CONTROL OF TURBIDITY AT CONSTRUCTION SITES

By E. J. Carlson, Research Hydraulic Engineer, U.S. Bureau of Reclamation, Division of General Research, Engineering and Research Center, Denver, Colorado

ABSTRACT

A study team was organized at the Bureau of Reclamation Engineering and Research Center, Denver, Colorado, to collect and disseminate information on Control of Turbidity at Construction Sites following the requirements of Public Law 92-500. A summary of most of the areas in which information was assembled is included in the report. A statement of policy on water pollution control in the United States by the Board of Control of the Water Pollution Control Federation is given. Public Law 92-500 and two Executive Orders from the Office of the President on pollution control are reviewed. The National Pollution Discharge Elimination System (NPDES) is described. Turbidity measurement and causes of turbidity at construction sites are described. An example of analysis of turbidity data obtained with typical turbidity measuring instruments and the accuracy obtained is given. Some typical variations of bid prices for control of turbidity at typical Bureau of Reclamation projects are listed. The variation of turbidity standards in the Western United States is discussed.

INTRODUCTION

Over the past several years national concern has been focused on the problem of pollution of all our national resources. A review of construction as related to control of turbidity in effluents to streams from construction activities is particularly timely now during the early stages of this general awareness. Water pollution control is being sought by various state and Federal agencies and by the profession working with water resources development within the United States. This new public awareness is felt in the areas of communication media, state and Federal regulations, and the political arena. Water is one of our most precious and irreplaceable resources, and it is under close scrutiny.

The following statement of policy on water pollution control in the United States was adopted by the Board of Control of the Water Pollution Control Federation on October 3, 1971. 12/* It gives the extent to which the public has become interested in control of water pollution including turbidity and for that reason it is included here.

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* Numbers refer to references at the end of the paper.

STATEMENT OF POLICY ON WATER POLLUTION CONTROL IN THE U.S.
Adopted by the Board of Control of the Water Pollution Control Federation - October 3, 1971

This Statement of Policy was adopted originally in 1960. Since then, revisions have been made to keep abreast of expansion and changes in the water pollution control field.

Water pollution means water quality damage and consequent interference with beneficial use of a vital resource - clean water.

Pollution of the Nation's inland surface waters, coastal waters, and ground waters is a continuing threat to the national health, esthetic enjoyment, safety, and economic welfare. National survival, in terms of future urban, industrial, and commercial growth and prosperity, dictates the protection of all water resources from any acts, such as the discharging of harmful substances which cause unreasonable impairment of water quality and adversely affect their highest level of usefulness. While considerable progress has been made in pollution control by municipalities and industries, many water resources are being degraded, impaired, and damaged by such discharges and acts, and they will be further adversely affected by the degree and pattern of population growth, industrial processing, commercial expansion, chemical usages, agricultural developments, and other technological advancements.

The Water Pollution Control Federation is pledged to provide leadership and guidance to all constructive efforts that contribute to the control of water pollution. Its pledge is summarized by the following points:

1. The discharge of all wastewater into the waters of the Nation must be controlled.

2. The objectives of water pollution control must include preservation of high quality waters for protection of public health; for industrial, agricultural, and recreational uses; for fish and wildlife propagation; and for the maintenance of an esthetically desirable environment.

3. The responsibilities for the adequate treatment and control of wastewater must be assumed individually and jointly by industry and local, state, interstate, and Federal governments.

4. The administration of water pollution control must be firm and effective and should remain in the hands of state and interstate water pollution control agencies. Regulatory agencies must be supported by adequate budgets and fully staffed by competent engineers, scientists, and supporting personnel.

5. Federal, state, and local laws and practices must reflect the changing needs in order to obtain and maintain the most economical

and effective means for financing the construction, management, operation, and maintenance of wastewater collection systems and treatment works.

6. The public must be made fully aware of the consequences of water pollution and the costs of its control. Only in this way can the public be prepared to sponsor and support sound water pollution control measures.

7. Basic and applied research by competent personnel must be encouraged by broad efforts to develop new knowledge that will solve water pollution problems.

8. Wastewater represents an increasing fraction of the Nation's total water resources and should be reclaimed for beneficial reuse. To this end the development and application of methods for wastewater reclamation must be accelerated.

9. Mandatory certification or licensing of adequately trained and properly compensated personnel must be encouraged as a requirement for maximum effectiveness of treatment facilities.

