# REPORT SS

# THE US DH-2: A ONE-LITER HAND-LINE ISOKINETIC SUSPENDED-SEDIMENT/WATER-QUALITY COLLAPSIBLE-BAG SAMPLER

June 2005

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Published by:

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Sponsored by:

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## FACTORS FOR CONVERTING INCH/POUND UNITS TO SI METRIC UNITS

| Multiply | By | To Obtain |
|---|---|---|
| Inch (in) | 2.54 | centimeter (cm) |
| pint, liquid (pt) | 0.4732 | Liter (L) |
| quart, liquid (qt) | 0.9464 | Liter (L) |
| gallon (gal) | 3.785 | Liter (L) |

# CONTENTS (continued)

| Multiply | By | To Obtain |
|---|---|---|
| pound, avoirdupois (lb) | 0.4545 | kilogram (kg) |
| feet per second (ft/sec) | 0.3048 | meter per second (m/sec) |
| $^{o}$F | 5/9($^{o}$F – 32) | $^{o}$C |

The use of brand names in this report is for identification purposes only and does not imply endorsement by the United States Government.

Superscripted numbers refer to references listed at the end of the report.

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## ABSTRACT

The Federal Interagency Sedimentation Project (FISP) has designed, fabricated, and tested a collapsible-bag sampler that will collect a depth-integrated isokinetic suspended-sediment/water-quality sample. The sampler will collect a 1-liter (L) sample at stream velocities ranging from 2 to 6 feet per second (ft/sec). Nozzles with intake diameters of 3/16, 1/4, and 5/16 inch (in) give the sampler the capability to sample to depths of 35, 20, and 13 feet (ft), respectively. Testing to determine the inflow efficiency of the sampler was conducted in a re-circulating flume. The inflow efficiency also was determined during raising and lowering of the sampler while towed by a boat in a lake to simulate a transit in a stream vertical. Drift angle tests documented the drift angle of the sampler at various wetted cable lengths and stream velocities. Underwater video documented the stability of the sampler while towing.

The sampler has been designated by the FISP as the US DH-2. It is 19 in long, fabricated from bronze, and plastic parts, and weighs 30 pounds (lbs). All metal parts are plastic-coated. Nozzles are fabricated from plastic and tetrafluoroethylene (TFE). The collapsible bags used with the sampler are made of polyethylene and perfluoroalkoxy (PFA). Plastic nozzles and polyethylene bags are used for sediment sampling, and TFE nozzles and PFA bags meet the U.S. Geological Survey's (USGS) Office of Water Quality's[1] requirements for collecting non-contaminated water-quality samples for trace-element analysis.

## INTRODUCTION

Various investigators including Gluschkoff[2] and the Rhine Works Authority[2] in the 1940s and Stevens[3] and Szalona[4] in the 1980s have documented research on the use of a collapsible-bag suspended-sediment sampler. Results were encouraging, but the proposed samplers were not able to collect isokinetic samples at all stream velocities typically encountered in natural streams. In 1996 the FISP began research and development of an isokinetic collapsible-bag suspended-sediment/water-quality depth-integrating sampler. A collapsible-bag sampler has several advantages over traditional rigid-container samplers. A primary advantage is sampling depth. Rigid-container samplers are limited to a maximum depth of 15 ft. A bag container is flexible and contains essentially no air. As a result, sampling depth is not limited because of air compressibility, meaning the depth to which the sampler can be used is limited only by the intake diameter of the nozzle and the volume of the bag. It also means the maximum transit rate is limited only by the apparent approach angle of the nozzle facing into the stream velocity as the sampler makes its vertical traverse, which is 0.4[5] times the mean stream velocity. The minimum transit rate is limited by the volume of the collapsible bag. Another advantage is cost savings in the use of collapsible bags as opposed to a rigid container or bottle.

The initial development effort beginning in 1996 resulted in a 3-liter sampler, designated the US D-96. The sampler was designed, tested, and approved for use by the FISP Technical Committee[6]. The US D-96 sampler weighs 130 lbs. In 1999, design and testing of a 6-liter collapsible-bag sampler was initiated. The result was the US D-99, a 275-lb sampler[7]. In 2003 an 80-lb version of the US D-96, designated the US D-96-A1, was designed, tested, and approved by the FISP Technical Committee[8]. Theoretically, the US D-96 and the US D-96-A1 can sample to a depth of 110 ft, and the US D-99 can sample to a depth of 220 ft. In practice, the depth to which the samplers can be used usually depends on the stream velocity. These samplers are in wide-spread use throughout the United States, and other countries.

