HISTORY OF THE FEDERAL INTERAGENCY SEDIMENTATION PROJECT,
PART V

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Abstract: In the late 19th and early 20th centuries, sediment-sampling activities in the United States increased rapidly to support the civil-works programs of several Federal agencies. These agencies and other domestic and foreign investigators developed and used physical samplers of suspended sediment, bedload, and bed material to collect data needed for specific elements of their missions. Most instruments were designed with limited attention to, or knowledge of, sediment-transport concepts or the influence of the equipment on the local flow pattern. As a result, data obtained by different investigators before the 1940s were neither comparable nor could their accuracy be evaluated.

The Federal Interagency Sedimentation Project (FISP) was created in 1939 to unify and standardize fluvial sediment-data-collection instruments and methods used by several Federal agencies. The priorities and thrusts of the FISP have evolved throughout its history in the wake of its accomplishments and in response to the needs of the Federal community for the quantifiably accurate characterization of fluvial sediment concentrations, size distributions, and fluxes. The FISP conducts and supports applied research in topics covering the range of its mission, which includes physical-sampler design, testing, quality assurance, and supply; field methods; computational methods; laboratory analytical methods; and indirect (surrogate) methods.

The priorities of the FISP, along with oversight of its activities, are provided by a Technical Committee comprised of representatives from the supporting Federal agencies. The results of applied research conducted by the FISP appear in over 60 FISP reports, industry standards, and many related journal articles, agency reports, and proceedings papers such as this.

This paper uses and expands upon summaries of the FISP published in 1950, 1963, 1965, 1976, 1979, and 1989 to describe the origins of the FISP, and its six principal phases from 1939-2014. Mission-specific endeavors and their products are highlighted, and potential future research endeavors are summarized.

INTRODUCTION

When the Federal Interagency Sedimentation Project (FISP) was formed in 1939, the objective(s) of most fluvial-sediment measurements focused on the potential for or presence of sediment deposition in reservoirs and in navigation and irrigation channels. The list of sediment-related concerns subsequently has expanded to include bridge scour, erosion of agricultural lands, turbidity-induced aquatic ecosystem degradation, loss of spawning substrate due to fine-grained sediment infilling, reduction in primary productivity, decreases in biotic diversity, and effects from sediment-associated chemical constituents (Larsen et al., 2010). Even reduced sediment-transport rates are now recognized as having deleterious morphologic and economic consequences associated with some of the world’s impounded rivers, receiving estuaries, and coastal systems starved of their natural/historical fluvial-sand supplies (Collier et al., 1996; Osterkamp and Gray, 2003).

In 2010, the physical, chemical, and biological damages attributable to fluvial sediment in North America were estimated to range from $20 billion to $50 billion annually (Larsen et al., 2010). Because effective remediation of sediment damages is predicated on the availability of demonstrably credible statistics describing rates of fluvial-sediment transport and deposition, the need for reliable, temporally and spatially consistent sediment data today is paramount. Additionally, a 21st century renaissance in sediment-surrogate technologies is revolutionizing the acquisition of fluvial-sediment data (Rasmussen,
2008; Gray and Gartner, 2009 and 2010a, b; Gray et al., 2010; Voichick and Topping, 2014; Gray and Landers, 2014). Hence, the importance of the FISP’s mission – to unify and standardize fluvial-sediment research and development activities of participating Federal agencies – arguably has never been greater.

Skinner’s (1989) “History of the Federal Interagency Sedimentation Project,” organized into three phases, followed – but did not list as references – at least five previous historical perspectives on the FISP, to wit:


Nelson and Benedict (1950) is the first-such summary of the entity now known as the FISP. Witzigman (1965) is identically titled to, and evidently based on FISP (1963). Thus, Witzigman (1965), which lists four FISP phases, and FISP (1963) together are construed to be the second FISP history. Holeman (1976) is less a historical perspective than a snapshot of the functions and activities of the FISP. Because it was deemed by the authors to add little in the way of historical perspective, it was excluded from this list of FISP histories. Thus, Benedict’s (1979) and Skinner’s (1989) contributions are considered to be the third and fourth histories of the FISP, respectively – all to the best knowledge of the authors.

This fifth installment weaves information gleaned from the aforementioned publications with other cited sources and contemporary recollections. The latter include contributions from co-author and current FISP Chief Mark N. Landers; perspectives shared by former FISP Chief C. Wayne O’Neal; and those of the principal author based on his 36-year association with the FISP as a customer, contributor, and former U.S. Geological Survey (USGS) representative to and twice-Chairman of the Technical Committee that provides oversight, guidance and programmatic priorities to the FISP.

