USE OF SOIL SURVEYS IN THE IDENTIFICATION OF FLOODPLAINS[1]

DONALD E. McCORMACK

State Soil Scientist, Soil Conservation Service, U. S. Dept. of Agriculture, Columbus, Ohio 43215

ABSTRACT

The frequency of flooding and depth of flood waters on alluvial soils and soils on stream terraces, was evaluated in selected sections of the Great Miami River Valley and tributaries in Montgomery and Preble Counties, Ohio.

The boundaries of the highest elevations of flood waters during the floods of 1913 and 1959 were compared to the boundaries of alluvial soils and soils on stream terraces. Essentially all of the alluvial soils were inundated in both floods. About forty percent of the area of terrace soils were inundated in 1913, but less than ten percent in 1959. It is estimated that the frequency of flooding of alluvial soils is more frequent than once in forty years, and that only the very lowest portions of the terraces are inundated during floods of that frequency. Analysis of the data indicate soil surveys can be used to delineate those areas where the probability of flooding is greatest, and thus where the need for land use restrictions, such as zoning, to minimize damages due to flooding is most urgent.

INTRODUCTION

The identification of floodplains is of great importance in land-use planning and in floodplain zoning. Unfortunately, much development is still talking place in flood-prone areas, perhaps because of the inability of most people to recognize the existence of and degree of the flooding hazard. Also important is the fact that most of the intensive development that accompanies population growth tends to increase runoff and is therefore likely to increase floods.

Since the earliest years of soil survey work, around 1900, soil scientists have identified and mapped alluvial soils on floodplains. Because they are in the lowest portion of floodplains, these soils are inundated whenever rising flood waters overtop the stream banks. The traditional idea is that these soils lack clearly developed soil horizons because they are frequently flooded is still generally accepted today. Yet relatively little definitive work has been done to compare the frequency of flooding on alluvial soils with that on nearby soils on stream terraces which have clearly developed soil horizons. In this study, data were collected and evaluated to serve as a basis for estimates of the frequency of flooding on each of these two situations.

In studies of the geometry of floodplains and terraces in the Appalachian Piedmont, Kikpatrick and Barnes (1964) found that, whereas lower elevations were flooded nearly every year, some terraces only became flooded at recurrence intervals of something less than fifty years. They concluded that, due to the differences in frequency of flooding, a line drawn between the terraces and the alluvial land should prove useful in floodplain zoning. In Wisconsin, Cain and Beatty

[1]Manuscript received February 16, 1971.

(1968) studied the Mississippi River valley and concluded that over ninety-nine percent of the alluvial soils were inundated in floods having frequencies of ten years or less; only seven percent of the terrace soils were inundated and these only during very rare floods. They also presented data to show that alluvial soils along smaller streams in southeastern Wisconsin were flooded frequently, and concluded that accurate soil survey maps, properly interpreted, could give a good estimate of areas subject to flooding. In a floodplain study along Wissahickon Creek in Montgomery County, Pennsylvania, Witner (1966) reported that the boundary of alluvial soils indicated by the soil survey corresponded very closely to the edge of the fifty-year floodplain as defined by the U. S. Army Corps of Engineers.

My purposes in this study were a) to determine, in a selected area, the frequency of flooding and the depth of flood waters on areas of alluvial soils and on any nearby soils on terraces, and b) from this data to evaluate the usefulness of soil surveys in zoning and other kinds of land-use restrictions designed to minimize flood damage. The area studied included randomly selected portions of the valleys of the Great Miami River and two of its tributaries, the Stillwater River and Twin Creek, in Montgomery and Preble Counties, Ohio. About twenty percent of the total area of the valleys of these streams in the two counties was chosen for study. This particular area was chosen because of the availability there of three independent sets of information:

a) soil survey field sheets, with the soils mapped at a scale of four inches per mile (1:15840), of Montgomery County (unpublished field sheets in the Soil Conservation Service office in Trotwood, Ohio) and of Preble County (Lerch, 1969);
b) topographic maps with a contour interval of one foot, showing the elevation and boundaries of the 1913 flood waters; and
c) aerial photographs of the valleys taken at the height of the flood in 1959.

The latter two items were obtained from the office of the Miami Conservancy District, 38 East Monument Avenue, Dayton, Ohio.

METHODS

Using colored pencils, the boundaries of the areas flooded at the heights of the 1913 and 1959 floods were traced onto the soil survey field sheets. With a planimeter, both the areas of alluvial soils and of terrace soils that were inundated in each of the floods, and the total acreage of these soils in the valley, were measured. A total of thirteen soil survey field sheets, fourteen by fourteen inches in size, were measured in this manner. In addition, the approximate depths of the flood waters on the alluvial and the terrace soils were determined at a large number of sites by comparing the flood elevation and the elevation of the soil surface. The difference in elevation between the terraces and the alluvial soils was also recorded.

