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Office of Water Quality Technical Memorandum 2004.03

Subject: Revision of NFM Chapter 6, Section 6.7—Turbidity

Purpose of Memorandum

This memorandum announces a rewrite of "Chapter 6, Section 6.7—Turbidity" of the U.S. Geological Survey (USGS) National Field Manual for the Collection of Water-Quality Data (NFM), and the implementation of new reporting units and parameter codes for storing and reporting turbidity data in USGS databases and products (Attachments 1 and 2). Information sources supporting these changes are included. This method will be effective October 1, 2004. The revised NFM Section 6.7 is available online at http://water.usgs.gov/owq/FieldManual/Chapter6/6.7_contents.html.

Problem

The NFM documents USGS protocols for the collection, quality assurance, storage, and publication of water-quality data. NFM Section 6.7—"Turbidity" documents methods for equipment selection, calibration, measurement, and data storage. Use of the revised method will help improve the quality and comparability of reported data, and will reduce the variability associated with such data.

Turbidity is a useful measurement that is growing in popularity and importance in scientific and resource monitoring programs, both within and outside of the USGS. Uses of turbidity data include measuring water clarity for drinking water and ecological applications, indicating visual impairment in water, real-time monitoring of conditions in watersheds, use as a surrogate for suspended-sediment concentration (SSC) and other constituents in water, and estimating transport of contaminants associated with suspended materials (Gray and Glysson, 2003).

However, turbidity itself is not an inherent physical property of water (as is, for example, temperature), but rather is a measure of light scattering through a liquid as measured by detectors with known geometry. The configuration of detectors and the source of light are important factors in the response of the turbidity instrument. Although comparisons among instruments with differing designs are often robust, they can also vary according to the character of the sample's matrix and particulates. Results from an interagency workshop held in 2002 demonstrated that turbidity data from different sources and instrumentation can be highly variable and are often in disagreement with each other, even when calibration methods are similar (Gray and Glysson, 2003). In effect, instruments with different detector geometries and light sources often do not make equivalent measurements.

The U.S. Environmental Protection Agency (USEPA) method 180.1 established specific requirements for instrument configuration for the measurement of turbidity in drinking water within the United States (U.S. Environmental Protection Agency, 1993). The International Organization for Standardization (ISO) method 7027 established instrument requirements for

measurement of drinking water in Europe (International Organization for Standardization, 1999), but uses a different light source than USEPA Method 180.1. Measurements complying with USEPA Method 180.1 are reported in Nephelometric Turbidity Units (NTU), whereas those complying with ISO 7027 are reported in Formazin Nephelometric Units (FNU) in Europe. In practice, during the past two decades most turbidity data in the U.S. have been reported in NTUs, regardless of their light source or detector geometry. Data stored in the USGS's National Water Information System (NWIS) and in USEPA's STORET database have been stored under parameter code 00076, and have been reported in NTUs; however, use of that parameter code has not been restricted to instruments that comply with USEPA Method 180.1.

Resolution

In order to reduce the variability associated with turbidity data, the USGS has created new reporting units for turbidity that are based on the instrument design (Attachment 1*)*. These reporting units correspond to new parameter and method codes for storing turbidity data in the National Water Information System (NWIS). The use of NTU and FNU will be retained, but will be restricted to data from instruments that comply with the specific designs defined in USEPA Method 180.1 and ISO 7027, respectively. Eight new reporting units have been promulgated that correspond to existing and anticipated instrument designs that do not strictly conform to USEPA Method 180.1 or ISO 7027. Finally, the protocol discontinues the use within USGS of Formazin Turbidity Units (FTU), a reporting unit that has been commonly used, but which lacks specificity to any particular measurement technology.

Along with the new reporting units as specified in Attachment 1, users are now required to record the specific instrument make and model using the method code field in NWIS. Table A-1 in NFM Section 6.7 (Attachment 2) provides a current (August 2004) list of each instrument make and model according to its detector configuration and light source as specified for each new reporting unit and shows the appropriate parameter and method codes for each. Method codes are required when storing data in NWIS in order to provide traceability and allow for more informed comparisons of data in the future.