The intent of this contribution is threefold: Summarize and expand on some of the information contained in the contributions of Nelson and Benedict (1950), FISP (1963), Witzigman (1965), Holeman (1976), Benedict (1979), and Skinner (1989); describe FISP endeavors and accomplishments from 1989-2014; and “peer into the crystal ball” as intrepid soothsayers in an attempt to identify potential future challenges for and directions of the FISP.

**BACKGROUND, FORMATION, LOCATION, LEADERSHIP, AND OVERSIGHT**

In the late 19th and early 20th centuries, sediment-sampling activities increased rapidly to support civil-works programs in several agencies of the United States (U.S.) Government. These agencies and other domestic and foreign investigators developed and used physical samplers of suspended sediment, bedload, and bed material (FISP, 1940a; b) to collect data needed for specific elements of their missions. Most instruments were designed with limited attention to, or knowledge of, sediment-transport concepts or the influence of the equipment on the local flow pattern (Glysson 1989). Consequently, data obtained by different investigators before the 1940s were neither comparable nor could their accuracy be verified.

By the late 1930s, Federal managers realized that, “…the accuracy of sediment data was affected by lack of standardization in equipment and techniques” (Skinner, 1989). This led to a proposal by G.A. Hathaway of the U.S. Army Corps of Engineers (Corps) and E.W. Lane of the Iowa Institute of Hydraulic Research to form, “[an interagency] project…to remedy the situation” (Skinner, 1989). The proposal was endorsed by the U.S. Geological Survey, U.S. Department of Agriculture, Bureau of Reclamation, Office of Indian Affairs, Tennessee Valley Authority, and the Corps, and led to the formation of an Intergovernmental Committee under the general supervision of E.W. Lane of (and at) the University of Iowa’s Institute of Hydraulic Research in 1939 (Nelson and Benedict, 1950; Brown, 1965; Benedict, 1979). This committee was charged with sponsoring, “an exhaustive study of all problems encountered in collecting sediment data and, eventually, to standardize accepted methods and equipment” (Nelson and Benedict, 1950).
In April 1946, the “activities and functions of the committee were transferred to the Subcommittee on Sedimentation of the Federal Inter-Agency River Basin Committee…which [coordinates] hydrologic activities of the Federal Departments through the assistance of several subcommittees” (Witzigman, 1965). In June 1948 the project was transferred to the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota under the leadership of the Corps’ Byrnon C. Colby (Holeman, 1976).

In 1956, the Subcommittee on Sedimentation reorganized the project and named it the Federal Inter-Agency Sedimentation Project, a title – minus the hyphen and either referred to as “the project” or identified by the acronym “FISP” – that remains today. Since 1956, the project has been overseen and sponsored by a Technical Committee comprised of representatives from FISP-member agencies (see the attachment, “A brief history of the Federal Inter-Agency Sedimentation Project”).

The USGS’s John V. Skinner succeeded Byrnon Colby as project chief and served in this capacity until his 1992 retirement. That year, the project was transferred to the Corps’ Waterways Experimentation Station in Vicksburg, Mississippi. The USGS’s Dallas Childers led the project in an acting capacity after John Skinner’s retirement until C. Wayne O’Neal became FISP Chief by or before 1994.

About two years prior to O’Neal’s 2005 retirement, the project’s inventory and functions to procure, quality assure, supply, and repair physical sediment samplers and supporting instrumentation were transferred to the USGS’s Hydrological Instrumentation Facility (2015) in Bay St. Louis, Mississippi, where those FISP functions continue to be successfully performed today. The project retained its in-house instrument development role. However, by then a sea change in the capabilities and means for acquiring fluvial-sediment data was well underway, to wit: From routine, periodic and/or episodic collection of physical samples, to continuous in situ monitoring of selected sedimentary characteristics using surrogate technologies field-calibrated with FISP physical samplers and sampling techniques.

Upon C. Wayne O’Neal’s 2005 retirement, the USGS’s Broderick C. Davis became project chief and led the project until his 2012 retirement. By the time the USGS’s Mark N. Landers became project chief in 2012, the FISP business model of in-house research and development lasting seven decades had largely yielded to a proposal-driven business model that took advantage of the broad-based experience and expertise in surrogate means for monitoring suspended sediment, bed material, and bedload.

The above-cited sources contain information that resolves a 2-decade-old “chicken-or-the-egg” controversy among FISP personnel and then-members of both the Technical Committee and Subcommittee on Sedimentation that included more than a modicum of jingoism: Which came first, the FISP (and Technical Committee), or the Subcommittee on Sedimentation?

A sedimentation project was formed in 1939 and managed until April 1946 by an “Interdepartmental Committee.” That year, oversight authority of the project was transferred to the Subcommittee on Sedimentation of the Federal Inter-Agency River Basin Committee.