SOIL DEVELOPMENT

In the identification of alluvial soils, or of any other natural soils, it is important to recognize that the properties of the soils provide an indication of the attributes of the physical environment in which they occur. Under a given set of environmental conditions, including (a) the climatic parameters, (b) the topographic position as it influences the ground-water table and the runoff or infiltration of water, and (c) the kind and number of organisms in or on the soil, all acting over (d) a given period of time and (e) in a given kind of geologic material, the resulting soil will have a unique set of properties (Soil Survey Staff, 1960). As a result of this principle, it is possible to predict in a rather specific manner the properties a particular soil will have if the attributes of its environment are known. The reliability of this prediction has been verified over and over again in soil survey work, where a particular kind of soil is found to occur repeatedly in the landscape where the above set of factors are the same.

Soils on stable land surfaces that do not receive annual, or somewhat less frequent, deposits of fresh sediment, develop a unique sequence of clearly developed soil horizons from the surface downward (Soil Survey Staff, 1951). The A horizon, eight to fifteen inches thick in most soils in Ohio, has been leached of bases and clay, and generally has accumulated organic matter in at least the upper few inches. Below the A horizon is the B horizon, in which clay and in some cases some of the bases have accumulated. The B horizon rests on relatively unaltered parent material (C horizon). The A, B, and C horizons are strikingly different in properties and are easily recognized in the field in most soils on relatively stable land surfaces.

Alluvial soils lack the distinctive horizon sequence characteristic of soils on stable land surfaces, because they receive periodic deposits of fresh sediment from the flood waters that flow over them during floods. In many places, the thinly stratified deposits extend to depths of twenty feet or more, indicating that small increments of alluvium have been deposited frequently over a long period of years. Such periodic accumulations prevent the development of the clear-cut horizons found in soils of the uplands or terraces.

Alluvial soils, therefore, have unique properties due to the fact that they have been inundated periodically throughout the geologic history of their development. Unless they are protected by levees, or by other major flood-control structures, they are still flooded periodically. In fact, it is likely that alluvial soils have been flooded more frequently since land in the watershed has been cleared and farmed or used for non-farm developments, than was the case before the time of such development, as a result of the increased runoff produced by destruction of woodlands and extended areas of impermeable asphalt and concrete.

Alluvial soils are described in soil survey manuscripts as soils of the floodplains developed in recent alluvium. Most are classed as Fluvents, Aquents, Udolls, or Aquolls at the suborder level in the new soil taxonomy (Soil Survey Staff, 1960). Soils of the Ross and Medway series are dominant among the alluvial soils considered in this study. Soils of the Wea series are dominant on the lower terraces, and soils of the Fox series are dominant on the higher terraces.

Boundaries of alluvial soils, as shown on maps prepared as a part of the National Cooperative Soil Survey, are typically indicated by either distinct valley walls that slope sharply down from the upland, or by escarpments at the margin of stream terraces. Such boundaries are easily located visually and plotted on soil survey maps. In the few cases where the boundary is less clear, there is a gradual slope from the alluvial soils upward to stream terraces or uplands over a distance of two hundred to three hundred feet, and the contrast in soil horizonation serves to differentiate the areas of alluvial soils and of terrace soils.

There are two rather distinct terraces along the Great Miami River in Montgomery county (Goldthwait, 1948). The higher terraces may be contemporaneous with the Mad River Outwash deposited during the retreat of the ice from the Springfield and Camden Moraines. The lower terraces, which are mostly north of Dayton, probably represent outwash deposited during the retreat of the ice from the Farmersville Moraine, or elevations cut by later meltwaters (R. P. Goldthwait, personal communication, 1971).

THE 1913 AND 1959 FLOODS IN THE GREAT MIAMI RIVER VALLEY

The floods of 1913 and of 1959, two of the largest recorded floods in southwestern Ohio, were selected for study because of the extensive data available on them. Should suitable data become available for a flood of greater frequency than either of these, preferably floods with a frequency of about once in twenty years, it would also be useful as a site where a meaningful comparison of flood levels and areas of alluvial and terrace soils could be made, as was done in this study of these Great Miami River valley floods.

The flood of 1913 was the greatest flood in history on the Great Miami River. The unprecedented level of flood waters caused very extensive damage throughout the Great Miami Valley (Cross and Mayo, 1969). The frequency of floods of this magnitude is probably well over one in every one hundred years.