PUBLIC LAW 92-500

Public Law 92-500, 15/ 92d Congress, S. 2770, October 18, 1972, which is the amendment to the Federal Water Pollution Control Act, states * * * "It is the national goal that the discharge of pollutants into navigable waters be eliminated by 1985:". Navigable waters are deemed to mean all streams for the purpose of this report. In the interim, before 1985, the Environmental Protection Agency (EPA) and the states have established standards of turbidity that an effluent can have which is passed into a stream. The states are reviewing their laws and going through the process of updating their standards to be in line with Federal Government recommendations.

Public Law 92-500 is complex and is difficult to get implemented because it requires many changes of present practices that are causing pollution in streams, including discharge of sediment from construction operations. Implementation of Public Law 92-500 has caused much discussion and many meetings because of its effect on so many operations and people. The cost of making the changes to comply with the law will require very large expenditures much of which must come from Federal funds. The procedures for obtaining the funds and doing the work in compliance with the law are not completely clear. The art and its application have not, in the main, begun to approach public expectations. Revisions of the art are needed and changes in the manner of its administration are required. It seems that there is a need to utilize more effectively, in harmony with Federal responsibility, the knowledge and experience of state and local officials and particularly of members of the engineering profession.

PRESIDENTIAL DOCUMENTS

Two Presidential documents under Title 3 - The President, were issued in the area of pollution control. Executive Order 11738 8/ provides for administration of the Water Pollution Control Act with Respect to Federal Contracts, Grants, or Loans; and Executive Order 11752 9/ concerns Prevention, Control, and Abatement of Environmental Pollution at Federal Facilities.

The goals of Public Law 92-500 and the Executive Orders above are consistent with the desires of the public. The means of obtaining these goals in an orderly and responsible manner will require long and arduous efforts on the part of private and public business, individuals, and the courts.

TURBIDITY 10/

Turbidity in water is caused by the presence of suspended matter such as clay, silt, very fine sand, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Turbidity should be clearly understood to be an expression of the optical property of a sample which causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Turbidity should be distinguished as entirely different from a weight concentration of suspended matter. Although attempts have been made to correlate turbidity with weight concentration of suspended matter, these correlations are for the most part impractical as size, shape, color, and refractive index of particulate materials are of great importance optically, but bear little direct relationship to the concentration by weight and specific gravity of the suspended matter. Instruments have been made that can indicate turbidity of grab samples very quickly and that can indicate turbidity of the stream continuously at a much less cost than determining weight concentrations of suspended solids. For this reason, some turbidity reading instruments (nephelometric, light scatter method) have been adopted as standard instruments for determining turbidity. It should be emphasized that instruments based on the light scatter principle do not reflect a weight concentration of suspended solids.

The standard method for determination of turbidity has been based on the Jackson Candle Turbidimeter. However, the lowest turbidity value which can be measured directly on this instrument is 25 Jackson turbidity units. With turbidity requirements of the states falling very near or below this value, indirect secondary methods have been required to estimate turbidity on such samples. The Jackson Candle Method is rather cumbersome and difficult to use particularly in field tests. Consequently, many companies have developed instruments which are indirect methods for estimating turbidity. Unfortunately, no instrument has been devised which will duplicate the results obtained on the Jackson Candle Turbidimeter for all samples. Owing to fundamental differences in optical systems, the results obtained with different types of secondary

instruments will frequently not check closely with one another even though the instruments are all precalibrated against a candle turbidimeter.

A further cause of discrepancies in turbidity analysis is the use of suspensions of different types of particulate matter for the preparation of instrumental calibration curves. Prepared suspensions have different optical properties depending upon the particle size, distribution, shapes, colors, and refractive indices. Most commercial turbidimeters available for measuring low turbidities give comparatively good indications of intensity of light scatter in one particular direction predominantly at right angles to the incident light. Since there is no direct relationship between Jackson Candle Turbidity and the intensity of light scatter at 90°, there is no valid basis for calibrating the 90° turbidimeters in terms of candle units.