The success of these large-volume collapsible-bag samplers generated the desire for a small, lightweight sampler that could sample to a depth of approximately 35 ft. Such a sampler would fill the gap between lightweight rigid-container samplers that have a depth limitation of 15 ft, and the heavier collapsible-bag samplers already in use. The goal of the sampler was to be light enough to be used by hand, collect a 1-liter sample, sample isokinetically at 2 ft/sec stream velocity, and sample to a depth of 35 ft. A sampler that meets these goals, the US DH-2, has been developed and tested by the FISP.

## US DH-2 SAMPLER DESCRIPTION

The US DH-2 is 19 in long with a 6 in diameter at its widest point, and weighs 30 lbs. The nozzle centerline is 4 in above the bottom of the sampler. The sampler (figure 1) is composed of a cast bronze body with a 3.75-in diameter longitudinal cavity, a neutrally buoyant plastic tail section that has a hollow cavity, and a plastic nose . A nozzle holder fits into the back of the nose. The nozzle threads into the front of the nozzle holder, and


*Figure 1-- Photograph of US DH-2*

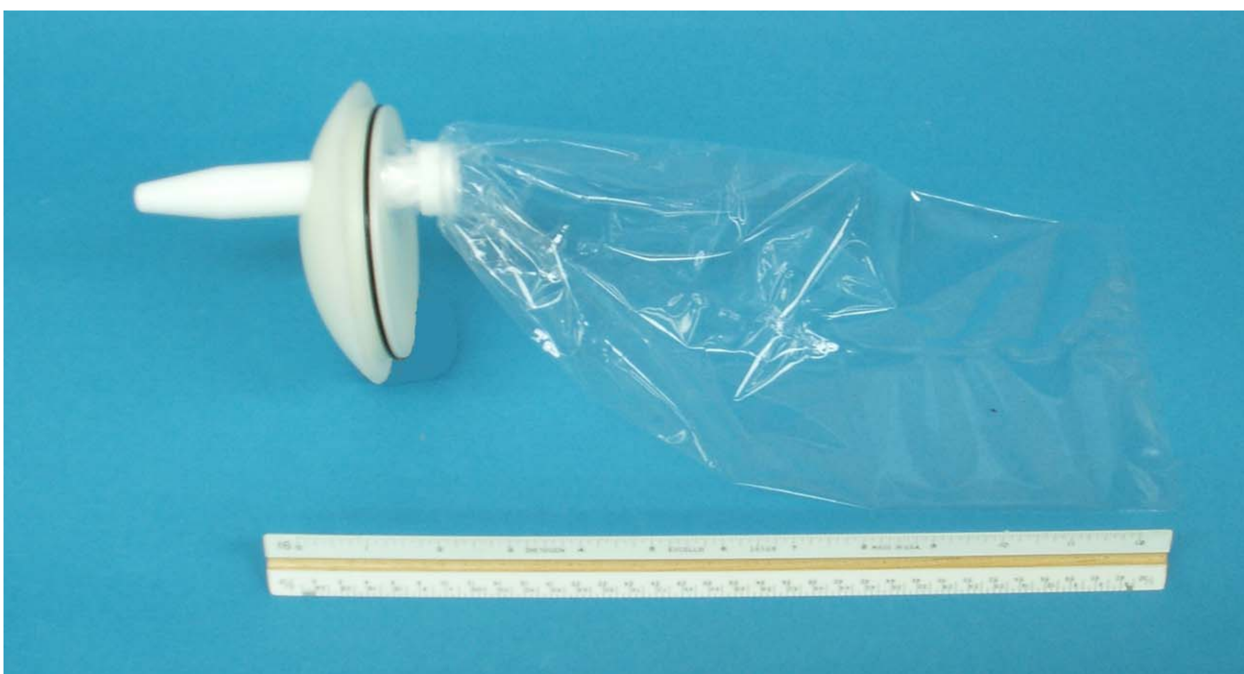

*Figure 2-- Nose with nozzle, nozzle holder, and bag attached*

the collapsible bag is attached to the rear of the nozzle holder with a hook-and-loop strap. Figure 2 shows the nose with the nozzle, nozzle holder, and bag assembled. The bag slides into the cavity of the sampler and the nose snaps into the front of the sampler body with an O-ring friction fit (figure 3). The cavity of the bronze body is lined with a clear plastic tube and the outside of the body is coated to minimize user contact with any metal parts. A 1/2-in diameter hole is located on the bottom of the sampler body near the front and a 1/2-in diameter hole is located in the bottom of the tail section at the rear of the tail cavity. A 3/4-in diameter hole is located near the top front of the sampler body, behind a deflector that is part of the cast body. The holes and deflector aid in quick evacuation of air in the cavity when the sampler is immersed, and in removal of water from the cavity as the collapsible bag fills with sample. Optimum hole sizes and locations were determined by their effect on inflow efficiency.

The tail section of the sampler is fabricated from high-density polyethylene plastic (HDPE). Horizontal and vertical fins fabricated from 0.25-in thick HDPE sheet are seated in milled slots in the tail body and welded in place. HDPE is neutrally buoyant in water, allowing the suspension point of the sampler to be located such that in air, the sampler maintains a tail-down attitude allowing it to quickly orient itself facing into the stream-flow. Once submerged, the sampler assumes a horizontal attitude.

The US DH-2 uses a lay-flat polyethylene or PFA bag 6 in by 14 in, with a 0.002-in wall thickness. The bag is secured to the nozzle holder with a hook-and-loop strap.

Plastic and TFE nozzle holders and nozzles with intake diameters of 3/16 in, 1/4 in, and


*Figure 3-- Insertion of nose into sampler*

5/16 in were used in testing the US DH-2, and are available for current use. Nozzles have their size and material stamped on them. At a maximum transit rate of 0.4 times the mean stream velocity, the sampler is capable of sampling to a depth of 35 ft with the 3/16-in internal diameter nozzle, 20 ft with the 1/4-in internal diameter nozzle, and 13 ft with the 5/16-in internal diameter nozzle.