In 1956 this Subcommittee, which today is known as the Subcommittee on Sedimentation of the Advisory Council on Water Information (2015), “reorganized the project and called it the Federal Inter-Agency Sedimentation Project” (Witzigman, 1965). Since 1956, the project has been overseen and sponsored by a Technical Committee comprised of representatives from FISP-member agencies.

Thusly is the “chicken-or-the-egg” controversy answered: The Federal Interagency Sedimentation Project was so named, and the Technical committee formed, in 1956. This was at least a decade after the project was referred to as the Subcommittee on Sedimentation.

However, the FISP’s mission and operational perspectives can be summarized by its 1939 formative charge which remains more-or-less relevant today, “to study problems in collecting sediment data and to develop, improve, and standardize methods and equipment for determining the quantity and character of sediment carried by streams” (Witzigman, 1965). It is referred to as “the project” in virtually all historical writings. Undoubtedly the aforementioned “basic purpose” of the FISP extends continuously from its
inception to the present, regardless of its title or that of its oversight committee. Ergo, save for any gain or loss of bragging rights, the chicken-or-the-egg question is rendered an immaterial historical footnote.

An epilogue to this story occurred in 2004 when the Subcommittee on Sedimentation was reorganized under the Advisory Committee on Water Information, a public-private entity governed by the Federal Advisory Committee Act. The expectation—subsequently borne out—that non-Federal organizations would join the Subcommittee raised the potential of non-funding organizations to exert influence on the FISP’s mission and priorities. This concern, coupled with other factors, resulted in the Subcommittee’s decision to formally sever its linkage with the FISP. The FISP’s stand-alone status with oversight by the Technical Committee remains extant today.

**SIX PHASES OF THE FEDERAL INTERAGENCY SEDIMENTATION PROJECT**

With due consideration to the contributions by Nelson and Benedict (1950), FISP (1963), Witzigman (1965), Benedict (1979), and Skinner (1989), the authors determined that the history of the FISP can be summarized as occurring in six phases: Developing,

I. Manual Samplers for Collection of Physical Sediment Samples
II. Sediment-Analytical Instruments
III. Automatic Samplers
IV. Automatic Sediment Gages
V. Manual Samplers for Collection of Trace-Element Water-Quality Samples
VI. Sediment-Surrogate Technologies

Although summaries of all six phases follow, the reader is directed to Nelson and Benedict (1950), FISP (1963), Witzigman (1965), Benedict (1979), and Skinner (1989), for more in-depth descriptions of phases I-IV. Emphases in the ensuing summaries are placed on successes or lack thereof, expressed in terms of knowledge gained, and the instruments and/or methodologies approved and rendered publically available.

**Phase I: Manual Samplers for Collection of Physical Sediment Samples, 1939-1980s** Phase I addressed two challenges: An insufficient understanding of the physics of the motion and distribution of sediment particles in suspension and as bedload, and a lack of standardization of samplers and sampling techniques. Research on sedimentary physics in the early years of the FISP led to the recognition of the need for, design, and development of isokinetic samplers and sampling procedures to address deficiencies associated with surface-grab or weighted-bottle samplers. An outstanding body of FISP literature on this topic is available at the FISP web site (water.usgs.gov/fisp) as part of FISP report Nos. 1-14 and A-TT.

Research and development efforts focused on samplers and sampling techniques for collection of representative sediment samples for subsequent laboratory analyses in three categories: In suspension (suspended sediment); rolling, sliding, or saltating on the bed (bedload); and stationary (bed material). Davis (2005) lists most of the FISP samplers described in the following sections. Edwards and Glysson (1999), Nolan et al. (2005), Gray and Landers (2014) and Gray and O’Halloran (2015) describe FISP- and USGS-approved sampler-deployment techniques. Three of the samplers developed as part of Phase I appear in figure 1.

<table>
<thead>
<tr>
<th>Selected Rigid-Bottle Samplers Developed During FISP Phase I</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="US DH-48" /></td>
</tr>
</tbody>
</table>

Figure 1 Examples of suspended-sediment samplers developed during Phase I of FISP.
Today there are 16 models of suspended-sediment samplers (table 1 and figures 1 and 2), including those also capable of sampling for trace elements (figure 2); two models of bedload samplers (table 2); four models of bed-material samplers (table 3); and a suite of passive single-stage suspended-sediment samplers developed as part of Phase I. These samplers are described in detail on the FISP web site catalog along with their specifications, operational limits, and links to operator’s manuals. The nomenclature for FISP sediment-sampling instruments (tables 1, 2, and 3) denotes the series, type, and year that sampler development started (Davis, 2005). All are available for purchase through the FISP or authorized private-sector firms.

