. Ground water levels in 1933 were generally higher than those in the river. The heavy industrial pumpage from wells which has grown in the last few decades at Peoria has resulted in a lowering of ground water levels to the point where, in much of the Peoria region, ground water levels are now far below the level of the water in the river. In most situations it is expected that the creation of such a situation will lead to discharge of water from the river into the ground, but this happens to only a very small extent at Peoria so that the ground water deposits in this region must depend primarily on the water entering them from other sources than the Illinois River. Thus the sediment in the river exerts a marked adverse effect on the availability of ground water for industrial use.

To overcome this situation the Water Survey (in cooperation with the local Association of Commerce) now has in operation at Peoria a pilot ground water recharge pit (Figure 2) capable of recharging directly the ground water formations with river water at a rate of about two

Figure 2. Ground Water Infiltration Pit near the Illinois River at Peoria.

million gallons per day. However, even the operation of this pit is subject to the vagaries of the river. Recharge can only be carried on when temperature and turbidity of the river water are low. Dr. Max Suter supervises this work.

It would seem that the greatest weakness in the Illinois program has been in the field of collecting and using information on the attitudes of the people, their economic resources, and the other human and economic factors that may either favor or handicap development of water projects. Much basic information on the economic aspects has been gathered by Elmer Sauer but so much difficulty is being met in carrying projects to completion under local sponsorship that we believe we know too little about human aspects to motivate people to act on their own problems.

Understanding the Facts

We learn nature's laws from analysis of the facts. We cannot use the facts we gather unless we understand their significance. And frequently we cannot know what facts we need without attempting to interpret the data available.

Nearly 20 years ago, two lakes were built in northwestern Illinois. One lake, of 800 million gallon capacity, was built in 1923 by a railroad to furnish a water supply. The drainage area was nine square miles and a 1949 survey showed the lake had lost 14.3 per cent of its original capacity in 25.6 years. Through the years a country club has developed the lake area under a long-time agreement with the railroad. The clubhouse enjoys an extremely delightful setting on the lake bank. Fifty or more private cabins, as well as group camp sites, have been constructed. The 18-hole golf course is the pride of the club members. The club anticipates many future years' use of these recreation facilities.

About the same time, another lake was constructed, located not 50 miles away. Here, similar cabins and a clubhouse were developed over the years since the lake was constructed in 1924. Here, a lake of 87 million gallons capacity was constructed on a drainage area of 13 square miles. Our survey of the lake in 1947 showed it had lost 73.6 per cent of its capacity to sediment in its life of 22.9 years. Water near the dam was formerly eight feet deep. This was reduced to two feet by sediment. The spillway of the lake failed in 1950 draining the lake. The beautiful clubhouse is now practically useless. This watershed was much too large to serve the size of the lake which was built. In our report on this lake we seriously suggest to the lake-owners that due to the exorbitant rate at which sediment is arriving in the reservoir, that the club abandon the lake at this site. The lake basin shown could surely be worked into a nice golf course and further expenditures toward prolonging the lake would be saved.

The bright and dismal futures of these two comparable recreational developments certainly present a contrast! The difference is believed to be a case of good luck in the first case and poor luck in the second. At the time these lakes were constructed, there were not available the facts and the understanding that we now have at our disposal. One turned out favorably and one badly. With the understanding that existed at the time of designing the cases might as easily have been reversed.

In reservoir design, the ratio of the lake capacity to the watershed area is of paramount importance. Where an exorbitant rate of storage loss occurs the watershed is probably too large for the lake. Even in cases where soil loss from the cultivated fields is reduced to the minimum, the presence of a disproportionately large watershed results in excessive sedimentation. Carl B. Brown's work on this subject is fundamental. The relationship of lake capacity and land area brings out the importance of watershed thinking in project development.

Conclusion

To plan and carry out soil and water conservation programs we need much factual information on hydrologic, land resource, and human situations. Some of the data must be collected continuously and this work requires stable programs for fact collecting. The collaboration of specialists in the fields of hydrology, agronomy and economics, and of local, state, and federal agencies, is important to ensure well-rounded programs. Illinois' experience demonstrates that these people can work together effectively. Getting the facts together is only part of the job; we must then correlate them and try to understand the natural laws that interrelate them. When we have done this, we are ready to begin planning for soil and water conservation programs.

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