## TESTING

### Development Testing

A testing program was conducted to determine the effect of design configurations on the inflow efficiency of the sampler that led to the final design described in this report. An inflow efficiency of 1.0 (water/sediment velocity through the nozzle divided by the ambient stream velocity) indicates that the sampler is sampling isokinetically. Tests conducted and reported in FISP Report 5[9] show that minimal error in sediment concentration for sediment up to 0.15-millimeter (mm) diameter is incurred as long as the inflow efficiency is 1.0 plus or minus 0.15. Szalona[4] also reports an acceptable inflow efficiency of 1.0 plus or minus 0.15. FISP currently calibrates samplers to sample at an inflow efficiency of 1.0 plus or minus 0.10.

Test work was conducted in a flume at the U.S. Army Corps of Engineers Engineer and Research Development Center (ERDC) located in Vicksburg, MS. The flume has a cross-section 3 ft wide by 4 ft deep, and a straight section approximately 60 ft long. The flume has valves at the head-bay and an adjustable tailgate to aid in control of water velocity. Water is supplied to the flume by two 25 cubic-feet-per-second (cfs) pumps and one 10-cfs pump that may be operated in any combination. A small lake serves as the water reservoir and water from the flume is re-circulated. The flume can be operated at mean water velocities up to approximately 6.5 ft/sec. A Price type AA current meter with a Current Meter Digitizer was used to measure water velocity in the flume. The meter had been previously calibrated by the USGS, Office of Surface Water Hydraulics Laboratory located at Stennis Space Center, Bay St. Louis, MS.

A prototype sampler was designed and fabricated. Previous research indicated that sampler body parameters that effect inflow efficiency are size and placement of vent holes and the presence or absence of a deflector in front of a vent hole[6]. Additional parameters that effect inflow efficiency are collapsible bag length and the depth of taper in the rear of the sampler nozzle. Initial tests were conducted at a flume flow velocity of 2 ft/sec. A set of plastic nozzles was tapered to the same depth as US D-96 nozzles. Although it is likely these would probably not be the final taper depths, they served as a starting base for initial tests. Various vent hole sizes and locations were tested with and without a deflector placed in front of the hole. Table 1 shows the effect on inflow efficiency of various vent hole locations. Although the inflow efficiencies did not meet the FISP minimum, the effect is apparent. A hole in the top and bottom near the front of the sampler, and a hole in the bottom rear of the tail section resulted in the highest inflow efficiency. Subsequent testing showed that a top hole diameter of 3/4 in reduced the time that it took to evacuate the air from the sampler cavity. A deflector creates a venturi effect and aides in the evacuation of water from the sampler cavity as the bag fills with sample. Inflow efficiency without a deflector was 0.83 and with a deflector in front of the top hole the inflow efficiency increased to 0.90.