Some turbidimeters have been developed that use a forward light-scattering technique to give indications of turbidity. A sealed submerged sensor head contains two separate light sources and detectors. The intensity of a direct collimated beam of white light directed through the sample or continuous stream is measured by the direct beam detector. The light scattered in the forward direction by turbidity in the sample is measured by the scattered beam detector. Output signals from the two detectors are then electronically ratioed to give the turbidity measurement. Manufacturers of the forward scatter instrument claim that it eliminates the effects of color in the sample, source light, and sample bottle or continuous-tube characteristics providing accurate and repeatable turbidity measurements. The forward scatter instrument is a much more complicated design and consequently more costly than the 90° light scatter instruments. Forward scatter instruments have not come into as much use as the 90° light scattering instruments for measuring turbidity caused by suspended sediments. Descriptions of the visual method (Jackson Candle turbidimeter) and the nephelometric method (light scatter in one direction) are given in several references. 2/ 3/ 7/ 11/ 13/ 16/

ANALYSIS OF TURBIDITY DATA - AN EXAMPLE

Grab samples were collected over a period of several weeks from the Arkansas River at Pueblo damsite. The samples were analyzed by three methods to determine turbidity and concentration of suspended sediment. Two commercial turbidity meters were used. One was calibrated with a Formazin standard to read in Jackson Turbidity Units. The second, a so-called Infra Red Direct Reading instrument, was calibrated to read in milligrams per liter (p/m). The third method of analysis was to filter the suspended solids and weigh the dried residue to determine the suspended sediment concentration in milligrams per liter (p/m). The drying and weighing method was taken as the standard in comparing results obtained from the two turbidity measuring instruments. The three different methods of measurement were made from the same sample in every case. Sixty-two samples were used from which the measurements and the analyses were made. Three samples which had extra large concentrations were excluded because of the great effect

they would have on the analysis and because the majority of turbidity measurements were less than 100 milligrams/liter. The three extra large concentrations were 367 to 1,172 milligrams per liter.

Linear least squares fit were made using the dried weight method as the independent variable and the two data sets from the turbidity instruments measurements as dependent variables.

The standard deviation was computed for each set of turbidity meter data. This is our indication of the accuracy and repeatability of the turbidity reading instruments for samples taken from one stream in one general location. A standard deviation of 6.0 milligrams per liter was computed for the first meter calibrated to read in Jackson Turbidity Units. For the second, direct reading, instrument a standard deviation of 10.4 milligrams per liter was computed. Standard deviations values were computed for different groupings of the data along the X axis. Higher and lower values than those for all data were computed, but the average values were very close to the standard deviations computed with all 62 data values.

Confidence limits were computed for the least squares fit lines for the turbidity meter data. Computations were then made to determine the number of samples that would be required to obtain accuracies of plus or minus 2, 3, and 5 milligrams per liter. For example it was shown that seven samples would be required to obtain an average within $\pm$ 5 milligrams per liter at a confidence level of 95 percent. The number of samples required rose to 31 for an average accuracy within $\pm$ 2 milligrams per liter at a confidence level of 95 percent.

This analysis gives some indication of the accuracy of two specific turbidity meters when compared to measurement of low concentrations of sediment by the drying and weighing method.

A survey made in 1973 showed there were over 25 companies making turbidity measuring instruments which varied in price from about $525 to over $4,000. Three typical continuous reading turbidity meters and one grab sample meter are presently being tested in the Hydraulics Laboratory of the Bureau of Reclamation at Denver, Colorado.

CONSTRUCTION ACTIVITIES THAT CAUSE TURBIDITY PROBLEMS

A list of construction activities that may cause turbidity problems are shown here. There may be many other items for other types of construction. For Bureau of Reclamation projects the list covers the major turbidity producing activities.

1. Excavation for the foundation of diversion, earth fill, and concrete dams, including handling of wet earth materials

2. Downstream channelization and excavation of river valley materials

3. Construction of diversion tunnels for dams

4. Processing natural or quarry materials for concrete aggregate.

5. Construction of tunnels for water conveyance systems (treatment of tunnel water and mud, hauling of waste materials, etc.)

6. Operation of concrete mixing plants

7. Construction wastewater for concrete dams (water for washing, curing, and cleanup)

8. Grouting

9. Construction of canals, temporary and permanent roads, and construction camps

10. Construction of siphons or other water conveyances across drainage channels

11. Reservoir clearing

These activities are separated into specific work processes that may require different technologies for turbidity or sediment control. For example, it may be desirable to utilize settling ponds or Clar-flocculators to settle out fines during excavation for the foundation of the dam. However, a similar technology would not be used when a reservoir area is cleared or a road built into a construction site.

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)

The Federal Water Pollution Control Act, as amended by Public Law 92-500, enacted October 18, 1972, requires a permit to discharge a pollutant into a waterway from one or more point sources. Federal departments, agencies, and instrumentalities are also subject to these requirements.

There are two sets of (NPDES) application forms to be used. Short forms (A-D) 5/ and standard forms (A-C).6/ The owner and operator of any activity or wastewater system, publicly or privately owned, which discharges waste into a waterway must obtain a permit for such discharges.

