A Study of the Errors Resulting from the Use of Turbidity in Computing the Suspended Sediment Discharge of Iowa Streams

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A STUDY OF THE ERRORS RESULTING FROM THE USE OF TURBIDITY IN COMPUTING THE SUSPENDED SEDIMENT DISCHARGE OF IOWA STREAMS

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The systematic measurement of the suspended sediment transported by streams has been limited to special investigations with the exception of a few daily sampling stations operated in southwestern United States to provide data on the probable life of present and proposed reservoirs. However, the vital importance of records of sediment discharge of streams in other sections of the United States has become apparent in connection with a variety of projects relating to river control and beneficial use of the nation's water resources. In the last few years, proposed developments in Iowa for flood control, navigation, drainage systems, recreational facilities, and water power and the paucity of quantitative data on soil erosion have revealed a need for factual information on the sediment discharge of Iowa rivers. This situation was recognized by the 50th General Assembly of Iowa which authorized the Iowa Geological Survey to participate in a cooperative program involving among other items the collection of concurrent records of water and suspended sediment discharge. This program has been integrated with then needs of investigations of the several U. S. Engineer Districts and other federal and state agencies operating in Iowa.

Measurements of fluvial sediment by public and private agencies have usually been based on sediment concentrations determined from samples collected with many different types of sediment sampling equipment. This equipment was selected or developed principally according to the ideas of each investigator as to the requirements of a satisfactory sampler. The uncertainty as to the overall efficiency of the different types of sampling equipment that were being used by all agencies resulted in an investigation which was carried out under the auspices of the Corps of Engineers, U. S. Army, in cooperation with five other federal agencies and the Iowa Institute of Hydraulic Research, State University of Iowa. The standardized methods and equipment recommended in a series of reports published in connection with this joint laboratory investigation are being used by the U. S. Geological Survey in the field and office work for the sediment measuring program in Iowa.

As one phase of the present program relates to a cursory review of the available records indicative of the material in suspension in streams, a study was made of the relationship between the turbidity data obtained in connection with the operation of the University of Iowa water-treatment plant and the concentrations of suspended sediment in samples collected at the cooperative sampling station at Benton Street Bridge for the months of May, June, and July 1944. The turbidities were measured with the Jackson turbidimeter and are the average of six samples taken at regular time intervals during the day from the pipe through which water is pumped to the purification plants from the intake works of the University of Iowa power plant which diverts water at the left end of the Burlington Street Dam. These data, in common with usual waterworks practice, are used as a basis for water treatment rather than as a quantitative measure of the material in suspension. The average daily concentrations of suspended sediment were determined from samples collected at the Benton Street Bridge located about one half mile below the Burlington Street Dam. No appreciable inflow occurs between the dam and the bridge, therefore, any change in sediment concentration between the sampling points would be limited to that resulting from degradation of the stream bed as the velocity in the pool above the dam is less than that in the channel below the dam. The variation between turbidity and the corresponding concentration of suspended sediment (in parts per million by weight) for the data studied is shown in Figure 1.