***Table 1-- Effect of vent configuration on inflow efficiency***

| Venting configuration | Inflow efficiency ($V_{nozzle}/V_{ambient}$) |
|---|---|
| 1/2-in diameter hole top front<br>1/2-in diameter hole bottom front<br>1/2-in diameter hole bottom tail | 0.71 |
| 1/2-in diameter hole top front<br>1/2-in diameter hole bottom front<br>1/4 in diameter hole bottom tail | 0.71 |
| 1/2-in diameter hole top front<br>1/2-in diameter hole bottom front<br>1/2-in diameter hole bottom tail<br>1/4-in diameter hole top tail | 0.61 |
| 1/2-in diameter hole top front<br>1/2-in diameter hole bottom front | 0.63 |
| 1/2-in diameter hole bottom front<br>1/2-in diameter hole bottom tail | 0.38 |
| 1/2-in diameter hole top front<br>1/2-in diameter hole bottom tail | 0.48 |

The cavity length of the sampler is 13.25 in. The cavity diameter of the sampler body is 3.75 in. It is important to use the highest volume bag possible to maximize sample volume. Polyethylene lay-flat bags 6 in wide by 16 in long were obtained for initial testing. Bags were shortened to obtain lengths of 13 and 14 in for additional testing. Table 2 shows the results. The 13- and 14-in bags had similar results with average inflow efficiencies of 1.03 and 1.04, respectively. The 16-in bag average inflow efficiency was 0.90. In the 16-in bag test (10 replicates), three tests resulted in inflow efficiencies of 0.75, 0.82, and 0.87, indicating inconsistency in sampling. During the tests it was observed that the longer bag sometimes partially blocked the top vent hole, explaining the inconsistent inflow efficiencies. The 14-in bag was used throughout the remainder of testing.

The final design determined from the development testing was a 14-in bag and a sampler with a 3/4-in diameter hole with a deflector located near the top front of the sampler, a 1/2-in diameter hole in the bottom of the sampler near the front, and a 1/2-in diameter hole in the bottom of the tail at the rear of the tail cavity.

***Table 2-- Effect of bag length on inflow efficiency***

| Bag length, in | Inflow efficiency, average of 10 replicates | Lowest inflow efficiency |
|---|---|---|
| 16 | 0.90 | 0.75 |
| 14 | 1.04 | 0.97 |
| 13 | 1.03 | 0.97 |

Previous research has shown that the inflow efficiency of a nozzle can be controlled by varying the depth of taper of the inside diameter of the rear of the nozzle[6]. Once the final design and configuration of the sampler was decided, tests were conducted to determine the optimum depth of taper for each nozzle. Plastic nozzles and polyethylene bags (used for collection of sediment samples) were tested in combination. TFE nozzles and PFA bags that meets the USGS' Office of Water Quality's[1] requirements for collecting non-contaminated water-quality samples for trace-element analysis were used in combination. Tests were conducted at flume flow velocities ranging from 1.5 to 6.5 ft/sec in 0.5 ft/sec increments. Ten replicates were taken with each nozzle at each velocity. Sample volume collected and collection time were recorded. Using the cross-sectional area of the nozzle, the water velocity through the nozzle was calculated and divided by the measured flume flow velocity to determine the inflow efficiency of the nozzle.

