Watershed (Hydrologic) Modeling Workshop Mar. '70
Tucson, Ariz.

KES-1

Cornbelt*
Hydrologic Models
Treynor, Iowa

DATA FOR HYDROLOGIC MODELS IN THE WESTERN CORNBELT

by

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INTRODUCTION

To confidently apply a watershed model to an ungaged watershed, it must be tested and verified by applying it to gaged watersheds. At the present time, we at the North Central Watershed Research Center, NCWRC, are collecting hydrologic and erosion data with an eye to the near future when we, or a cooperator, will use our data to guide development and verification of a watershed model. This discussion, therefore, will primarily concern characteristics of our gaged watersheds and the data which we are collecting, or have at hand, that are applicable to watershed modeling.

From my viewpoint, hydrologic models are necessary for three reasons: First, we know far more about hydrology than we are currently using in our design methods. We need better organization and ways to implement existing and new knowledge. We know or can reasonably estimate the effects of varying crops, fertility levels, channels, etc., on the performance of a watershed, but these are difficult to integrate into our present techniques. Second, there are important hydrologic variables that are now not considered, or are considered only superficially. For example, evapotranspiration plays a significant role in the hydrologic cycle; yet, we most often consider it only as an average annual geographic variable. Third, the interactions among the hydrologic variables will not be well understood and applicable until all major components in the hydrologic system can be modeled. We often estimate the antecedent soil moisture conditions from precipitation amounts during some previous period because we realize the two are related. However, we are ignoring other processes

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such as evapotranspiration, percolation, rainfall distribution, etc. Saxton (1)[2] showed, by modeling the soil moisture component, that there is actually very little relation between soil moisture and precipitation amounts the previous 7 days. The need for defining antecedent soil moisture is itself the result of an observed interaction between soil moisture and infiltration. Hydrologic models need to be developed to enable us to utilize all of our hydrologic knowledge, involve all of the important variables, and define interactions of the variables.

The philosophy of model development is interesting when model definition, development, evaluation, accuracy, etc., are considered. Bross (2) comments "The great advances in science are those in which a useful new model is introduced," and he sites Newton's and Einstein's equations as successful examples. From this view, engineers and physical scientists are model specialists. Bross (2) also states "Progress in science is based on this constant interplay between model and data," but he concludes "...it is rather pointless to say that the model maker is a greater scientist than the data-grubber..." This need of coordination between model builders and those collecting data is heavily stressed by Smith (3) and other members of the ASCE urban hydrology committee. This raises the question: If the models are not written and the data collected by the same person or group, how can the needed coordination best be implemented? This cooperation will not "just happen" but will result only after a concerted effort.

DATA REVIEW

As we scan the data from our gaged watersheds, we need to keep organized from the viewpoint of watershed models. To accomplish this, I will use the two-phase concept, land phase and channel phase. Although these are common watershed model terms, let's review by noting that land phase encompasses the processes of precipitation, infiltration, evapotranspiration, interflow, transmission losses, depression storage, and overland flow. In essence, this phase provides a time-distributed runoff supply to the edge of a watershed's channel system. Here the channel phase processes of translation, storage, and summation govern until the runoff is delivered out of the watershed.

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[2] Numbers in parentheses refer to literature cited, page 9.

We are primarily considering the deterministic portion of modeling. This is not to suggest an elimination of stochastic methods. On the contrary, I am certain any model will contain techniques of both. Our data are physical measurements over only a few years and thus will be most useful in developing and verifying deterministic aspects.

With these thoughts in mind, let's first consider the overall view of our watershed's locations and features, and then each location and its data in some detail. Figure 1 shows the location of the four sites where watersheds are operated by our research group at the NCWRC, where we have data of interest to those working on watershed models. Having several locations, we are obtaining data from watersheds of highly diversified soil, cover, geologic, and geomorphic features. Following are the characteristics of these data as they relate to watershed model application, with an occasional side glance at interpreted results. Most of these data are on computer cards or magnetic tape and therefore are readily available for computer processing.

TREYNOR, IOWA:

We have five gaged watersheds in the Missouri Valley deep loess soils area located about 20 miles east of Council Bluffs, Iowa. Compared with our other watersheds, these have the best land use control and are gaged the most intensively. We have complete land use control on four of these watersheds. The fifth, W-5, is farmed by the owners, but they are bound by a cooperative conservation effort. The watershed sizes and land uses are:

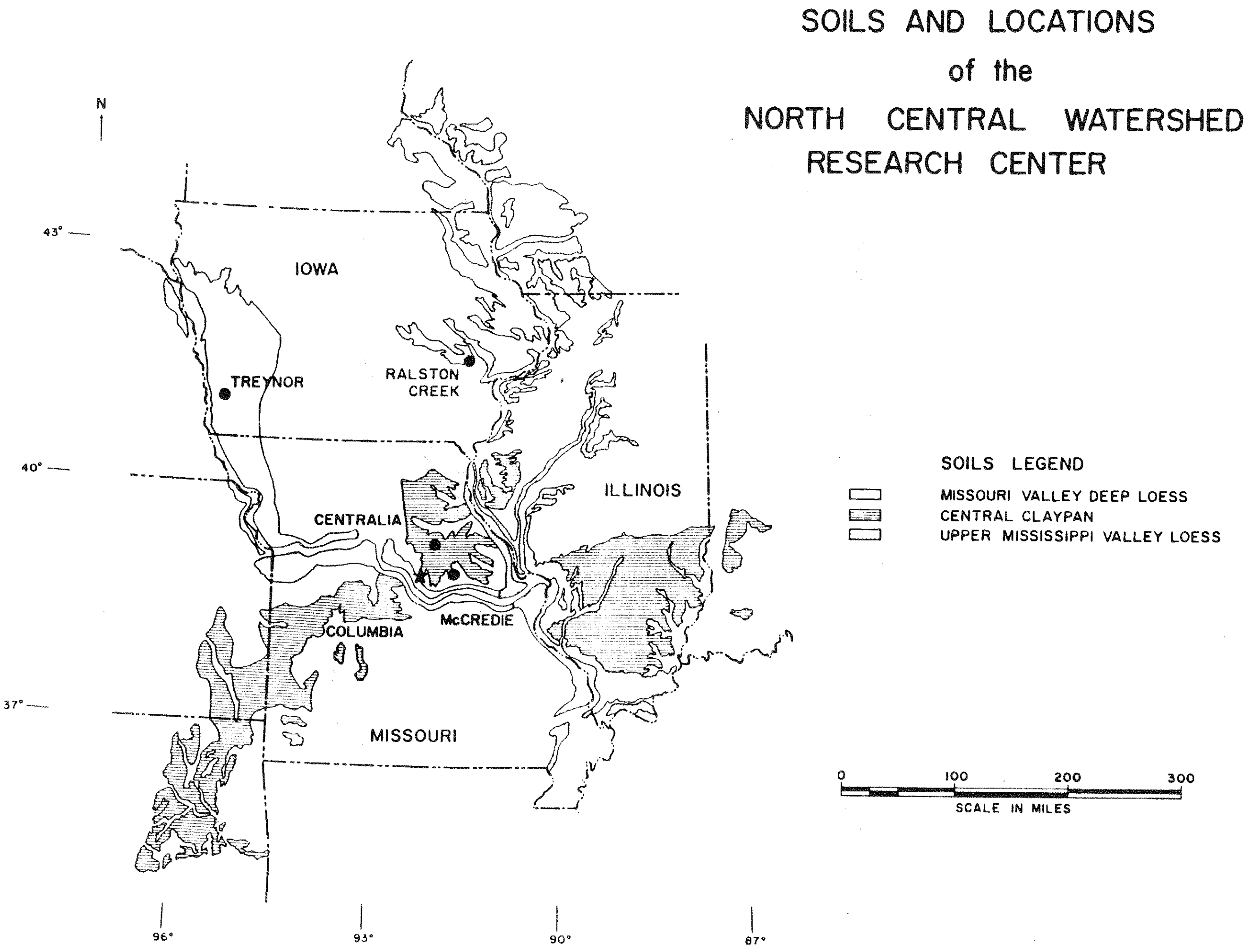

Figure 1.--Locations of watersheds being studied by the North Central Watershed Research Center.

Watershed	Area Acres	Crop	Land Treatment
W-1	74.5	Corn	Contour
W-2	82.8	Corn	Contour
W-3	107	Grass	Pastured
W-4	150	Corn	Level-Terraced
W-5	389	Mixed	Level-Terraced

The primary objective of these watersheds is to study the gullies that exist on each watershed. In addition, all major hydrologic variables and total sediment yields are being measured. Figure 2 shows the surface features and instrumentation of watershed 2--which is typical of the other watersheds. A schematic geologic section is shown in figure 3. These two figures indicate several important features. The topography is quite steep, with a well-developed but relatively small channel system. The loess mantle is relatively permeable and has a high water-holding capacity. The glacial till is quite impermeable and forms a hydrologic boundary. Water apparently percolates nearly vertically until it reaches the saturated zone, then moves horizontally, to reappear as base flow. Only a small amount is expected to percolate through the glacial till.

Each major variable within the hydrologic cycle is being measured on these watersheds. These include precipitation, streamflow, ground water, soil moisture, and evapotranspiration. These measurements are either continuous or at intervals that will allow a detailed representation throughout the year. This complete set of measurements over time is giving insight into the interrelations of the processes that govern the hydrologic cycle--for example, the relations of soil moisture, ET, infiltration, and percolation. In this way, these data will be valuable in defining the principles to be used in a watershed model. For a model to perform satisfactorily through varied conditions, it must give adequate representation to each of the components that must be considered. By having measured these components, their representation can be evaluated in addition to the usual model outputs.

A characteristic hydrograph from these watersheds is shown in figure 4. Note the quick response and sharp recessions, which reflect the steep slopes and lack of channel storage. The ϕ-indexes, average infiltration rates expressed in the same units as rainfall, show the effect of antecedent

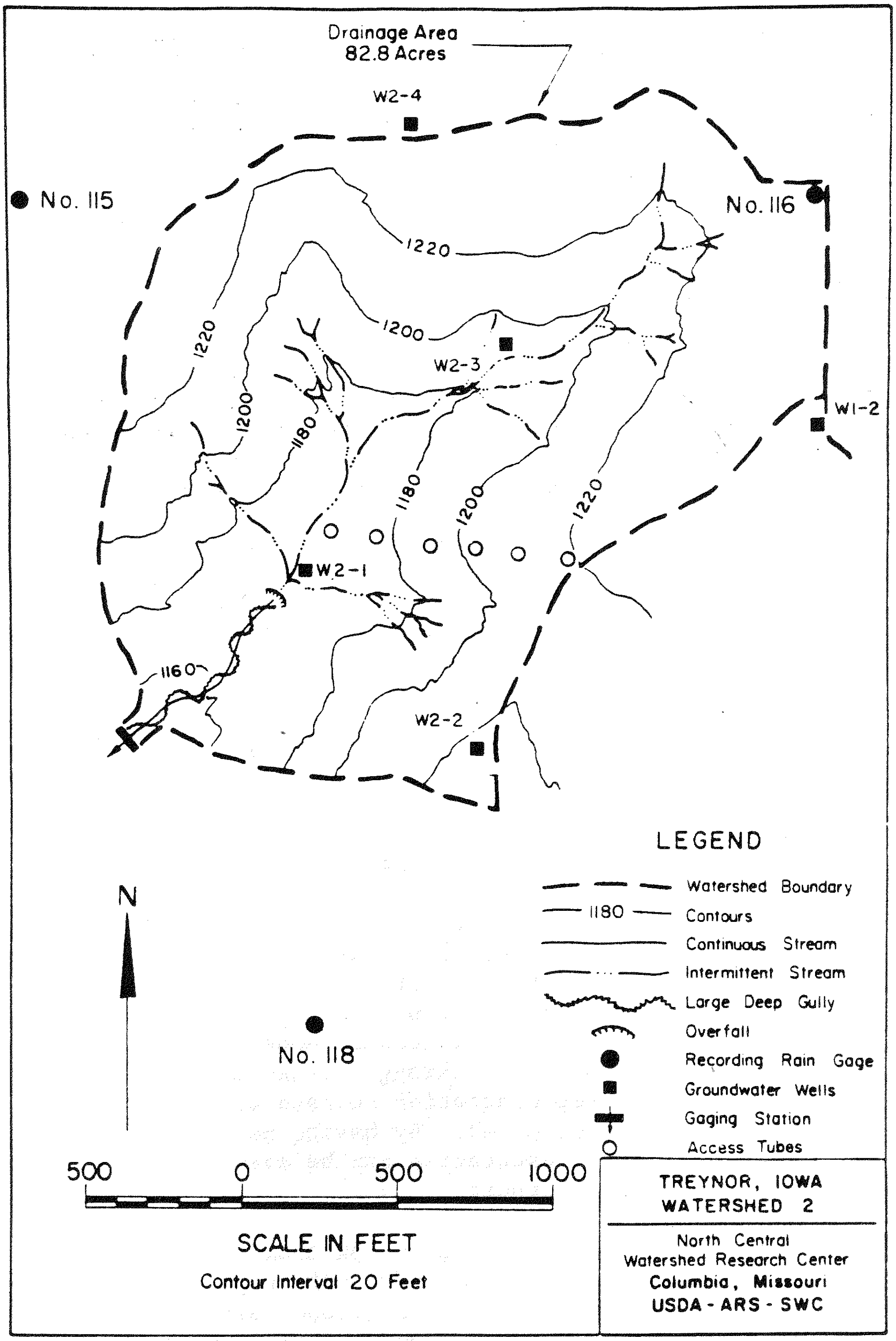

Figure 2.--Topography and instrumentation of Treynor Watershed 2.