As the USGS is changing its reporting units for turbidity, other organizations are making the same changes. The American Society for Testing and Materials (ASTM) is in the process of making these changes and will use the same new reporting units. The USGS and ASTM have been working together in order to ensure traceability and improve comparability among turbidimeters.

The revised protocol also clarifies the use of appropriate calibration standards, in accordance with ASTM provisions. Although "scratch" formazin is recognized as the primary calibration standard, commercially-prepared solutions of stabilized formazin and styrene divinylbenzene polymer beads are also accepted as calibrants. However, consistent use of one type of calibrant is required to minimize errors introduced during calibration.

The revised turbidity protocol in Section 6.7 provides additional tools for USGS users. A decision tree will help the user determine the most appropriate instrument type for a given application. An appendix lists specific turbidity instruments, including manufacturer and model, so that users can look up the appropriate NWIS parameter code and method code for data entry.

Implementation and Data Handling

The revised turbidity protocol, including the use of new parameter codes and method codes, will be implemented on October 1, 2004. Concurrently with implementation of the new parameter codes, parameter code 00076 is no longer to be used for storing new data. This code will eventually be locked so that it will not accept new data. Historical data, stored previously under

NWIS parameter code 00076, may be migrated to the new parameter codes on a case by case basis, only where knowledge of specific instruments and their instrument configuration is sufficient to allow selection of an appropriate reporting unit, parameter code, and method code according to Table A-1. These changes should be done with the guidance of the District Water-Quality Specialist. Attachment 3 provides information on a program that is available to aid in migrating historical data to the new parameter and method codes.

Training on the new data reporting and storage requirements will take place through cyber seminars initially to be held on September 22 and 28, 2004. Information will also be provided in the Field Water-Quality Methods for Ground Water and Surface Water training course (QW1028TC) and the NFM.

NWISWeb (real-time)

Currently, NWISWeb is incapable of displaying or retrieving method codes with real-time continuous data. Efforts are underway through the USGS Surface Water Users Group (SWUG) to add database functionality so that method codes would be displayed along with real-time data. As an interim measure, station descriptions for sites that serve continuous turbidity data to the web must be updated to include a description of the turbidity instrumentation used at the site, along with the appropriate method code.

Publications

Districts may need documentation or references in report products to cooperators to support the use of the new reporting units. Some appropriate documents are listed in the 'Reference' section of this memo and in NFM Section 6.7. All products should use the new reporting limits and list the instruments used for the study. Guidelines for rounding data for reports are provided in NFM Section 6.7 (Table 6.7-6).

Future modifications and maintenance

New parameter and method codes will be added as the technology for measuring turbidity evolves. These will be included in, and announced with, the quarterly NWIS updates and in the "Comments and Errata" page of the online NFM.

Sources of information

Approved Methods

NFM Section 6.7 (Anderson, Chauncey W., 2004)

ASTM – Low-Level Static Method (ASTM International, 2003)

ISO 7027 (International Organization for Standardization, 1999)

Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting, Water-Resources Investigations Report 00-4252 (Wagner and others, 2000)

USEPA 180.1 (U.S. Environmental Protection Agency 1993)

References

Anderson, C.W., 2004, Turbidity, (version 2): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.7, accessed September 24, 2004 from http://water.usgs.gov/owq/FieldManual/Chapter6/6.7_contents.html.

ASTM International, 2003, D6855-03 Standard test method for determination of turbidity below 5 NTU in static mode: ASTM International, Annual Book of Standards, Water and Environmental Technology, 2003, vol. 11.01, West Conshohocken, Pennsylvania, 13 p. [http://www.astm.org/cgi-bin/SoftCart.exe/DATABASE.CART/REDLINE_PAGES/D6855.htm?L+mystore+flap7535+1094151215]

Davies-Colley, R.J., and Smith, D.G., 2001, Turbidity, suspended sediment, and water clarity—A review: Journal of the American Water Resources Association, v. 37, no. 5, p. 1085–1101.