The flood of 1959 is estimated to have a frequency of about one in every forty years. A total of 4.3 inches of rainfall was reported at Dayton, Ohio, during a twenty-four hour period on January 20 and 21, 1959. It fell on soil frozen to depths of 14 to 18 inches and covered with up to two inches of snow (Division of Water, 1960), a condition which in part explains the tremendous amount of water causing the flood. James T. Rozelle, Engineer with the Miami Conservancy District, has calculated the frequency of the 1959 flood in the following manner. At the height of this flood, a flow of sixty thousand nine hundred cubic feet per second was recorded (Cross and Mayo, 1969). The adjusted mean annual flood at Dayton, since the flood-control structures upstream were installed in the 1920's, is thirty thousand cubic feet per second. Hydrographs from Mr. Rozelle's files indicate that the flow during a flood with a frequency of fifty years at Dayton is greater than the adjusted mean annual flood by a factor of 2.1 to 2.4. At nearby stations, comparable factors for a flood with a frequency of twenty years are 1.8 to 2.0. The 1959 flood was 2.03 times the adjusted mean annual flood, indicating a frequency of between twenty and fifty years, with forty years being a reasonable interpolation.

RESULTS AND DISCUSSION

Essentially all of the alluvial soils along the Great Miami River valley were flooded in both the 1913 and 1959 floods (Table 1). In 1913 all areas of alluvial soils studied were flooded, and in 1959 ninety-five percent of these areas were flooded, as shown by the aerial photographs. However, the aerial photographs of the 1959 flood were taken at the time of the highest water in the main valley, a time when not all the areas of alluvial soils in the floodplains of several small tributary streams were covered with flood waters. They almost certainly were flooded during or shortly after the height of the precipitation, but flooding had receded

TABLE 1

Total acreage, and acreage and percentage flood in 1913 and in 1959, in selected areas of the valleys of the Great Miami River and two of its tributaries

Stream or Section of Stream	ALLUVIAL SOILS: Total Acreage of Alluvial Soils Studied	Acreage and Percentage of Alluvial Soils flooded in: 1913	1959	TERRACE SOILS: Total Acreage of Terrace Soils Studied	Acreage and Percentage of Terrace Soils flooded in: 1913	1959
Great Miami River						
A. North of Dayton	1,024	1024 (100%)	988 (97%)	2,016	466 (23%)	156 (8%)
B. South of Dayton	860	860 (100%)	802 (93%)[1]	1,980	1584 (80%)	124 (6%)
Totals for Great Miami R.	1,884	1884 (100%)	1790 (95%)	3,996	2050 (50%)	280 (7%)
Stillwater River	358	358 (100%)	[2]	1,246	96 (8%)	[2]
Twin Creek	1,524	1524 (100%)	[2]	552	156 (28%)	[2]
Total for Areas Studied	3,766	3766 (100%)	N.A.	5,794	2302 (40%)	N.A.

[1]48 acres did not flood in 1959 because it was protected by a levee. Adjusted percentages excluding this acreage are 99% for the valley south of Dayton and 98% for the entire area of the Great Miami River studies.

[2]Data not available.

in these floodplains by the time the high water mark in the main valley was reached, when the aerial photographs were taken.

Some areas of soils on terraces were also flooded by both floods (Table 1). In 1913, forty percent of the areas of terrace soils were flooded; in 1959 only seven percent of such areas were flooded. As the data were plotted on the soil survey maps, it was evident that in 1913 a much higher proportion of the terrace soils were flooded south of Dayton than were flood north of Dayton. North of Dayton, two distinct terrace levels occur. Most extensive is the higher terrace, which is 15 to 20 feet above the alluvial soils. The soils of this higher terrace did not become flooded in either of the floods. The soils of the lower terrace, which are four to eight feet above the alluvial soils, were covered with four to six feet of flood water in 1913.

South of Dayton the two distinct terrace levels are generally not evident. Here the terraces are mostly five to twelve feet above the alluvial soils, with a few small ridges as much as 18 feet above the alluvial surface. About eighty percent of these terrace soils flooded in 1913, with water depths mostly two to six feet.

In the flood of 1959, about one-third of the soils of the lower terraces north of Dayton were flooded, with flood waters mostly only one foot or less in depth. Only six percent of the terrace soils south of Dayton were flooded in 1959, and in the areas flooded, water depths were less than one foot.

The depths of the flood waters on the alluvial soils were mostly eight to fifteen feet in 1913 and mostly three to nine feet in 1959. It can be safely assumed that flooding of alluvial soils is substantially more frequent than once in forty years, as flood-water depths were mostly more than three feet in the forty-year 1959 flood. However, no data were obtained in this study that would permit estimation of just how frequently such flooding occurs. It is commonly believed by soil scientists that alluvial soils are flooded at least every ten years, but additional data from floods with frequencies of from 5 to 20 years would be necessary to substantiate this hypothesis.