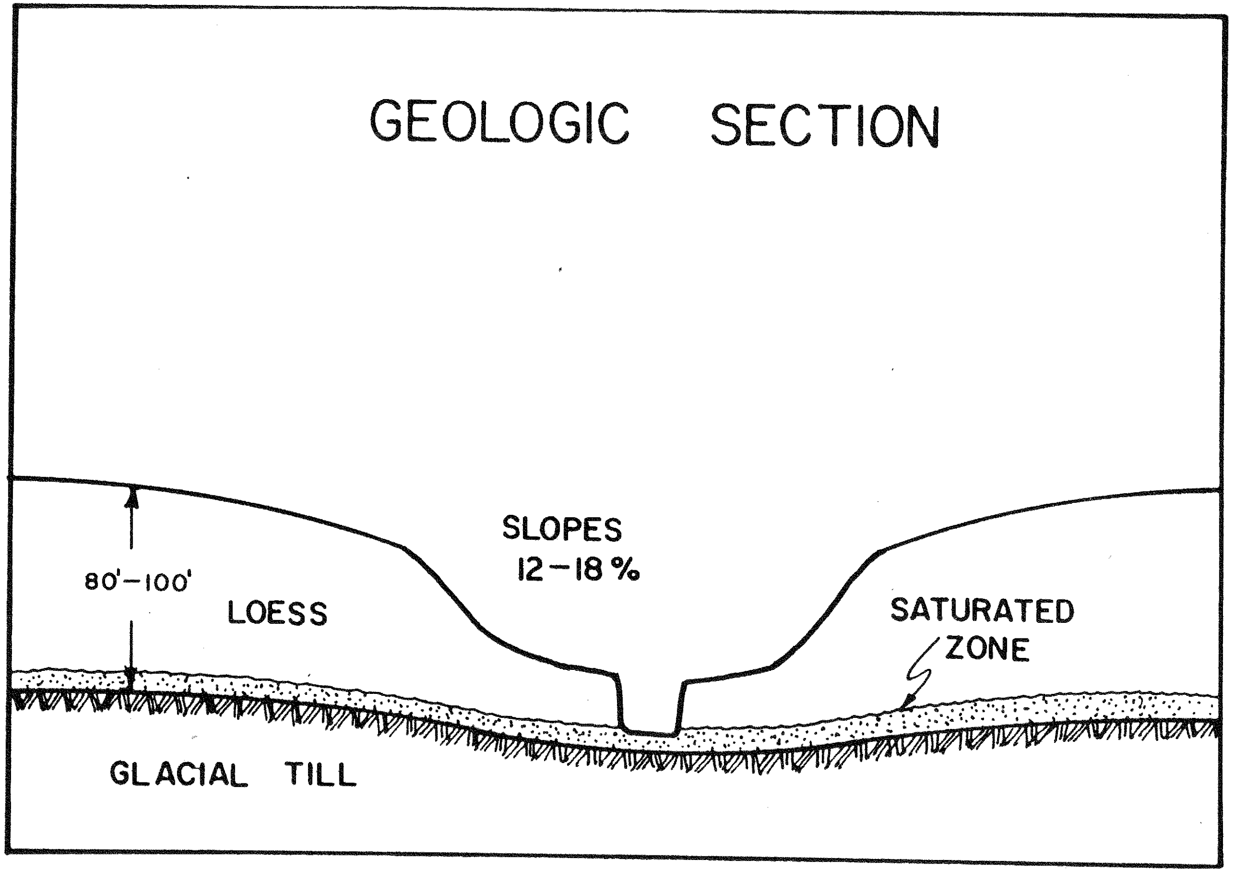

Figure 3.--Schematic geologic cross section of loessial watersheds.

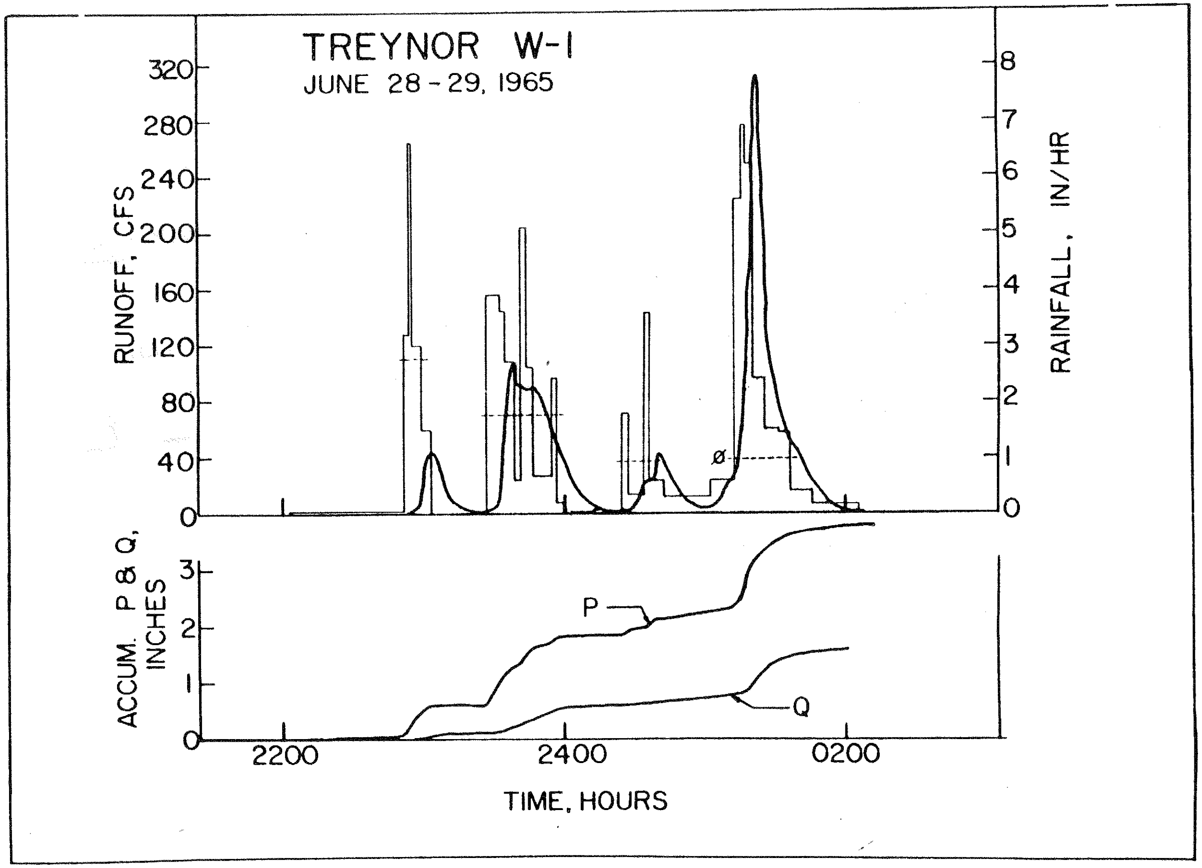

Figure 4.--Example hydrograph from the steep, loessial watersheds.

rainfall. This example shows the watersheds' reaction to two variables, surface features and soil moisture, that must be modeled.