Gray, J.R., and Glysson, G.D., 2003, Proceedings of the Federal Interagency Workshop on turbidity and other sediment surrogates, April 30-May 2, 2002, Reno, Nevada: U.S. Geological Survey, Circular 1250, 56 p. [http://pubs.water.usgs.gov/circ1250]

International Organization for Standardization, 1999, Water quality — Determination of turbidity: Geneva, Switzerland, International Organization for Standardization, ISO 7027, 10 p.

U.S. Environmental Protection Agency 1993, Methods for the determination of inorganic substances in environmental samples: Cincinnati, OH, U.S. Environmental Protection Agency EPA/600/R-93/100, 178 p.

Wagner, R.J, Mattraw, H.C., Ritz, G.F., and Smith, B.A., 2000, Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting, U.S. Geological Survey Water-Resources Investigations Report 00-4252, 53 p. [http://water.usgs.gov/pubs/wri/wri004252/]

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This memorandum does not supersede any other Office of Water Quality Technical Memorandum.

Distribution: All WRD Employees

Attachments

Attachment 1-

NFM Table 6.7-4: Reporting units corresponding to different turbidity instrument designs. [Parameter code numbers begin with a "P"; nm, nanometers; °, degree; ±, plus or minus; K, kelvin]

Detector geometry	Light Wavelength	
	White or broad band (with a peak spectral output of 400-680 nm)	**Monochrome (spectral output typically near infrared, 780-900 nm)**
Single Illumination Beam Light Source		
At 90° to incident beam	Nephelometric Turbidity Unit (NTU)[a](P63675)	Formazin Nephelometric Unit (FNU)[b](P63680)
At 90° and other angles. An instrument algorithm uses a combination of detector readings, which may differ for values of varying magnitude.	Nephelometric Turbidity Ratio Unit (NTRU) (P63676)	Formazin Nephelometric Ratio Unit (FNRU) (P63681)
At 30°± 15° to incident beam (backscatter)	Backscatter Unit (BU) (P63677)	Formazin Backscatter Unit (FBU) (P63682)
At 180° to incident beam (attenuation)	Attenuation Unit (AU) (P63678)	Formazin Attenuation Unit (FAU) (P63683)
Multiple Illumination Beam Light Source		
At 90° and possibly other angles to each beam. An instrument algorithm uses a combination of detector readings, which may differ for values of varying magnitude.	Nephelometric Turbidity Multibeam Unit (NTMU) (P63679)	Formazin Nephelometric Multibeam Unit (FNMU) (P63684)

a. USEPA Method 180.1 defines the optical geometry for NTU measurements. The detector angle must be 90° ± 30 to the incident light beam. The light source must be a tungsten lamp with color temperature 2,200 - 3,000 K. (Source: U.S. Environmental Protection Agency, 1993)

b. ISO 7027 defines the optical geometry for FNU measurements. The detector angle must be 90° ± 2.5 to the incident light beam. The light source must be a light-emitting diode (LED) with wavelength 860 ± 60nm. (Source: International Organization for Standardization, 1999).

Attachment 2- NFM Table A-1: Parameter codes and method codes corresponding to instrument designs, reporting units, and currently available instruments, as of August 19, 2004.

Table A-1: Parameter codes and method codes corresponding to instrument designs, reporting units, and currently available instruments, as of August, 2004.
[For decisions on appropriate instrument design refer to figure 6.7-2. For specific instrument specifications, contact manufacturers directly. **Abbreviations**: PCODE, parameter code; N/A, not applicable or unavailable; NTU, nephelometric turbidity units; NTRU, nephelometric turbidity ratio units; BU, backscatter units; AU, attenuation units; NTMU, nephelometric turbidity multi-beam units; FNU, formazin nephelometric units; FNRU, formazin nephelometric ratio units; FBU, formazin backscatter units; FAU, formazin attenuation units; FNMU, formazin nephelometric multibeam units; nm, nanometers; °, degree; USEPA 180.1, United States Environmental Protection Agency method 180.1; ASTM D1899-00, American Society for Testing and Materials method D1899-00; ISO 7027, International Organization for Standardization method 7027; GLI M2, Great Lakes Instruments Company Method 2; >, greater than; **±** plus or minus]