FISP samplers not only are used by several Federal agencies and other organizations in the U.S., but in a number of countries around the world on every continent except Antarctica (Gray and Demas, in press). The simplicity and minimal moving parts of FISP isokinetic samplers, strong theoretical underpinnings supported by laboratory and field-based research, and still-water calibrations impart general confidence in the representativeness of the samples produced.

*The US P-6 point-integrating suspended-sediment sampler (figure 2), which was designed to replace the US P-61, was approved by the Technical Committee in 2012. It cannot be used to collect contamination-free samples for trace-element analyses.

**Phase II: Sediment-Analytical Instruments, 1940s-70s** Witzigman (1965) and Benedict (1979) describe several laboratory-analytical instruments, some of which remain in use by USGS and other sediment laboratories. Several reports on this subject can be found at FISP (2015). The bottom-withdrawal tube was developed to determine the size distribution of material up to 0.7 millimeters in diameter in suspended-sediment samples. Only the USGS Louisiana Water Science Center sediment laboratory continues to use this instrument, and only for samples submitted by the Corps’ New Orleans District (Cheryl Joseph, USGS written commun., 2015).

The visual-accumulation tube method was developed to determine the size distribution of sand-size material in suspended-sediment, bed-, and beach-material samples. This method remains in use in several USGS fluvial-sediment laboratories.

Investigations into the use of X-rays to quantify particle-size distributions resulted in the development and commercial availability of the Sedigraph in or about 1967. Only one USGS production sediment laboratory – located at the Cascades Volcano Observatory in Vancouver, Washington – continues to use a Sedigraph (Dan Gooding and Julie Nason, USGS, written commun., 2015).

At least two other sediment-analyzing methodologies were investigated: Turbidity and ultrasonics. Turbidity is an optical water-quality characteristic affected by several factors including the color and size of the sediments and the color of the fluid in which they are suspended, in addition to sediment concentration. The ultrasonic method was developed to determine concentrations and size distributions of sediments ranging from 0.040-1.0 millimeters. A laboratory instrument was considered to operate well, but was not considered “competitive” with existing laboratory equipment. No contemporary USGS production sediment laboratory uses ultrasonics to analyze sediment samples.

**Phase III: Automatic Samplers, 1940s-60s** The FISP developed and produced two types of automatic samplers after the midpoint of the 20th century: Passive single-stage samplers, and the US PS-69 pumping sampler. As designed, both types of samplers drew water from a fixed point in the stream (in the case of the US PS-69, with or without a strainer affixed to the intake orifice).
Table 1 Designations for and Characteristics of FISP Manually Operated Isokinetic Suspended-Sediment Samplers (Davis, 2005; Gray et al., 2008; Gray and Landers, 2014).