In figure 5 are shown the results of observations within the soil and geologic profile. It is quite apparent that each zone operates in response to the precipitation input and to each other. This certainly expresses the subsurface system as a continuum and a system to be recognized in any watershed model encompassing base flow.

The long-term performance of these watersheds is indicated in figure 6 by the average annual water yields and soil losses measured from 1964 to 1968. Annual precipitation has averaged about 34 inches, compared with a normal of 28 inches, and has been quite uniform among the watersheds. Some of the significant findings shown in figure 6 are: (1) Level-terraced W-4 has similar water yields to corn watersheds W-1 and W-2, but only a small amount is surface flow. This results in drastic reduction of sediment yields but not of streamflow. (2) The grass watershed, W-3, reduces both water and sediment yields. (3) The larger watershed, W-5, confirms the findings from the other watersheds. A more detailed explanation can be found in papers by Piest and Spomer (4) and Saxton and Spomer (5).

The data just discussed are basic to hydrologic models. However, a logical extension would be to model erosion, sediment transport, and nutrient movement. These data are also being obtained. Both gully and surface erosion are measured by frequent suspended-sediment samples during each storm. Nitrogen and phosphorus have been applied at two levels and their movement in the soil and water is being monitored. Although modeling of these variables may represent a sophistication not yet feasible, the usefulness is apparent and we should make this a projected goal.

In summary of our data at Treynor, the watersheds are on a relatively uncomplicated and definable geologic setting, land use is varied and controlled, and several years of data are already at hand. For application to watershed models, these data primarily represent the land phase, since channel processes are not dominant in hydrograph development. The land use and surface soils play a dominant role in surface runoff, but a significant portion of the water yield is controlled by the deeper profile through percolation and base flow.

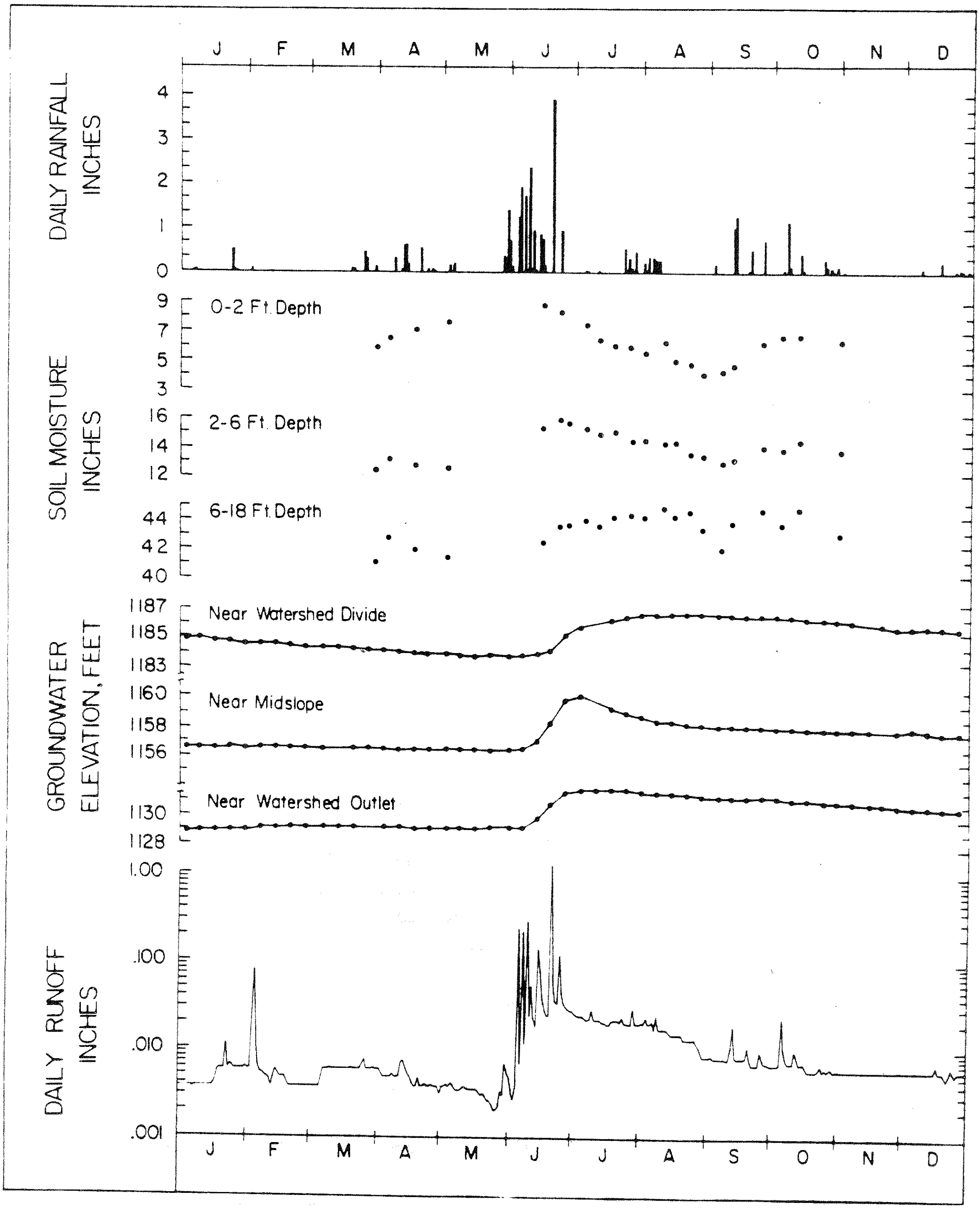

Figure 5.--Example of subsurface response on loessial watersheds, Treynor W-3, 1967.