Instrument Design	Reporting Unit	Method Comments	PCODE	Method (Instrument Name, mandatory)	Method Code	Method Source	Static/ Dynamic/ Process	Comments
White or Broadband (480-680 nm) Light Source, 90° detection angle, one detector.	**NTU**	**Compliant with USEPA 180.1, Hach 10133, and ASTM D1899-00.** **Primarily for drinking water applications or low turbidity. Measurement should not be >40 NTU.**	63675	HACH, sensor model 2100 AN (Ratio OFF), NTU	A	USEPA 180.1	Static	Flow-through accessory provides more dynamic measurement, making readings more stable.
				HACH, sensor model 2100 N (Ratio OFF), NTU	B	USEPA 180.1	Static	Flow-through accessory provides more dynamic measurement, making readings more stable.
				HACH, sensor model 1720 C, NTU	C	USEPA 180.1	Process	
				HACH, sensor model 1720 D, NTU	D	USEPA 180.1	Process	
				HACH, sensor model 1720 E, NTU	E	USEPA 180.1	Process	
				HACH, sensor model Filter Track 660, NTU	F	Hach 10133	Process	
				HACH, sensor model SS6, NTU	G	N/A	Process	Not USEPA 180.1 approved
				HF Scientific, Sensor Model Micro100 (Light source WHITE), NTU	H	USEPA 180.1	Static	
				HF Scientific, Sensor Model Micro200, NTU	I	USEPA 180.1	Process	
				HF Scientific, Sensor Model DRT-15CE, NTU	J	USEPA 180.1	Static (Portable)	
				HF Scientific, Sensor Model Micro 1000 (light source WHITE, Ratio OFF), NTU	K	USEPA 180.1	Static	Flow-through accessory provides more dynamic measurement, making readings more stable. Instrument option allows choice of ratiometric or non-ratiometric mode.
				ICM, Sensor Model 11150, NTU	L	USEPA 180.1	Static	
				ICM, Sensor Model 11152, NTU	M	USEPA 180.1	Static (Portable)	
				LaMotte Instruments Sensor Model 2008, NTU	N	USEPA 180.1	Static	

Table A-1: Parameter codes and method codes corresponding to instrument designs, reporting units, and currently available instruments, as of August, 2004.
[For decisions on appropriate instrument design refer to figure 6.7-2. For specific instrument specifications, contact manufacturers directly. **Abbreviations**: PCODE, parameter code; N/A, not applicable or unavailable; NTU, nephelometric turbidity units; NTRU, nephelometric turbidity ratio units; BU, backscatter units; AU, attenuation units; NTMU, nephelometric turbidity multi-beam units; FNU, formazin nephelometric units; FNRU, formazin nephelometric ratio units; FBU, formazin backscatter units; FAU, formazin attenuation units; FNMU, formazin nephelometric multibeam units; nm, nanometers; °, degree; USEPA 180.1, United States Environmental Protection Agency method 180.1; ASTM D1899-00, American Society for Testing and Materials method D1899-00; ISO 7027, International Organization for Standardization method 7027; GLI M2, Great Lakes Instruments Company Method 2; >, greater than; **±** plus or minus]