Figure 4 highlights the effect of taper depth on the inflow efficiency verses flume flow velocity for four plastic 1/4-in internal diameter nozzles. Nozzle #1 was shortened by 1/4 in from its original length of 4 3/8 in and tapered to a depth of 2.25 in. Nozzle #2 was tapered to a depth of 2.25 in, nozzle #3 tapered to a depth of 1.556 in, and nozzle #4 tapered to a depth of 1.188 in. The horizontal lines at 0.90 and 1.10 inflow efficiencies represent the acceptable range. It is apparent from the figure that nozzle #1 over-sampled throughout most of the velocity range. Nozzle #2 was better, but over-sampled through some of the velocity range, and remained high at the upper velocity range. The inflow efficiency with nozzle #4 was in the acceptable range, but dropped off at the upper velocities. Nozzle #3 resulted in the optimum inflow efficiency. Nozzle #3 reached the

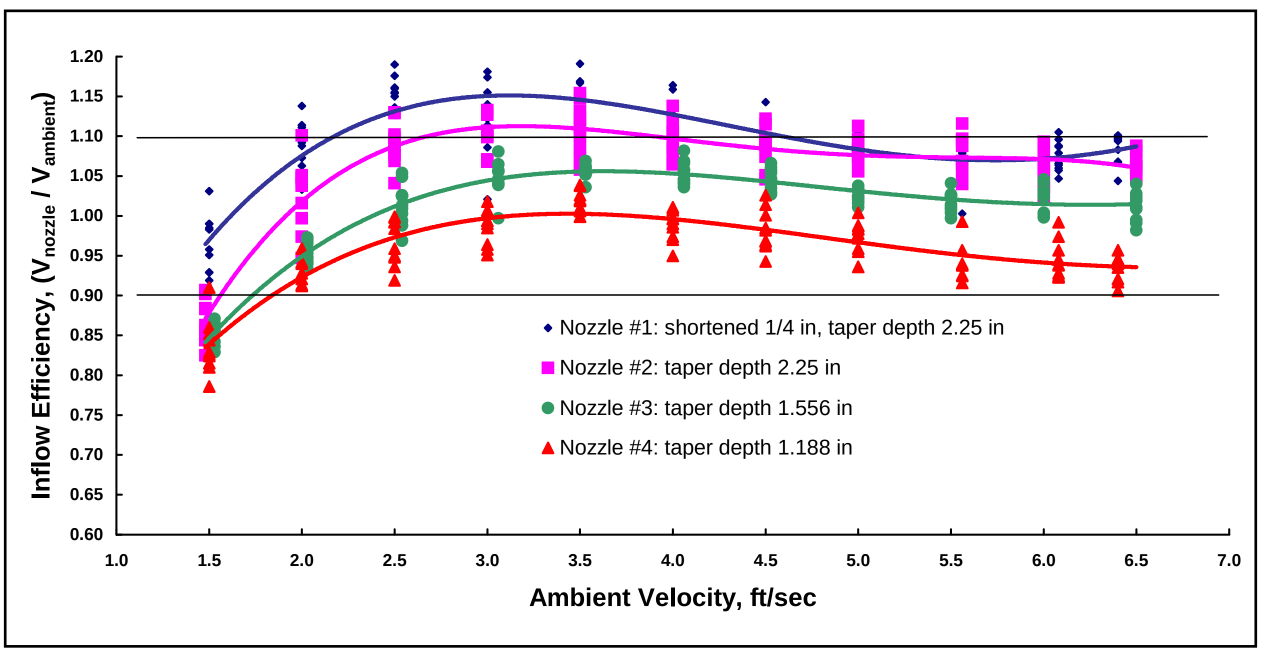


***Figure 4-- Effect of taper depth on inflow efficiency using 1/4-in internal diameter plastic nozzles***

acceptable inflow efficiency at approximately 1.6 ft/sec and maintained an efficiency of near 1.0 at the upper velocity range. The slopes of the curves shown in figure 4 indicate that an acceptable inflow efficiency would be obtained at velocities higher than tested. Because of the weight of the sampler, however, it was not practical to test higher velocities. Drift-angle tests subsequently conducted confirmed that 6 ft/sec is the recommended maximum velocity. It is also of interest to note that the taper depth affected the minimum velocity at which an acceptable inflow efficiency was obtained, with nozzle #1 reaching an inflow efficiency of 0.90 at approximately 1.0 ft/sec. The indication is that a nozzle could be designed for a specific low velocity application if such a need is identified. A specific low velocity application was not included in the investigation and no specific applications have been identified to date.