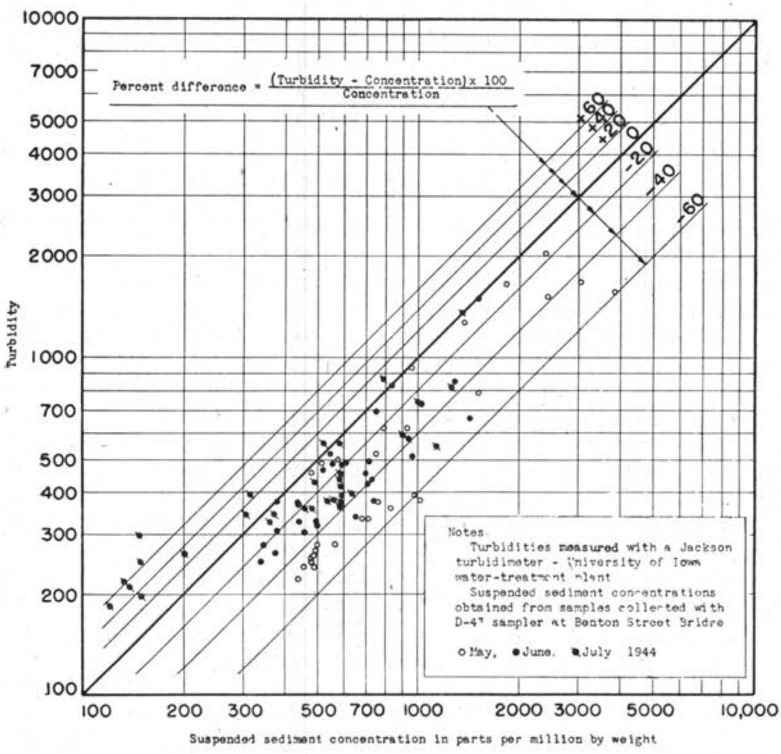

Figure 1. Comparison of turbidity and suspended sediment concentration Iowa River at Iowa City.

The plotting of the data in Figure 1 illustrates the lack of any direct relation between turbidity and suspended sediment concentration as shown by samples collected from the Iowa River at Iowa

City and, more important, the fact that rather exhaustive studies are necessary to correlate the dissimilar variables and define the probable limits of error if turbidity is to be used quantitatively in computing the amount of suspended sediment transported by streams.

The material transported by streams has been variously designated as matter, silt, and sediment, and referred to as turbidity of a water. The term sediment has been accepted by the agencies participating in the previously-mentioned joint investigation. Sediment is defined as fragmental material transported by, suspended in, or deposited by, water or air, or accumulated in beds by other material agents. Likewise, the definition of turbidity and the standard for measuring it may be of interest in connection with the data and discussion herein. Turbidity may be defined as a measure of the appearance of a water or its capacity for absorbing light. The standard generally accepted for use in measuring turbidity is that proposed by Hazen and Whipple and published in 1902 as follows:

> "The standard of turbidity shall be a water which contains 100 parts of silica per million in such a state of fineness that a bright platinum wire 1 millimeter in diameter can just be seen when the center of the wire is 100 millimeters below the surface of the water and the eye of the observer is 1.2 meters above the wire, the observation being made in the middle of the day, in the open air, but not in sunlight, and in a vessel so large that the sides do not shut out the light so as to influence the results. The turbidity of such water shall be 100."

As turbidity is an optical property of a water, it can only be properly expressed in arbitrary units and not in parts per million by weight and, as turbidity is considered from the viewpoint of opacity rather than quantity, equal turbidities may represent unequal concentrations owing to the different kinds or colors of sediment or other material in suspension. Additional error may be introduced when the turbidity exceeds 500 if the sample is not diluted, and the result corrected by a factor corresponding to the dilution. Because turbidimeter measurements are relatively easy to make a number of attempts have been made to use turbidity as a measure of the amount of material in suspension in streams. However, it appears that no method has been developed which will permit quantitative correlation of the optical properties of fluids with the weight of solids in suspension.

The suspended solids in a sample of water and sediment may be accurately determined by filtering the water through a Gooch crucible or filter paper, or by the ordinary sedimentation, decantation, and evaporation procedure. If the latter method is used the weight of the residue is generally corrected for the dissolved solids present in the water. The concentration determined by either method is usually expressed in percent or parts per million by weight.

Sediment concentrations may also be determined by means of a hydrometer or a pipette. However, no studies of the relationship between the results obtained by these methods and corresponding turbidities are known to the writer.

The inaccuracies introduced by using turbidity as a measure of the concentration of suspended solids in computing the sediment discharge of streams may be further illustrated by the results of an investigation of the composition of waters of Iowa rivers conducted by the Iowa Geological Survey during the years 1912 and 1913. Samples of river water were collected in gallon glass jugs at about the center of the stream from a boat. The chemical and physical characteristics of the water were determined in accordance with standards and procedures as given in Volume 30, part 2 of a bulletin published by the American Public Health Association in 1905. The uncertain relation between the concentration of suspended sediment in parts per million by weight and the turbidity of each sample analyzed is shown in Figure 2.