Instrument Design	Reporting Unit	Method Comments	PCODE	Method (Instrument Name, mandatory)	Method Code	Method Source	Static/ Dynamic/ Process	Comments
White or Broadband (480-680 nm) Light Source, 90° detection angle, one detector. (*continued*)	**NTU (*continued*)**	**Compliant with USEPA 180.1, Hach 10133, and ASTM D1899-00. Primarily for drinking water applications or low turbidity. Measurement should not be >40 NTU.**	63675	Orbeco-Hellige, Sensor Model 965-10A, NTU	O	USEPA 180.1	Static	
				Orbeco-Hellige, Sensor Model 966-01, NTU	P	USEPA 180.1	Static (Portable)	
				WTW Measurement Systems, sensor model 550, NTU	Q	USEPA 180.1	Static	
				Turbiquant Sensor Model 1500 T, NTU	R	USEPA 180.1	Static	
				Turbiquant Sensor Model 3000 T (Ratio OFF), NTU	S	USEPA 180.1	Static	
				Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.
White or Broadband (480-680 nm) Light Source, 90° detection angle, multiple detectors with ratio compensation.	**NTRU**	**Compliant with USEPA 180.1 and ASTM D1899-00 for turbidities <40 NTRU. Use Ratio mode on applicable NTU instruments when turbidity >40.**	63676	HACH, sensor model 2100 AN (Ratio ON), NTRU	A	USEPA 180.1	Static	
				HACH, sensor model 2100 N (Ratio ON), NTRU	B	USEPA 180.1	Static	
				HACH, sensor model 2100 P, NTU	C	USEPA 180.1	Static (Portable)	
				HF Scientific, Sensor Model Micro 1000 (light source WHITE, Ratio ON), NTRU	D	USEPA 180.1	Static	
				LaMotte Instruments, Sensor model 2020, NTRU	E	USEPA 180.1	Static	
				Turbiquant Sensor Model 3000 T (Ratio ON), NTRU	F	USEPA 180.1	Static	
				WTW Measurement Systems, sensor model 555, NTRU	G	USEPA 180.1	Static	
				Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.

Table A-1: Parameter codes and method codes corresponding to instrument designs, reporting units, and currently available instruments, as of August, 2004.
[For decisions on appropriate instrument design refer to figure 6.7-2. For specific instrument specifications, contact manufacturers directly. **Abbreviations**: PCODE, parameter code; N/A, not applicable or unavailable; NTU, nephelometric turbidity units; NTRU, nephelometric turbidity ratio units; BU, backscatter units; AU, attenuation units; NTMU, nephelometric turbidity multi-beam units; FNU, formazin nephelometric units; FNRU, formazin nephelometric ratio units; FBU, formazin backscatter units; FAU, formazin attenuation units; FNMU, formazin nephelometric multibeam units; nm, nanometers; °, degree; USEPA 180.1, United States Environmental Protection Agency method 180.1; ASTM D1899-00, American Society for Testing and Materials method D1899-00; ISO 7027, International Organization for Standardization method 7027; GLI M2, Great Lakes Instruments Company Method 2; >, greater than; **±** plus or minus]

Instrument Design	Reporting Unit	Method Comments	PCODE	Method (Instrument Name, mandatory)	Method Code	Method Source	Static/ Dynamic/ Process	Comments
White or Broadband (480-680 nm) Light Source, 30 ± 15° detection angle (backscatter).	**BU**	**Applicable for high particle densities**	63677	HACH, sensor model 2100 AN (light source WHITE, Backscatter ON), BU	X	N/A	Static	
				HF Scientific, Sensor Model Micro 1000 (light source WHITE, Ratio OFF, Backscatter ON), BU	Y	N/A	Static	
				Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.
White or Broadband (480-680 nm) Light Source, 180 ° detection angle (attenuation)	**AU**	**Instrument response negatively correlated with particle density**	63678	HACH, sensor model 2100 AN (light source WHITE, Attenuation ON), BU	X	N/A	Static	
				HF Scientific, Sensor Model Micro 1000 (light source WHITE, Ratio OFF, Attenuation ON), AU	Y	N/A	Static	
				Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.
White or Broadband (480-680 nm) Light Source, Multiple light sources. Detectors at 90° and possibly other angles to each beam.	**NTMU**	**Instrument algorithm uses a combination of detector readings, which may differ for values of varying magnitude**	63679	Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.