<table>
<thead>
<tr>
<th>Sampler Designation</th>
<th>Nozzle Inner Diameter, cm (in)</th>
<th>Container Type and Capacity</th>
<th>Mode of Suspension</th>
<th>Maximum Depth, m (ft)</th>
<th>Min Isokinetic Velocity, m/s (ft/s)</th>
<th>Max Recommended Velocity, m/s (ft/s)</th>
<th>Unsampled Zone, cm (in)</th>
<th>Mass, kg (weight, lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US DH-48</td>
<td>0.48 (3/16), 0.64 (¼)</td>
<td>Rigid bottle 0.47 L (pint)</td>
<td>Wading Rod</td>
<td>2.7 (9)</td>
<td>0.5 (1.5)</td>
<td>2.7 (8.9)</td>
<td>8.9 (3.5)</td>
<td>2 (4)</td>
</tr>
<tr>
<td>US DH-59</td>
<td>0.48 (3/16)</td>
<td></td>
<td>Handline or Cable Reel</td>
<td>4.6 (15)</td>
<td>0.6 (2.0)</td>
<td>1.5 (5.0)</td>
<td>11 (4.5)</td>
<td>10 (22)</td>
</tr>
<tr>
<td>US DH-76</td>
<td>0.48 (3/16), 0.64 (¼)</td>
<td>Rigid bottle 0.95 L</td>
<td>Wading Rod</td>
<td>2.7 (9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US DH-81</td>
<td>0.48 (3/16)</td>
<td></td>
<td>Handline or Cable Reel</td>
<td>4.6 (15)</td>
<td>0.6 (2.1)</td>
<td>1.9 (6.2)</td>
<td>12 (4.8)</td>
<td>13 (29)</td>
</tr>
<tr>
<td>US DH-95</td>
<td>0.48 (3/16)</td>
<td></td>
<td></td>
<td>4.6 (15)</td>
<td>0.5 (1.7)</td>
<td>2.1 (7.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US DH-2</td>
<td>0.48 (3/16)</td>
<td>Flexible 1-L bag</td>
<td>Wading Rod</td>
<td>11 (35)</td>
<td>0.6 (2.0)</td>
<td>1.8 (6.0)</td>
<td>8.9 (3.5)</td>
<td>14 (30)</td>
</tr>
<tr>
<td>US DH-2</td>
<td>0.79 (5/16)</td>
<td></td>
<td>Handline or Cable Reel</td>
<td>6.1 (20)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US D-74</td>
<td>0.48 (3/16)</td>
<td></td>
<td>Rigid bottle 0.47 L (pint) or 0.95 L (quart)</td>
<td>4.6 (15)</td>
<td>0.5 (1.5)</td>
<td>2.0 (6.6)</td>
<td>10 (4.1)</td>
<td>28 (62)</td>
</tr>
<tr>
<td>US D-74</td>
<td>0.48 (3/16)</td>
<td></td>
<td></td>
<td>4.6 (15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US D-95</td>
<td>0.48 (3/16)</td>
<td>Rigid bottle 1 L</td>
<td>Rigid bottle 1 L</td>
<td>4.6 (15)</td>
<td>0.5 (1.7)</td>
<td>1.9 (6.2)</td>
<td>12 (4.8)</td>
<td>29 (64)</td>
</tr>
<tr>
<td>US D-95</td>
<td>0.64 (¼)</td>
<td></td>
<td></td>
<td>4.6 (15)</td>
<td>0.6 (2.0)</td>
<td>2.0 (6.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US D-96</td>
<td>0.64 (¼)</td>
<td>Flexible 3-L bag</td>
<td>Flexible 3-L bag</td>
<td>34 (110)</td>
<td></td>
<td></td>
<td>3.8 (12.5)</td>
<td>60 (132)</td>
</tr>
<tr>
<td>US D-96</td>
<td>0.79 (5/16)</td>
<td></td>
<td></td>
<td>12 (39)</td>
<td>0.9 (3.0)</td>
<td>10 (4.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US D-96-A1</td>
<td>0.48 (3/16)</td>
<td></td>
<td></td>
<td>34 (110)</td>
<td></td>
<td></td>
<td>1.8 (6.0)</td>
<td>36 (80)</td>
</tr>
<tr>
<td>US D-96-A1</td>
<td>0.64 (¼)</td>
<td></td>
<td></td>
<td>12 (39)</td>
<td>1.8 (6.0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US D-99</td>
<td>0.48 (3/16)</td>
<td>Flexible 6-L bag</td>
<td>Flexible 6-L bag</td>
<td>67 (220)</td>
<td>1.22 (4.0)</td>
<td>24 (7.8)</td>
<td>125 (275)</td>
<td></td>
</tr>
<tr>
<td>US D-99</td>
<td>0.64 (¼)</td>
<td></td>
<td></td>
<td>37 (120)</td>
<td>1.13 (3.7)</td>
<td></td>
<td>4.6 (15.0)</td>
<td></td>
</tr>
<tr>
<td>US D-99</td>
<td>0.79 (5/16)</td>
<td></td>
<td></td>
<td>24 (78)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USP-S-61-A1</td>
<td>0.48 (3/16)</td>
<td>Rigid bottle 0.47 L (pint)</td>
<td>Rigid bottle 0.47 L (pint) or 0.95 L (quart)</td>
<td>55 (180), pint 37 (120), quart</td>
<td>0.5 (1.5)</td>
<td>3.0 (10.0)</td>
<td>11 (4.3)</td>
<td>48 (105)</td>
</tr>
<tr>
<td>US P-63</td>
<td>0.48 (3/16)</td>
<td></td>
<td></td>
<td>22 (72), pint 16 (51), quart</td>
<td>0.5 (1.5)</td>
<td>4.6 (15.0)</td>
<td>15 (5.9)</td>
<td>91 (200)</td>
</tr>
<tr>
<td>US P-72</td>
<td>0.48 (3/16)</td>
<td></td>
<td></td>
<td>49 (160), quart</td>
<td>0.5 (1.5)</td>
<td>4.0 (13)</td>
<td>8.9 (3.5)</td>
<td>45 (100)</td>
</tr>
</tbody>
</table>

1Samplers designated in *italics* may also be used for collection of trace-element samples as described in the USGS National Field Manual for the Collection of Water Quality-Data (USGS, 2014).

2For rigid-bottle samplers, the maximum recommended velocity for sampler deployment is based either on measured isokinetic limitations or on the maximum velocities used in isokinetic and stability tests. Bag samplers were determined to retain isokinetic characteristics at the highest velocities tested.

3The 3/16-inch-diameter nozzle is more sensitive to velocity and temperature effects than larger-diameter nozzles, and only should be used when necessary to sample greater depths with these bag samplers.