The optimum depth of taper for the remainder of the nozzles was determined by increasing the taper depth of the nozzle until a hydraulic efficiency of 1.0 was obtained at a flume flow velocity of 3.7 ft/sec. The optimum results are shown in figures 5-9. The 3/16-in internal diameter plastic nozzle had an acceptable inflow efficiency ranging from 1.75 to 6.5 ft/sec. The 5/16-in internal diameter plastic nozzle had an acceptable inflow efficiency ranging from 1.5 to 6.5 ft/sec. The 3/16-in internal diameter TFE nozzle had an acceptable inflow efficiency ranging from 2.25 to 6.5 ft/sec. The 1/4-internal diameter TFE nozzle had an acceptable inflow efficiency from 1.75 to 6.5 ft/sec. The 5/16-in internal diameter TFE nozzle had an acceptable inflow efficiency ranging from 1.6 to 6.5 ft/sec. Table 3 summarizes these results.

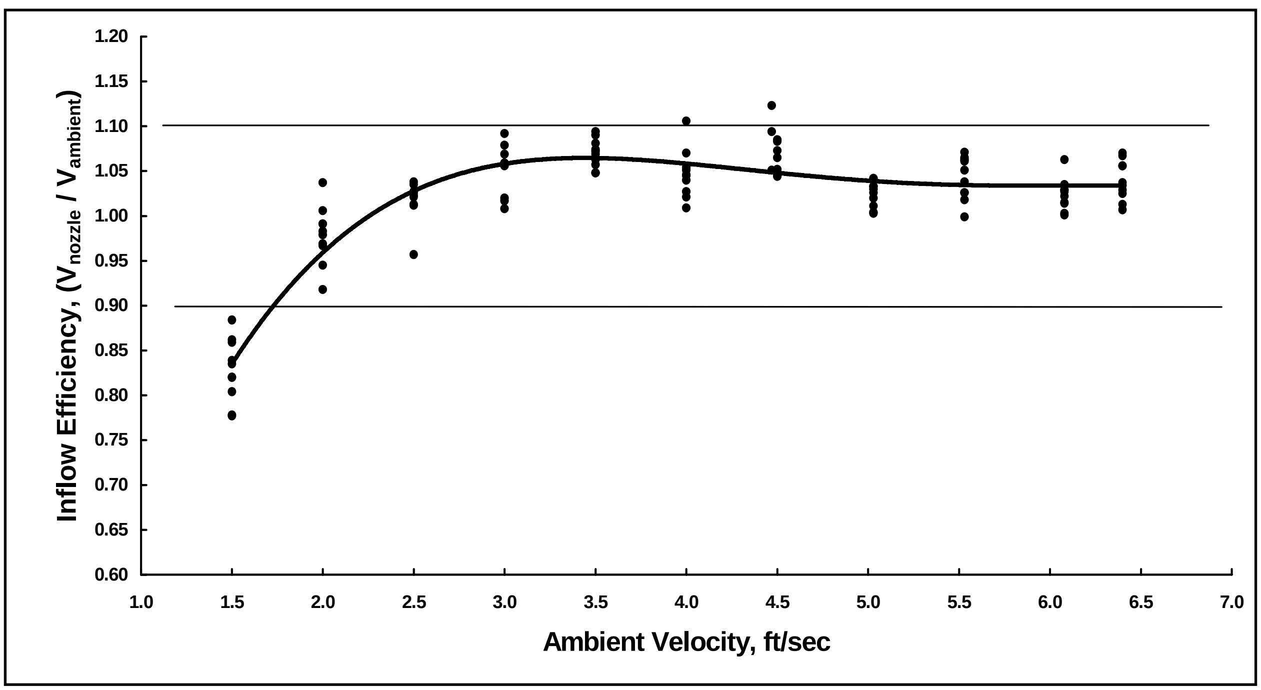