Much variation between watersheds of course exists in factors such as watershed size and shape, ratio of watershed size to cross-sectional areas of valley, stream gradients, relative elevations of alluvial soils versus terrace soils, etc., factors that may cause considerable variation in the frequency of flooding on alluvial soils and terrace soils. However, this variation is likely to be confined within the limits dictated by, or related to, the lack of clearly developed soil horizons in the alluvial soils and their presence in the terrace soils. Further analyses, such as that presented here, quantifing these limits in other places, would be very useful.

That there is a wide difference in the frequency of flooding between the alluvial soils and the terrace soils is amply demonstrated in this study. This fact should prove of considerable value in land-use planning and zoning. Some zoning ordinances prohibit buildings and a number of other uses in that portion of the floodplain which is flooded most frequently and most deeply. The data summarized here indicate that the boundaries of the alluvial soils might logically be used to delineate such zoning districts. In addition to these zoning districts, some orinances permit building with flood proofing in the flood fringe, areas where flooding is infrequent and of shallow depth. Such ordinances commonly use the elevation of the regional flood (flood with a frequency of one hundred years) as the upper limit of the area where such building might be permitted (Department of Conservation, 1970). The data presented here indicate that areas of terrace soils that are below the elevation of the regional flood as indicated by the soils, could be used to delineate the flood fringe.

Soil surveys, like those used in this study, are available for much of Ohio. Such mapping has been completed in slightly more than half of the land area of Ohio. Mapping is completed in thirty-one counties and in progress in sixteen additional counties in Ohio (information on soil survey progress in a given county may be obtained from the local office of the U. S. Soil Conservation Service).

CONCLUSIONS

This study shows that alluvial soils are flooded rather deeply by floods with a frequency of forty years or less, and that there is little flooding of terrace soils in floods with a frequency of forty years. Sizeable areas of terrace soils were flooded during a flood having a frequency of more than one hundred years. Soil surveys, therefore, can be used with confidence in the delineation of areas most likely to be flooded.

For several of the large streams in Ohio, data pin-pointing the elevations of flood crests and engineering computations giving the projected elevations of flood waters in floods of a given frequency is available. Where such data is available, it may be used to delineate zoning districts. When it is used, existing soil surveys should prove helpful in extending information between known points. Where such engineering data is lacking, as is the case for most of the smaller streams in the state, soil surveys may be used to delineate zoning districts that will restrict land uses in flood-prone areas.

ACKNOWLEDGMENTS

The author is indebted to Ralph L. Meeker, Soil Scientist, U. S. Soil Conservation Service, Columbus, Ohio, for plotting and measuring the maps used, and to the Miami Conservancy District, especially James T. Rozelle, Engineer, Dayton, Ohio, for maps and data, and the computation of the frequency of the 1959 flood.

LITERATURE CITED

Cain, J. M., and **M. T. Beatty.** 1968. The Use of Soil Maps in the Delineation of Flood Plains. Water Resources Research Quart. 4: 1.

Cross, W. P., and **R. I. Mayo.** 1969. Floods in Ohio—Magnitude and Frequency. Ohio Dept. Natur. Res., Div. of Water, Bull. 43, Columbus, Ohio. 79 p.

Division of Water. 1960. Preliminary Report of Floods in Ohio—January, 1959. Ohio Department of Natural Resources, Division of Water, 1960, Columbus, Ohio. 102 p.

Goldthwait, R. P. 1948. Glacial Geology. p. 28–36. *in* Norris, S. E. The Water Resources of Montgomery County, Ohio. Ohio Water Resources Board, Columbus, Ohio Bull. 12. 87 p.

Kilpatrick, F. A., and **H. H. Barnes, Jr.** 1964. Channel geometry of piedmont streams as related to frequency of floods. U. S. Geol. Survey Prof. Paper 422. 13 p.

Lerch, Norbert K., R. E. Davis, L. A. Tornes, E. N. Hayhurst, and **N. A. McLoda.** 1969. Soil Survey of Preble County, Ohio. U. S. Dept. of Agr., Soil Cons. Service. 101 p.

Soil Survey Staff. 1960. Soil Classification, A Comprehensive System, 7th Approximation. U. S. Dept. of Agric., Soil Conservation Service, Washington, D.C. 265 p.

Soil Survey Staff. 1951. Soil Survey Manual. U. S. Dept. of Agric., Soil Conservation Service, Washington, D.C. 503 p.

Witner, D. B. 1966. Soils and Their Role in Planning a Suburban Community. p. 15–30. *In* Bartelli, L. J., A. A. Klingebiel, J. V. Baird, and M. R. Heddleson, eds. Soil surveys and land use planning. Soil Science Soc. of Amer. and Amer. Soc. of Agronomy. 196 p.

Minnesota Department of Conservation. 1970. Statewide Standards and Criteria for Management of Flood Plain Areas in Minnesota. Minn. Dept. of Conser., St. Paul, Minnesota. mimeo. 31 p.