4The minimum isokinetic velocities for the US D-99 sampler at water temperatures greater than 10°C and less than 10°C are 0.91 m/s (3.0 ft/s) and 1.1 m/s (3.7 ft/s), respectively, unless the 0.48-mm (3/16-in) nozzle is used, in which case it is 1.22 m/s (4.0 ft/s).
Table 2 Designations for and Characteristics of FISP Manually Operated Bed-Material Samplers (Davis, 2005).

<table>
<thead>
<tr>
<th>Sampler Designation</th>
<th>Description</th>
<th>Sampler Weight (pounds)</th>
<th>Maximum Sampler Penetration (inches)</th>
<th>Maximum Sample Volume (cubic inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US BMH-53</td>
<td>Hand-held, 2-inch diameter, piston-type bed-material sampler.</td>
<td>7.5</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>US BM-54</td>
<td>Cable-suspended, spring-loaded scoop, bed-material sampler</td>
<td>100</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>US BMH-60</td>
<td>Cable-suspended, spring-loaded scoop, bed-material sampler</td>
<td>32</td>
<td>1.7</td>
<td>11</td>
</tr>
<tr>
<td>US RBMH-80</td>
<td>Hand-held rotary-scoop bed-material sampler</td>
<td>8</td>
<td>1.8</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 3 Designations for and Characteristics of FISP Manually Operated Bedload Samplers (Davis, 2005).

<table>
<thead>
<tr>
<th>Sampler Designation</th>
<th>Description</th>
<th>Sampler Weight (pounds)</th>
<th>Nozzle Width X Height (inches)</th>
<th>Maximum Velocity (feet per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US BL-84</td>
<td>Cable-suspended, mesh bag bedload sampler</td>
<td>32</td>
<td>3 x 3</td>
<td>9</td>
</tr>
<tr>
<td>US BLH-84</td>
<td>Hand-held, mesh bag bedload sampler</td>
<td>10</td>
<td>3 x 3</td>
<td>**</td>
</tr>
<tr>
<td>Bed Load Trap</td>
<td>Portable mesh bag, fixed location bedload sampler</td>
<td>32</td>
<td>12 x 8</td>
<td>variable</td>
</tr>
</tbody>
</table>

**rod-deployed either by wading or from above the stream; maximum velocity is probably 9 ft/s.

A U-series single-stage sampler (FISP, 1963; Witzigman, 1965; Benedict, 1979; FISP, 2015) collects samples of near-surface water on the rising hydrograph. They are typically deployed in a series of samplers affixed at different elevations to a pier, wingwall, or other stable structure. When the total head incident on the intake orifice results in water cresting inside the intake-tube weir, stream water siphons into a sample bottle and the displaced air vents through an exhaust tube. When the sample rises to the elevation of the exhaust pipe’s orifice inside the bottle, an airlock forms and sample collection should cease. However, in practice, sample recirculation sometimes occurs, preferentially enriching the sedimentary content of the sample. Additional unreliability could result from a presumed inability to representatively capture sand-size material. In spite of these drawbacks, the FISP U-series samplers and other types of passive automatic samplers that they inspired, including a design by Gray and Fisk (1991) that precludes the potential for sample recirculation, remain in use at some field sites.

Skinner (1989) describes the PS-69 pumping sampler, which the FISP developed and produced to collect fixed-point samples at gaging stations on relatively “flashy” streams and at those that could not be adequately sampled by an observer. FISP-produced prototypes include the PS-62, PS-66, and PS-67 pumping samplers, which, along with the PS-69, were field tested in the 1960s in Maryland (Yorke, 1976). Desirable features of the PS-69 included a 12-volt power system; sample rack that held 72 quart-size containers; and an intake-line backflush system using an in-gage reservoir that was refilled after each backflush cycle. Its drawbacks included its large size and power requirements, complexity with many moving parts, and lack of reliability in the challenging field environment. The FISP ceased to supply and support the PS-69 samplers some years after the first commercial pumping samplers made by Manning Environmental Corporation, and ISCO Corporation became available by the early 1980s.
Phase IV: Automatic Sediment Gages, 1950s-80s FISP (1963), Skinner and Beverage (1976), and Skinner (1989) summarized FISP endeavors to automate the collection of suspended-sediment data in the field and laboratory. They describe investigations in radiant energy (acoustic and electromagnetic, including gamma rays), applied forces (a densimetric technique), a vibratory technique as part of a U-tube, and electrical conduction. The latter takes advantage of a disparity in the conductivity of river water to that of the entrained sediments. In retrospect, the FISP was ahead of its time in this pre-microcomputer age. None of these efforts resulted in the wide-scale field-deployment of “automated sediment gages.”