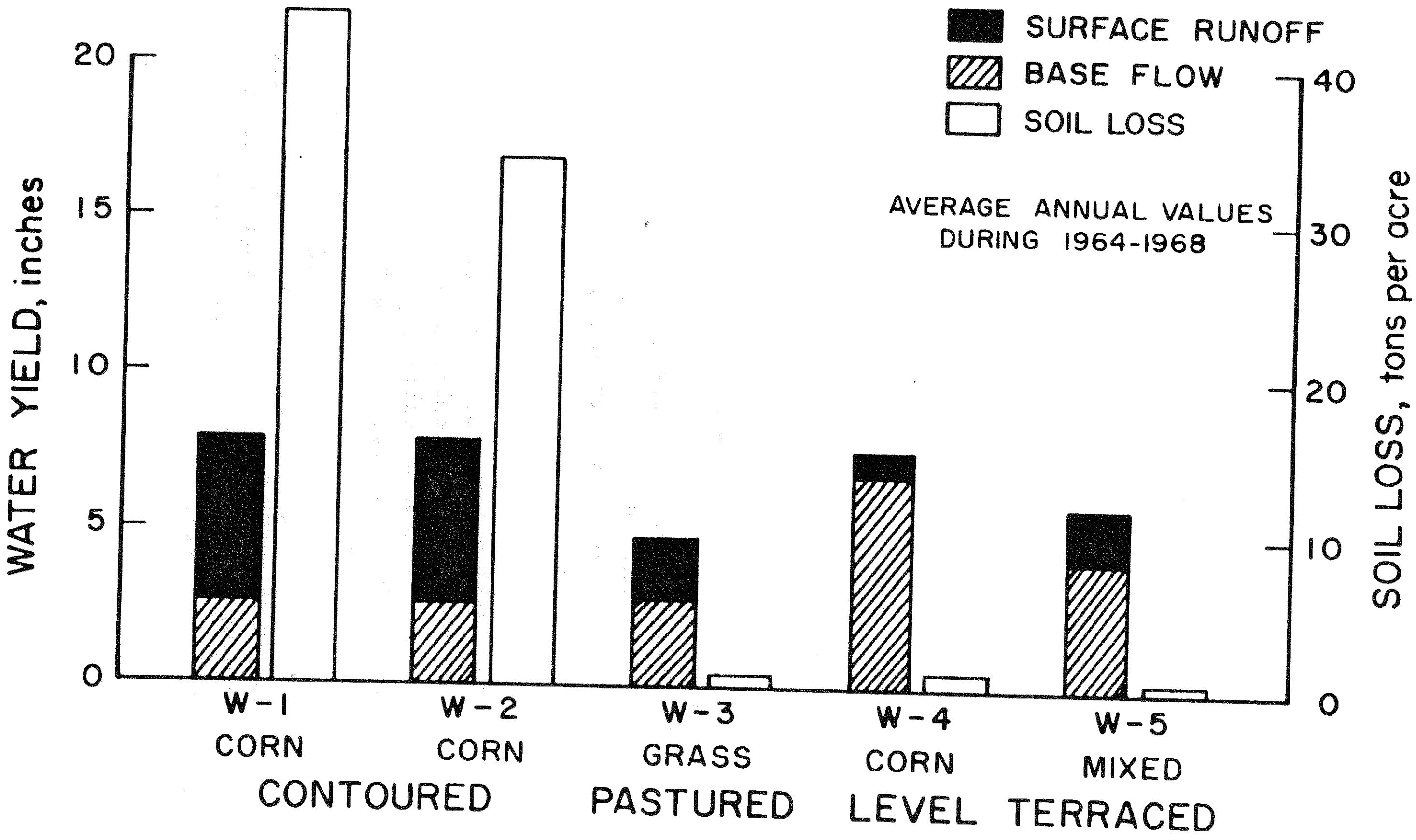

Figure 6.--Observed water and sediment yields from the Treynor watersheds.

RALSTON CREEK, IOWA:

One of the longest precipitation-runoff records on small agricultural watersheds is available from the Ralston Creek watershed (3.01 square miles) near Iowa City, Iowa. Records have been obtained since 1924. Complimentary data are available from Rapid Creek watershed (25 square miles, 1937 to present) and South Branch watershed (3.01 square miles, 1963 to present). The location of these watersheds is shown in figure 7. Their soils and geology are similar to the Treynor location, but the loess cap is only 5 to 10 feet thick and the subsurface flow system is not as definable.

The two Ralston Creek watersheds are now becoming urbanized. As indicated in figure 8, South Branch Ralston Creek is now about 25 to 30 percent urbanized and is being developed at a faster rate than Ralston Creek. In a cooperative effort by ARS, USGS, and State University of Iowa, hydrologic data are being collected on these three watersheds and the urbanization recorded by aerial flights at 2- to 3-year intervals. Other pertinent data, such as storm sewer construction, are also being obtained. These data will reflect both the land and channel phases. Particularly large changes will be expected in the channel phase as the city storm sewer system replaces the natural agricultural drainage channels.

If the watersheds urbanize as expected, data will be obtained that will allow testing of models over a long period of record on an agricultural watershed and then on simultaneous conditions of urban and agricultural. In contrast to the detailed data on the Treynor watersheds, the Ralston Creek data are only the input and the outflow of the watersheds and thus will be useful for the usual model testing rather than component evaluation. However, this testing will give much-needed insight into the effects of urbanization and allow more adequate modeling of watersheds in this land use.

MC CREDIE, MISSOURI:

The central claypan soil areas of Missouri and Illinois have features that contrast sharply with the loessal areas. Their land form is quite flat, with most slopes ranging from 2 to 5 percent. The soils have developed on a shallow