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[For decisions on appropriate instrument design refer to figure 6.7-2. For specific instrument specifications, contact manufacturers directly. **Abbreviations**: PCODE, parameter code; N/A, not applicable or unavailable; NTU, nephelometric turbidity units; NTRU, nephelometric turbidity ratio units; BU, backscatter units; AU, attenuation units; NTMU, nephelometric turbidity multi-beam units; FNU, formazin nephelometric units; FNRU, formazin nephelometric ratio units; FBU, formazin backscatter units; FAU, formazin attenuation units; FNMU, formazin nephelometric multibeam units; nm, nanometers; °, degree; USEPA 180.1, United States Environmental Protection Agency method 180.1; ASTM D1899-00, American Society for Testing and Materials method D1899-00; ISO 7027, International Organization for Standardization method 7027; GLI M2, Great Lakes Instruments Company Method 2; >, greater than; **±** plus or minus]

Instrument Design	Reporting Unit	Method Comments	PCODE	Method (Instrument Name, mandatory)	Method Code	Method Source	Static / Dynamic / Process	Comments
Near Infrared (780-900 nm) or Monochrome light source. 90° detection angle, one detector	**FNU**	**ISO 7027 compliant (at <40 FNU). Compensates for color in sample.** **Includes most submersible probes used for profiling and continuous monitoring.**	63680	Eureka Environmental, Sensor model Trimeter, FNU	A	ISO 7027	Dynamic	
				Forest Technology Systems, Sensor Model DTS-12, FNU	B	ISO 7027	Dynamic	
				Greenspan, sensor model TS 100, FNU	C	ISO 7027	Dynamic	
				Greenspan, sensor model TS 300, FNU	D	ISO 7027	Dynamic	
				Greenspan, sensor model TS 1200, FNU	E	ISO 7027	Dynamic	
				HACH, sensor model 2100 N IS (Ratio OFF), FNU	F	ISO 7027	Static	With Infrared filter installed downstream of white light source
				HACH, sensor model 2100 AN IS (Ratio OFF), FNU	G	ISO 7027	Static	With Infrared filter installed downstream of white light source
				HACH, sensor model 1720 D/L, FNU	H	ISO 7027	Static (Portable)	
				HACH, sensor model Optiquant, FNU	I	ISO 7027	Static	
				HACH, sensor model Pocket Turbidimeter, FNU	J	ISO 7027	Static	
				HF Scientific, Sensor Model Micro TPI, FNU	K	ISO 7027	Static	
				HF Scientific, Sensor Model Micro100 (light source INFRA RED), FNU	L	ISO 7027	Static	
				HF Scientific, Sensor Model Micro 1000 (light source INFRA RED, Ratio OFF), FNU	M	ISO 7027	Static	
				Hydrolab, sensor model Datasonde 4, FNU	N	ISO 7027	Dynamic	
				In-Situ, sensor model MP TROLL 9000, FNU	O	ISO 7027	Dynamic	

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Instrument Design	Reporting Unit	Method Comments	PCODE	Method (Instrument Name, mandatory)	Method Code	Method Source	Static/ Dynamic/ Process	Comments
Near Infrared (780-900 nm) or Monochrome light source. 90° detection angle, one detector *(continued)*	**FNU *(continued)***	**ISO 7027 compliant (at <40 FNU). Compensates for color in sample.** **Includes most submersible probes used for profiling and continuous monitoring. *(continued)***	63680	McVan, sensor model Analite NEP 160-3 (90 deg), FNU	P	ISO 7027	Dynamic	
				McVan, sensor model Analite NEP 195, FNU	Q	ISO 7027	Dynamic	
				McVan, sensor model Analite NEP 390, FNU	R	ISO 7027	Dynamic	
				McVan, sensor model Analite NEP 391, FNU	S	ISO 7027	Dynamic	
				McVan, sensor model Analite NEP 395, FNU	T	ISO 7027	Dynamic	
				McVan, sensor model Analite NEP 396, FNU	U	ISO 7027	Dynamic	
				McVan, sensor model Analite NEP 495, FNU	V	ISO 7027	Dynamic	
				McVan, sensor model Analite NEP 9000, FNU	W	ISO 7027	Process	
				McVan, sensor model Analite NEP 9500, FNU	X	ISO 7027	Process	
				Orbeco-Hellige, Sensor Model 965-IR, FNU	Y	ISO 7027	Process	
				Orbeco-Hellige, Sensor Model 966-IR, FNU	9	ISO 7027	Process	
				Turbiquant sensor model 1000 IR, FNU	0	ISO 7027	Static	
				Turbiquant sensor model 1500 IR, FNU	1	ISO 7027	Static	
				Turbiquant sensor model 3000 IR (Ratio OFF), FNU	2	ISO 7027	Static	
				YSI Environmental, sensor model 6026, FNU	3	ISO 7027	Dynamic	
				YSI Environmental, sensor model 6026-4000, FNU	4	ISO 7027	Dynamic	YSI 6026 sensor factory adjusted to allow readings and calibration to 4000 FNU