Phase V: Manual Samplers for Collection of Trace-Element Water-Quality Samples, 1990s-2006 In the 1980s, a need for trace-element data at parts-per-billion-level concentrations (as opposed to the parts-per-million-level concentrations measurements for suspended sediment and many chemical constituents including nutrients and common ions) presented the prospect of contamination from the sampling apparatus, particularly for samples collected for trace-metal analyses. A decision to simply coat FISP suspended-sediment samplers used to collect trace-element samples with white marine epoxy paint proved disastrous from a data-quality perspective. Much of the derived dissolved trace-element data were rendered unreliable due to contamination from the sampler in spite of the epoxy coating (USGS, 1991).

<table>
<thead>
<tr>
<th>Figure 2 Examples of suspended-sediment samplers developed during Phase V of FISP (the US P-6 cannot be used to collect samples for trace-element analyses).</th>
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<tbody>
<tr>
<td><strong>Rigid-Bottle Samplers Developed During FISP Phase V</strong></td>
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<tr>
<td>US DH-81</td>
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<tr>
<td><strong>Bag-Type Samplers Developed During FISP Phase V</strong></td>
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| Phase VI: Developing Sediment-Surrogate Technologies, approximately 2004-present By the arrival of the third millennium, the availability of hardware and relatively robust software that postdated FISP’s Phase III automated sediment gage-development efforts were being exploited by a number of researchers and some private-sector firms to develop surrogate means for measurements of suspended-sediment concentrations and size distributions, bedload-transport rates, and bed-material size distributions. Their primary focus was on bulk-optic, laser-optic, acoustic, and pressure-differential surrogate metrics capable of providing high-temporal – and in some cases also high-spatial – resolution time-series data (Gray and Gartner, 2009). When calibrated to sediment characteristics using concurrently collected physical samples, these surrogate methods provide substantial improvements in the acquisition and accuracy of the data produced, primarily due to the temporal continuity afforded by in situ surrogate instruments. Moreover, these surrogate methodologies promise to lower monitoring costs in the medium-to-long term. By 2004, after its successful decade-long, primary focus on development of trace-element samplers, the FISP found itself in need of expertise and momentum if it hoped to take on a leadership role in the burgeoning field of sediment-surrogate technologies. By then, bulk optics (turbidity) had matured as a surrogate metric for suspended-sediment concentration and was being integrated into selected operational programs (Rasmussen et al., 2008). With the publication of the USGS-produced and -sanctioned technique for converting continuous turbidity measurements to mass-concentration values (Rasmussen et
al., 2009), the FISP subsequently refrained from supporting turbidity research projects in lieu of other compelling but inadequately resolved sediment-surrogate technologies.

The initial Phase VI surrogate technology to be evaluated by the FISP was laser scattering (Gray and Gartner, 2009). Laser scattering provides at-a-point values for volumetric concentrations back-calculated from the sum of particles measured volumetrically in 32 size classes. The FISP has funded research projects to evaluate the LISST-SL, an isokinetic laser-scattering instrument (Czuba et al., 2015). This research led to the FISP’s sanctioning laser-diffraction analyzers for environmental volumetric measurements for both suspended-sediment concentrations and particle-size distributions, albeit with important caveats (FISP, 2013).

FISP is currently funding sediment-acoustic research. Sediment acoustics was deemed by Gray and Gartner (2009) to be the most promising for meeting the needs of large-scale fluvial-sediment monitoring programs, a contention reiterated by the authors today. The use of manually deployed or in situ acoustic Doppler current (ADCP) meters, in particular, shows considerable potential as a surrogate technology for suspended-sediment concentration and possibly also to quantify particle-size classes, to wit:

1. ADCPs already are used extensively for streamflow monitoring and provide river-velocity data,
2. A direct measure of the cross-sectional variability in sediment concentrations is provided,
3. The technology is not as susceptible to biofouling as other surrogate technologies, such as turbidity sensors,
4. The technology measures a larger volume than other surrogate technologies, and
5. Acquisition of sediment-size information is possible using multiple acoustic frequencies.

FISP continues to fund evaluations of a densimetric technology that exploits the differences in the pressures simultaneously sensed by precision pressure transducers at two in situ orifices separated by a fixed distance in a water column. The technology’s performance theoretically improves with increasing suspended-sediment concentrations exceeding some 10-20 grams per liter. The densimetric technology was evaluated by the USGS in Puerto Rico, Arizona, and, most recently and successfully, at New Mexico’s Rio Puerco, a tributary of the middle Rio Grande renowned for conveying highly sediment-laden flows (Brown et al., 2015).