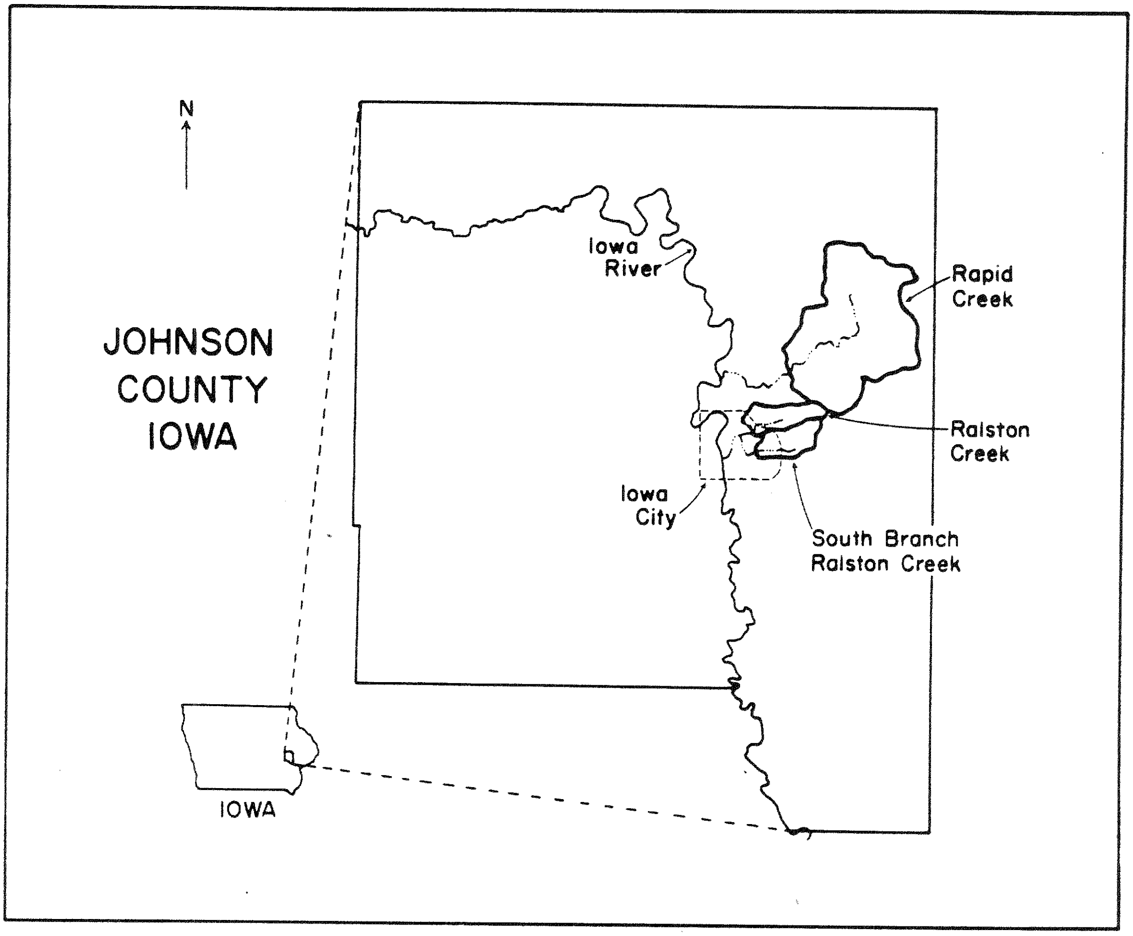

Figure 7.--Locations of the Ralston Creek Watersheds.

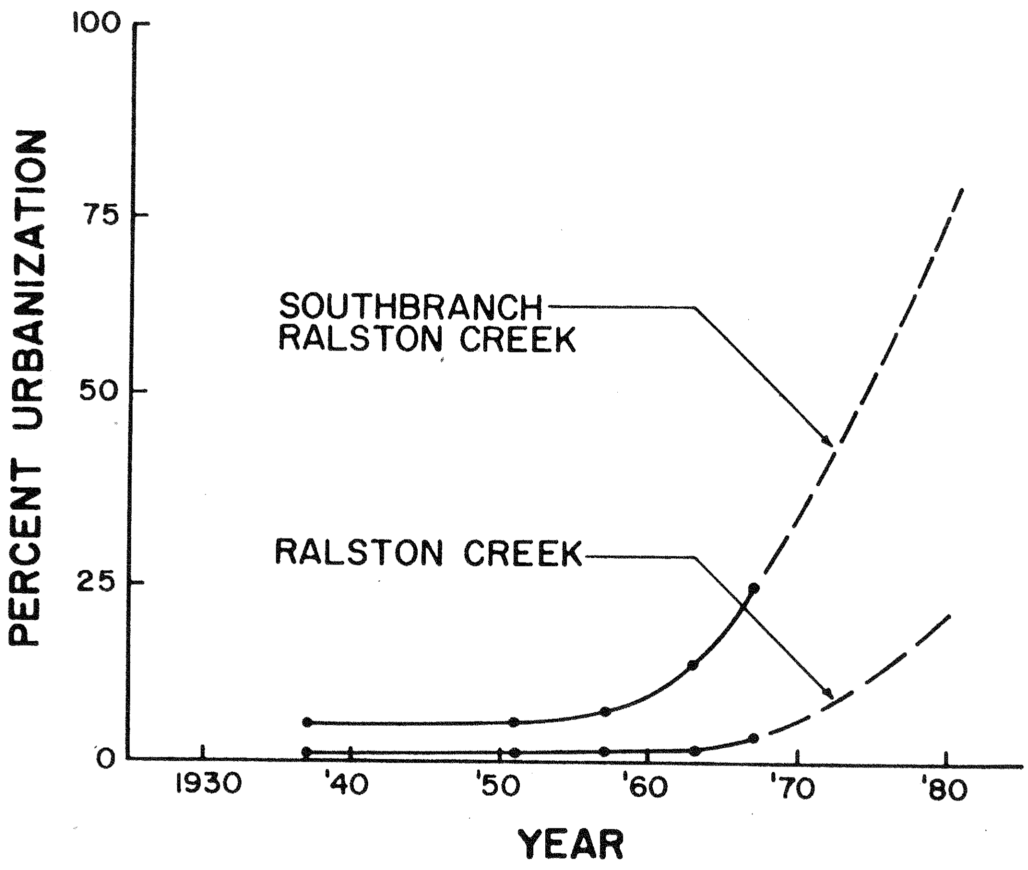

Figure 8.--Rate of urbanization on the Ralston Creek Watersheds.

(4-to 6-foot) loess cap which lies on a relatively thick, impermeable blanket of glacial till. A schematic diagram of this system is shown in figure 9. The soil profiles have a well-developed clay accumulation zone 12 to 18 inches below the surface, usually 6 to 12 inches thick. When moist or wet, this zone becomes nearly impermeable and thus severely limits the depth of profile available for water storage. As a result, the upper part of these soils will occasionally become essentially saturated and almost all precipitation will run off.

There is no ground water outflow from these watersheds due to the flat topography and the limited percolation through the glacial till. During some wet periods, trickle flows occur for several days after rainfall. This is apparently the result of soil drain-out, or interflow.

The MCredie watershed is located in the claypan area 25 miles east of Columbia, Missouri. Continuous P-Q records are available from 1941 to the present. Surface features are shown in figure 10. Land use has been mixed but is recorded. Few topographic modifications have been made. A complete review of this watershed, 25 years of data, and hydrologic analyses are given by Saxton and Whitaker (6).

The drainage system on this watershed consists of shallow, grassed channels. Thus, in terms of model use, this watershed again represents the land phase. However, the hydrologic response is quite different from the loessal watersheds due to soil, crop, and topography differences.