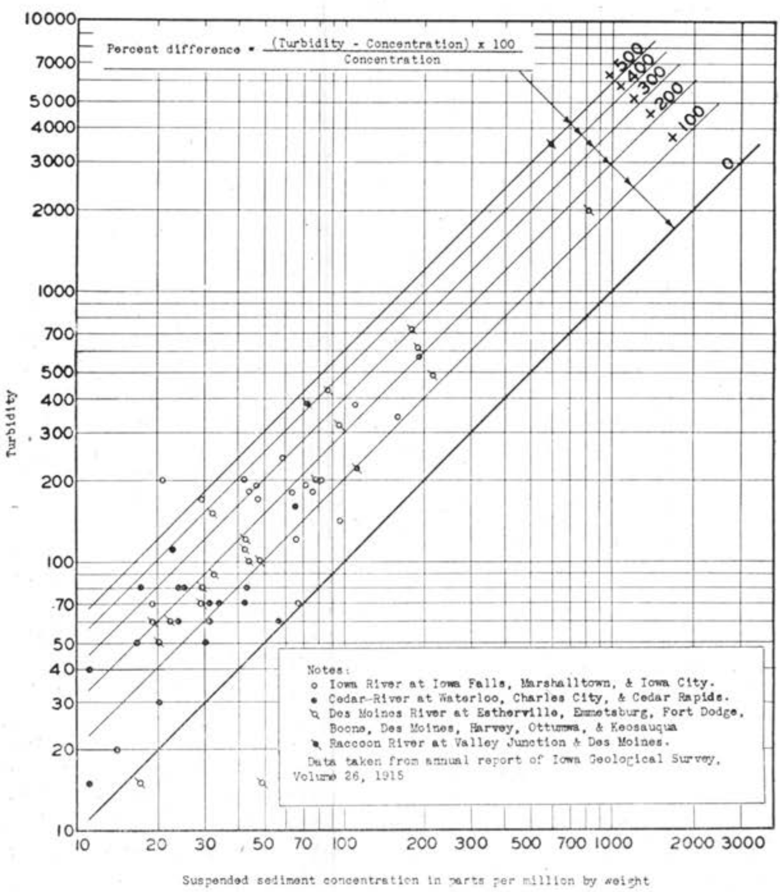

Figure 2. Comparison of turbidity and suspended sediment concentration, Iowa, Cedar, Des Moines, and Raccoon Rivers.

The percent difference between the two methods of determining the concentration of suspended solids in water is thus shown to range from zero to 500. The methods and practices used in analyzing water samples during that investigation may vary somewhat from the present procedures but the early data also substantiate and illustrate the fundamental difference between the turbidity of a water and the corresponding concentration of suspended sediment when determined by the suspended-solids method of analysis.

The measurement of turbidity has become established practice in connection with the operation of water treatment plants. The uncertainties resulting from the use of turbidities as a measure of the concentration of materials in suspension is apparently inconsequential in the satisfactory treatment of water for municipal and industrial uses.

As demonstrated in figures 1 and 2 the probable error introduced by the indiscriminate use of turbidities in estimating sediment concentrations in Iowa streams appears extremely variable and the desirability of such procedure is questionable. The unfavorable relation, which was found, results in part from the absence of a definite or direct relation between turbidity and the solids in suspension and in part from the methods and equipment used in collecting the samples.

A closer relation between turbidity and quantity of sediment may be shown by a systematic determination of the "coefficient of fineness" which is the ratio of the suspended sediment to the turbidity. Nevertheless, the method of collecting sediment samples and the type of sampler used will affect the reliability of the results except in streams carrying very fine sediments. Furthermore, it should be emphasized that the total sediment load transported by streams is generally classified as suspended load and bed load according to the mode of movement. The two types of transportation are obviously inter-related, but methods and facilities available at the present time ordinarily will permit only the collection of base data relative to the suspended sediment load transported by streams.

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