### Future Challenges and Directions

The purpose of the FISP continues to be driven by the need for reliable sediment-monitoring equipment and methods in a world where the relevance of sediment information continues to increase. The future directions of the FISP – in response to known and emerging challenges – involve a growing knowledge of and improved methods for physical sampling and for continuous sediment monitoring using surrogate technologies. Primary focus areas and concomitant challenges for the FISP in the foreseeable future may include the following:

- Develop and improve operational instrumentation and methods to monitor suspended-sediment characteristics (concentrations, loads, particle-size distributions) using acoustic backscatter at high-temporal and/or high-spatial resolution.
- Develop and improve operational instrumentation and methods to monitor bedload using acoustic and other surrogates at high-temporal and/or high-spatial resolution.
- Obtain improved understanding and characterization (including sampling accuracy) of physical sediment samplers, particularly bag-type samplers, using computational fluid dynamic modeling and field verification.
- Evaluate and improve instruments and methods for physical bedload sampling.
- Continued evaluation and development of new technologies including those based on laser-diffraction and densimetric principals.
- Evaluate technologically advanced methods for fluvial-sediment laboratory analyses and records processing.
The foci and thrusts of the FISP have changed in response to member-agency needs and evolving capabilities over its ¾-century existence. The authors hope to read a “FISP History Part VI” before the cessation of their respective dotages – perhaps to commemorate the FISP’s centennial in 2039.

ACKNOWLEDGEMENTS

The veracity and content of this contribution benefited considerably from peer reviews provided by Jerry Bernard (retired) and Marie Garsjo (retired), Natural Resources Conservation Service; C. Wayne O’Neal (retired), FISP; and Robert Hildale, Bureau of Reclamation. The artistic prowess of the USGS’s Annette Goode toward formatting of the tables and figures in this manuscript was greatly appreciated.

REFERENCES CITED


ATTACHMENT

A BRIEF HISTORY OF THE FEDERAL INTER-AGENCY SEDIMENTATION PROJECT*

(unattributed and undated, inferred from content to have been written in or after 1956)

In 1939, representatives of several Federal Agencies met to discuss ways of improving methods for measuring the quantity and characteristics of sediment that is transported in rivers. These representatives organized an Interdepartmental Committee to standardize methods and equipment for collecting sediment data. The following agencies supported the standardization effort: Corps of Engineers of the Department of the Army; Flood Control Coordinating Committee of the Department of Agriculture; U.S. Geological Survey; Bureau of Reclamation; Office of Indian Affairs of the Department of Interior; and the Tennessee Valley Authority. The Iowa Institute of Hydraulic Research cooperated in the work which was performed at the Hydraulic Laboratory, State University of Iowa, Iowa City, Iowa.

From 1939 to 1942 the project was under the general supervision of Professor E. W. Lane. From July 1942 to July 1945, the project was supervised by M. E. Nelson, Army Corps of Engineers, and L. C. Crawford, Geological Survey; the research work was conducted by personnel from both agencies.

In April 1946, the Interdepartmental Committee transferred its authority the Subcommittee on Sedimentation of the Federal Inter-Agency River Basin Committee. The River Basin Committee was composed of representatives from the Department of the Army, Department of the Interior, Department of Agriculture, Department of Commerce, Tennessee Valley Authority, and Federal Power Commission. The main objective of the Committee was to coordinate all Federally sponsored hydrologic studies.

In June 1948, the Subcommittee on Sedimentation moved the project from the Iowa Institute of Hydraulic Research to the St. Anthony Falls Hydraulic Laboratory at the University of Minnesota in Minneapolis, Minnesota. From 1946 to 1955, project activities were under the general supervision of M. E. Nelson, Army Corps of Engineers, and P. C. Benedict, U.S. Geological Survey. Mr. B. C. Colby directed the research work.

In 1956, the Subcommittee reorganized the project and called it the Federal Inter-Agency Sedimentation Project. The Subcommittee also adopted a formal Guidance Memorandum that described the project's objectives and organization.

Since 1956, the project has been sponsored by a Technical Committee composed of representatives from Federal Agencies that are involved in sediment studies. Major policies that affect the project are made by the Sedimentation Committee of the Interagency Advisory Committee on Water Data of the Water Resources Council. The project's staff conducts basic and applied research and also develops, tests, and calibrates sediment equipment.


*This title and ensuing text reflects verbatim the contents of an unattributed, undated 2-page FISP “history” discovered by John R. Gray (USGS Scientist Emeritus) when G. Douglas Glysson (USGS, retired) cleaned the last USGS office that Glysson occupied on the 5th floor of the USGS National Center, Reston, Virginia, in late 2014. The file was scanned by Annette Goode, USGS Office of Surface Water, in December 2014. It was subsequently reformatted to fit on one page as it appears above.

Although the veracity of this “history” has not been unequivocally verified, some parts are undoubtedly correct based on Gray’s knowledge of the Project, and on histories published by Witzigman (1965) and Skinner (1989). Coupled with the circumstances under which it was found, there is little doubt that it is authentic and reliable. Thus it is hereby included as part of the permanent FISP record by John R. Gray, 2015