CENTRALIA, MISSOURI:

A new set of watersheds has been selected for research in the claypan areas. These are near Centralia, Missouri, about 25 miles north of Columbia, Missouri. Figure 11 shows the location of the four largest watersheds. A smaller watershed, 50 to 100 acres, will be selected within watershed 9 for intensive instrumentation. Rain gages are now in place and stream gaging will begin in 1970.

These watersheds have the flat topography and claypan soils that typify this area. In contrast to the McCredie data, these larger watersheds have well-defined channels; thus, both the land and channel phases will perform significant roles in the observed data. The smaller area will

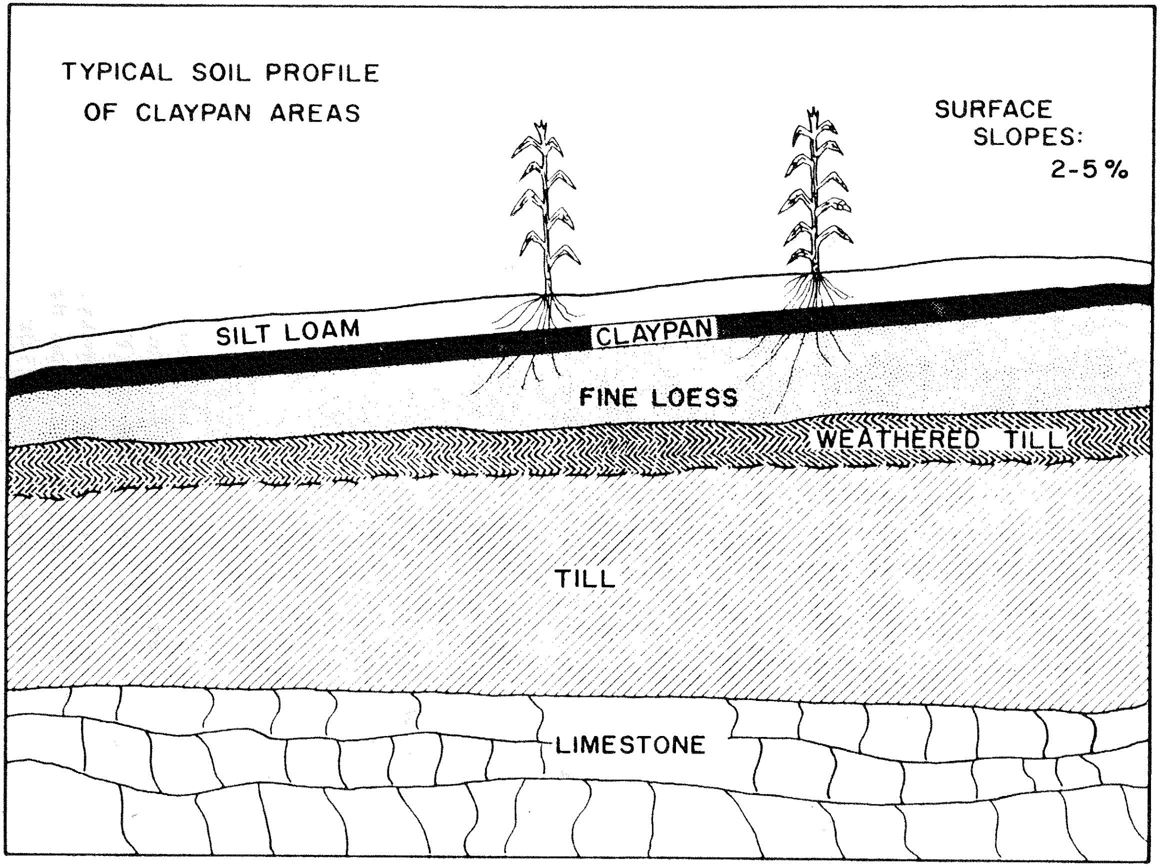

Figure 9.--Claypan soil schematic profile typical of northeast Missouri.