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Instrument Design	Reporting Unit	Method Comments	PCODE	Method (Instrument Name, mandatory)	Method Code	Method Source	Static/ Dynamic/ Process	Comments
Near Infrared (780-900 nm) or Monochrome light source. 90° detection angle, one detector *(continued)*	**FNU *(continued)***	**ISO 7027 compliant (at <40 FNU). Compensates for color in sample. Includes most submersible probes used for profiling and continuous monitoring. *(continued)***	63680	YSI Environmental, sensor model 6136, FNU	5	ISO 7027	Dynamic	
				WTW Measurement Systems, sensor model 350 IR, FNU	6	ISO 7027	Static (Portable)	
				WTW Measurement Systems, sensor model 550 IR, FNU	7	ISO 7027	Static	
				WTW Measurement Systems, sensor model VisoTurb 700 IQ, FNU	8	ISO 7027	Static	
				Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.
Near Infrared (780-900 nm) or Monochrome light source. 90° detection angle, multiple detectors, ratio compensation	**FNRU**	**ISO 7027 compliant (at <40 FNU). Compensates for color in sample. Ratio mode provides added color compensation and stability at high particle densities.**	63681	HACH, sensor model 2100 AN IS (Ratio ON), FNRU	A	ISO 7027	Static	
				HF Scientific, Sensor Model Micro 1000 (light source INFRA RED, Ratio ON), FNRU	B	ISO 7027	Static	
				Turbiquant sensor model 3000 IR (Ratio ON), FNRU	C	ISO 7027	Static	
				WTW Measurement Systems, sensor model 555 IR, FNRU	D	ISO 7027	Static	
				Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.

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[For decisions on appropriate instrument design refer to figure 6.7-2. For specific instrument specifications, contact manufacturers directly. **Abbreviations**: PCODE, parameter code; N/A, not applicable or unavailable; NTU, nephelometric turbidity units; NTRU, nephelometric turbidity ratio units; BU, backscatter units; AU, attenuation units; NTMU, nephelometric turbidity multi-beam units; FNU, formazin nephelometric units; FNRU, formazin nephelometric ratio units; FBU, formazin backscatter units; FAU, formazin attenuation units; FNMU, formazin nephelometric multibeam units; nm, nanometers; °, degree; USEPA 180.1, United States Environmental Protection Agency method 180.1; ASTM D1899-00, American Society for Testing and Materials method D1899-00; ISO 7027, International Organization for Standardization method 7027; GLI M2, Great Lakes Instruments Company Method 2; >, greater than; **±** plus or minus]

Instrument Design	Reporting Unit	Method Comments	PCODE	Method (Instrument Name, mandatory)	Method Code	Method Source	Static/ Dynamic/ Process	Comments
Near Infra-Red (780-900 nm) or Monochrome light source. 30±15° detection angle (Backscatter)	**FBU**	**Applicable for high particle densities where color compensa-tion also is Required.**	63682	D-A Instruments Co, Sensor Model OBS-3, FBU	S	N/A	Static	
				D-A Instruments Co, Sensor Model OBS-3A, FBU	T	N/A	Static	
				HACH, sensor model 2100 AN IS (light source INFRA RED, Backscatter ON), FBU	U	N/A	Static	
				HF Scientific, Sensor Model Micro 1000 (light source INFRA RED, Ratio ON, Backscatter ON), FBU	V	N/A	Static	
				McVan, sensor model Analite NEP 160-1 (180 deg), FBU	W	N/A	Static	
				McVan, sensor model Analite NEP 180 (180 deg), FBU	X	N/A	Static	
				McVan, sensor model Analite NEP 185 (180 deg), FBU	Y	N/A	Static	
				Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.
Near Infrared (780-900 nm) or Monochrome light source, 180° detection angle (Attenuation)	**FAU**	**ISO 7027 compliant (at >40 FAU).**	63683	HF Scientific, Sensor Model Micro 1000 (light source INFRA RED, Ratio ON, Attenuation ON), FAU	A	ISO 7027	Static	
				Turbiquant sensor model 3000 IR (>40), FAU	B	ISO 7027	Static	
				Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.