To ensure that the administering office has sufficient time to examine applications from new sources of discharge of pollutants, a complete NPDES application must be filed (1) no less than 180 days in advance of the date on which it is desired to commence the discharge of pollutants, or (2) in sufficient time prior to commencement of the discharge of pollutants to insure compliance with the requirements of the act.

For a contractor-owner arrangement of a construction project, the contractor is usually the operator during the construction period after the

contract has been awarded. However, in preparation of plans and specifications for a construction project, the owner should consult with appropriate EPA and state offices to assure that water pollution control specifications paragraphs provide adequate guidance for the contractor to meet the pertinent water quality standards in the area which will be affected by the contractor's activities. It may be appropriate for the owner to apply to the EPA for a (NPDES) permit. The application assumes that the construction will create a definite pollutant discharge. Instructions printed in the Federal Register (Vol. 37, No. 247 - Friday, December 22, 1972) indicate the permit to discharge could be transferred from the owner to the contractor during the actual construction period. Additional paragraphs of explanation in the specifications may be necessary as the particular situation requires.

For contracts and construction that would make 180 days notice in applying for a permit to discharge impossible, a temporary permit or verbal permission could possibly be obtained from the EPA or state director as the case dictates.

FLOCCULANTS AND COAGULANT AIDS

Various chemicals have been used for many years to assist in removing suspended solids from water. They have been used in connection with sanitary water supply and sewage treatment systems. In recent years many chemical companies have developed many different flocculants and coagulant aids that can assist in removing fine sediments from water. Some of them are made from polymer-type chemicals and are specified for use depending on whether the water and sediment is ionic or cationic.

The Environmental Protection Agency compiled a list of companies and the flocculants and coagulant aids that they make. EPA emphasizes that its findings bear only on the health aspects of the use of the chemicals in drinking water treatment and do not endorse nor indicate effectiveness for the proposed use. The list comprises 206 separate product names made by 46 companies.

TURBIDITY STANDARDS IN WESTERN STATES

To administer Public Law 92-500 each of the states must have standards by which they will allow owners and operators to discharge pollutants into streams. The standards are set by the states to be equal or better than recommendations made in Public Law 92-500 and administered by the Environmental Protection Agency.

An investigation to determine the pollution control standards in streams was made in the Western part of the United States, the area of operation of the Bureau of Reclamation. Most of the states had some standards for discharging into their streams before passage of Public Law 92-500. To come within the recommendations of EPA, the Western states are generally

changing their standards. Some states specify different standards for different streams, lakes, and in some cases bays in the ocean. The differences in standards between states are so great they are too extensive to list within the space allowed here. Whenever an owner or contractor plans construction in a different state from where he is familiar, a thorough investigation should be made of the turbidity standards for the particular state where work is planned.

TURBIDITY CONTROL DURING CONSTRUCTION ON TYPICAL BUREAU OF RECLAMATION PROJECTS

Several Bureau projects have been started and some have been completed since Public Law 92-500 was enacted on October 18, 1972. In the specifications for each construction project, paragraphs are provided on "Prevention of Water Pollution and Control of Turbidity." The paragraphs give information that is adequate for contractors to bid this item and plan construction and satisfy the requirements for monitoring and maintaining pollution control. In most cases suggested methods for pollution control of effluents returning to streams and also methods for monitoring the streams are given in the specifications. The contractor is always directed to comply with applicable Federal and state laws that apply to pollution control. A contingency plan is required in the case of an emergency spill or discharge of a highly turbid effluent.

Some contractors have been very innovative in devising methods of controlling water pollution. As experience is gained under the new law it is expected that costs for controlling turbidity at construction sites will be reduced. Bid prices for the line item, Prevention of Water Pollution and Control of Turbidity, over the past few years has varied widely. Some of the variations for typical Bureau projects are given here:

Bid Variations for Prevention of Water Pollution and Control of Turbidity
Typical Projects

Project	No. of bidders	Variation of bids	
		Low	High
Teton Dam, Idaho	6	$150,000	$ 925,000
Pueblo Dam, Colorado	8	200,000	1,000,000
Auburn Dam, California			
Excavation and Foundation Treatment	9	10,000	150,000
Crystal Dam Diversion and Foundation Tunnels	10	50,000	396,000
Cunningham Tunnel	9	100,000	547,112

The wide variation is due to the fact that in most cases these jobs are the first time the contractor has bid an item for control of turbidity and water pollution. It is expected that the bids will generally be in line and somewhat reduced when experience is gained and pollution control equipment becomes more readily available.

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