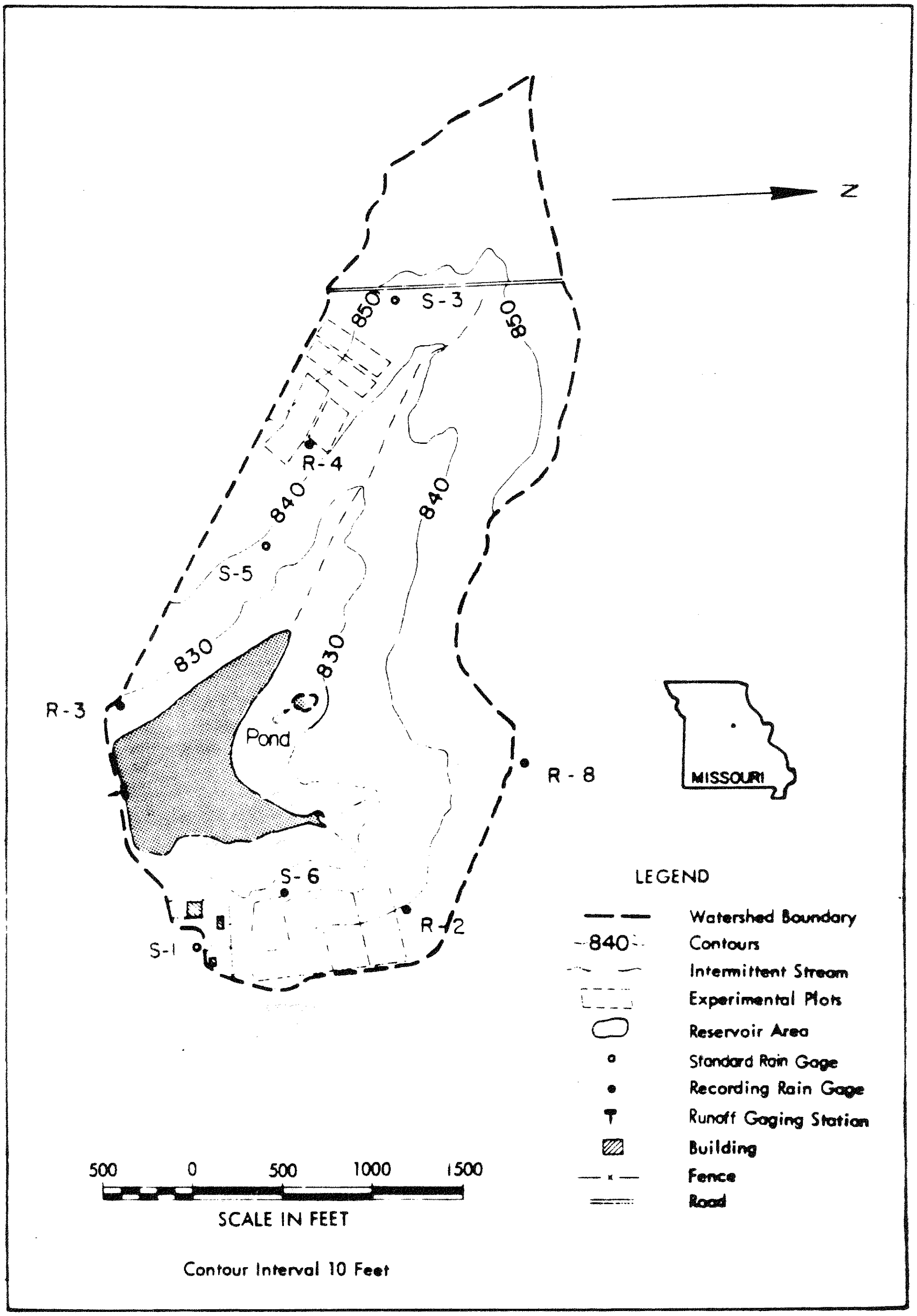

Figure 10.--Topography and instrumentation of the McCredie, Missouri watershed.

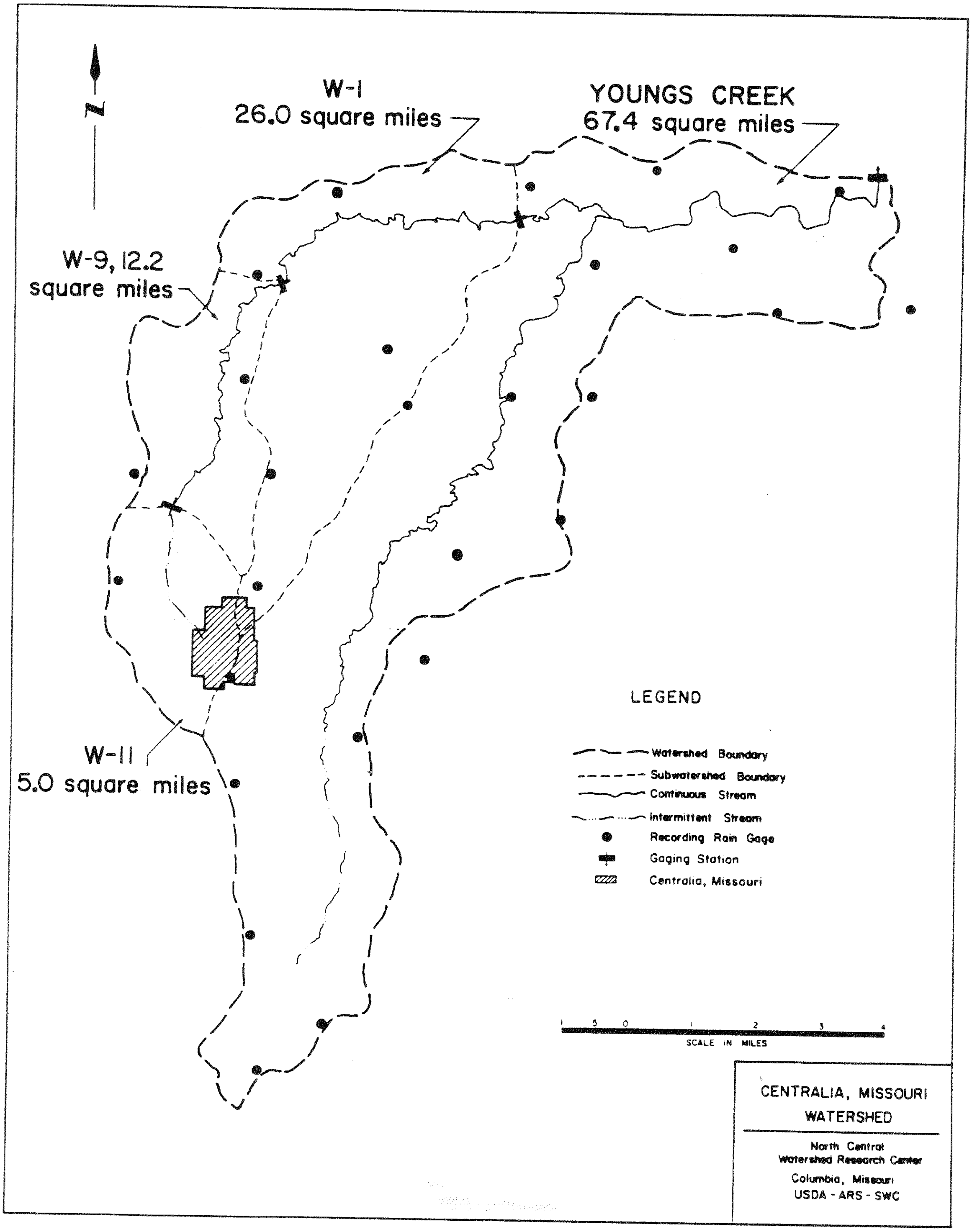

Figure 11.--Centralia watersheds, 25 miles northeast of Columbia, Missouri.

provide data on the land phase. Detailed channel information will be obtained to evaluate the channel phase.

A model for the subsurface flow system on these claypan soils is now being developed by ARS cooperaters at the University of Wisconsin. The small watershed within this group will be instrumented to verify this model system. Although only a component of the total hydrologic model, this subsurface flow system may prove to be more important than usually considered due to interactions with processes such as infiltration and evapotranspiration.

SUMMARY

We are collecting hydrologic, erosion, and pollution data which will be valuable for developing and testing of watershed models. Our data are from quite diverse physiographic watersheds, ranging from the steep loessal watersheds to the flat claypan areas. Land use is varied from continuous corn, level terraces, grass, urban, etc. Since much of our data are from small watersheds, they will contribute mostly to understanding the land phase, although the Ralston Creek and Centralia data will involve channel evaluations.

Our current analyses are concerned with land use effects and evaluating components within the hydrologic system--e.g., the methods of predicting evapotranspiration, soil moisture distributions, percolation, etc. These will provide important methods for developing the components of a watershed model. We hope to soon begin using our data and results in developing a watershed model or cooperating with someone who would like to test and improve an existing model.

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3. Smith, R. L., "Application of Models in Urban Hydrology," Appendix A, Chapter C in Urban Water Resources Research, by ASCE Urban Hydrology Research Council, September 1968.

4. Piest, R. F., and Spomer, R. G., "Sheet and Gully Erosion in the Missouri Valley Loessial Region," Transactions of ASAE, Volume 11, Number 6, 1968.

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6. Saxton, K. E., and Whitaker, F. D., "Hydrology of a Claypan Watershed." (Now in press as a Missouri Agricultural Experiment Station Research Bulletin. Publication expected about June 1970).