Table A-1: Parameter codes and method codes corresponding to instrument designs, reporting units, and currently available instruments, as of August, 2004.
[For decisions on appropriate instrument design refer to figure 6.7-2. For specific instrument specifications, contact manufacturers directly. **Abbreviations**: PCODE, parameter code; N/A, not applicable or unavailable; NTU, nephelometric turbidity units; NTRU, nephelometric turbidity ratio units; BU, backscatter units; AU, attenuation units; NTMU, nephelometric turbidity multi-beam units; FNU, formazin nephelometric units; FNRU, formazin nephelometric ratio units; FBU, formazin backscatter units; FAU, formazin attenuation units; FNMU, formazin nephelometric multibeam units; nm, nanometers; °, degree; USEPA 180.1, United States Environmental Protection Agency method 180.1; ASTM D1899-00, American Society for Testing and Materials method D1899-00; ISO 7027, International Organization for Standardization method 7027; GLI M2, Great Lakes Instruments Company Method 2; >, greater than; **±** plus or minus]

Instrument Design	Reporting Unit	Method Comments	PCODE	Method (Instrument Name, mandatory)	Method Code	Method Source	Static/ Dynamic/ Process	Comments
Near Infrared (780-900 nm) or Monochrome light source, Multiple light sources. Detectors at 90° and possibly other angles to each beam.	**FNMU**	**Instrument algorithm uses a combination of detector readings, which may differ for values of varying magnitude.**	63684	Great Lakes Instruments, Sensor 95 T, FNMU	V	GLI M2	Static	
				Great Lakes Instruments, Sensor Accu4, FNMU	W	GLI M2	Static	
				Hydrolab, sensor model 4a, FNMU	X	GLI M2	Dynamic	
				Hydrolab, sensor model Quanta 4-beam, FNMU	Y	GLI M2	Dynamic	
				Other, unspecified	Z	N/A	N/A	Only for interim storage while method codes are being generated for new instruments.

Attachment 3 – Program for migrating historical turbidity data to the new parameter and method codes

The program is located at: http://phoenix.cr.usgs.gov/reload/do.pcode.swap

(1) **Make a file of the record numbers** of the samples where a pcode would be changed from A to B.
(2) Create tab-delimited batch files for the list of record numbers (qwsample & qwresult) using **qwdata-8-6**
(3) Rename the qwresult file:
mv qwresult qwresult.old

(3) Run the program, as follows:

do.pcode.swap -f AAAAA -t BBBBB < qwresult.old > qwresult

(4) Reload the data using **qwdata-8-9** (DQI-override-env) or **qwdata-8-10** (DQI_override_QC)
(5) Review watlist & Delete the work files

The program only produces qwresult records for pcodes A and B. Other pcodes are silently ignored. The program never checks to see if pcode B was already stored in the record, so if it were present, the previously stored result would be overwritten. Two output records are produced for each occurrence of pcode A: a deletion of pcode A and an insertion of pcode B. The original create-date & userid + the modify-date & userid are "lost" (reset) by this operation.
If leading zeroes are omitted from either of the pcodes, the program will supply them. The program prints diagnostics indicating the number of result records read, and the number of occurrences of pcode A changed to B.

To install the program to a Unix directory:
(1) Detach the file
(also located at: http://phoenix.cr.usgs.gov/reload/do.pcode.swap)
(2) In a Unix window, in that directory:
chmod +x do.pcode.swap

To run the program, specify the pathname to the installed program.