***Figure 5-- Inflow efficiency for the 3/16-in internal diameter plastic nozzle***

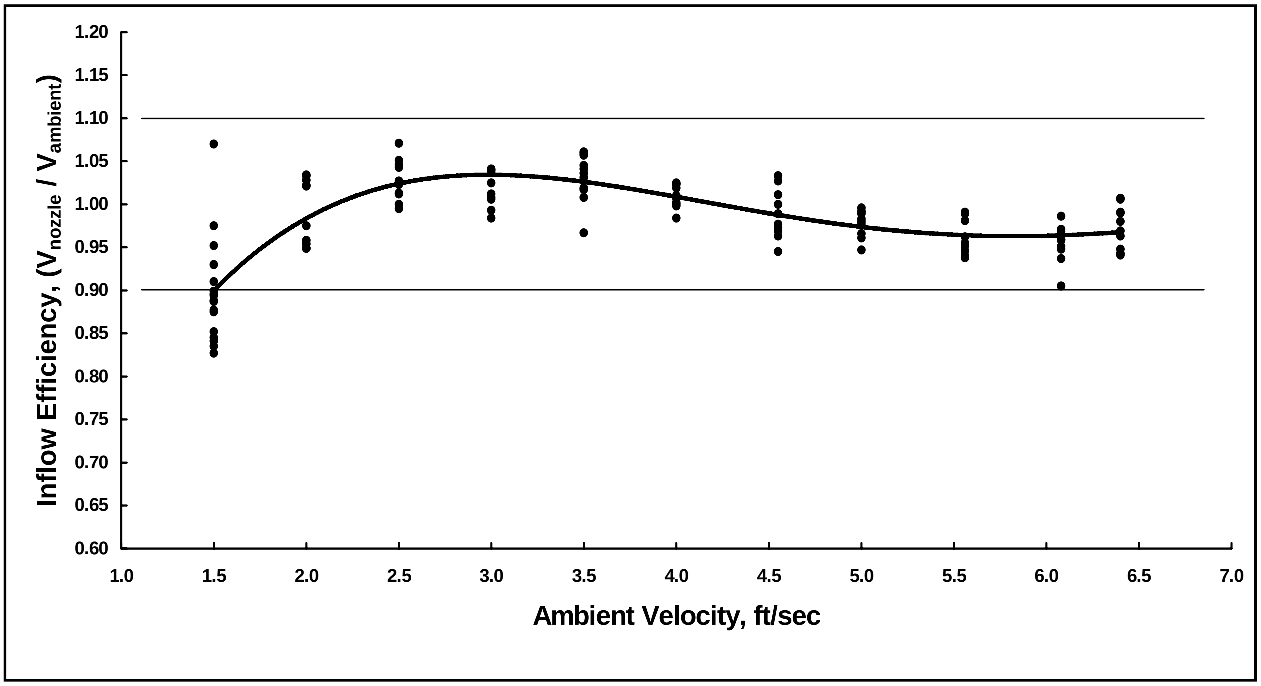


*Figure 6-- Inflow efficiency for the 5/16-in internal diameter plastic nozzle*

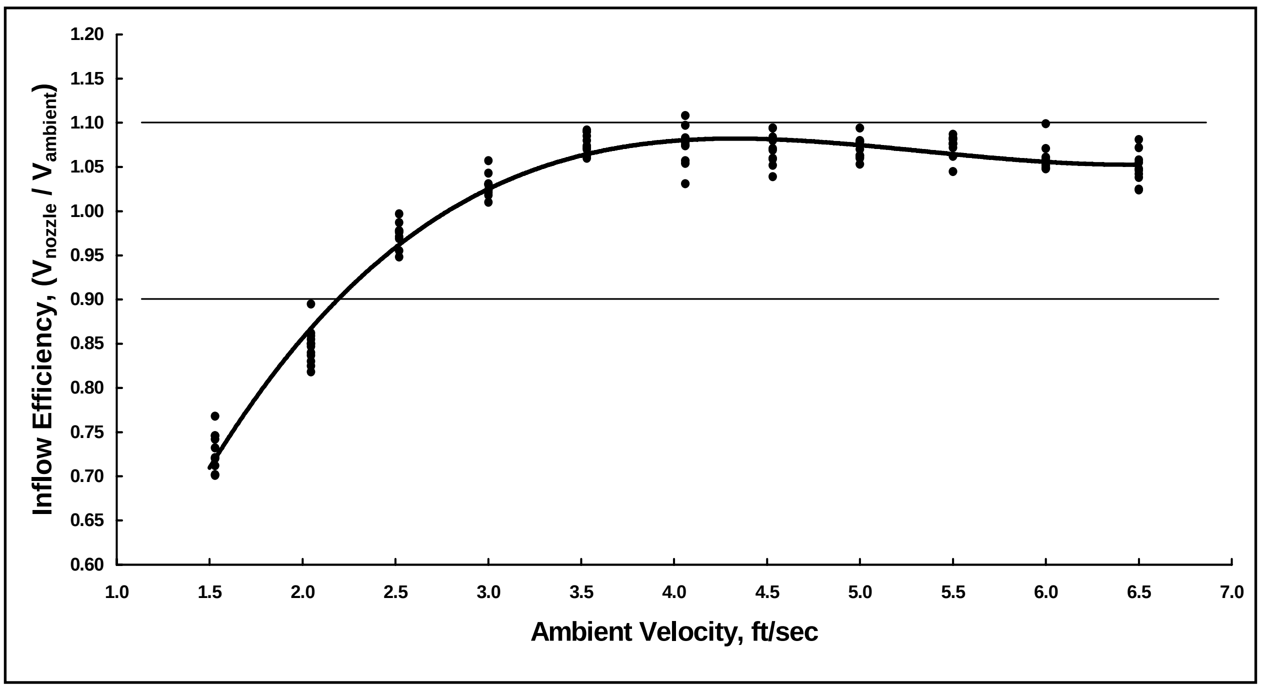


*Figure 7-- Inflow efficiency for the 3/16-in internal diameter TFE nozzle*

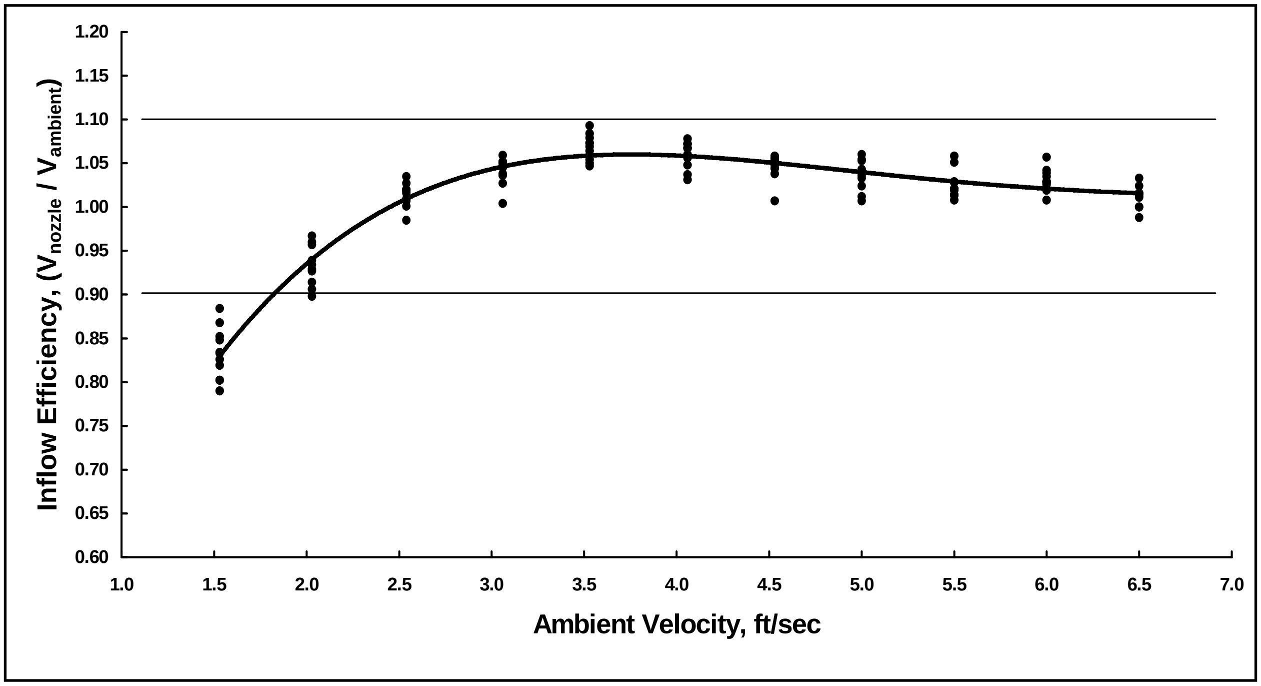


*Figure 8-- Inflow efficiency for the 1/4-in internal diameter TFE nozzle*

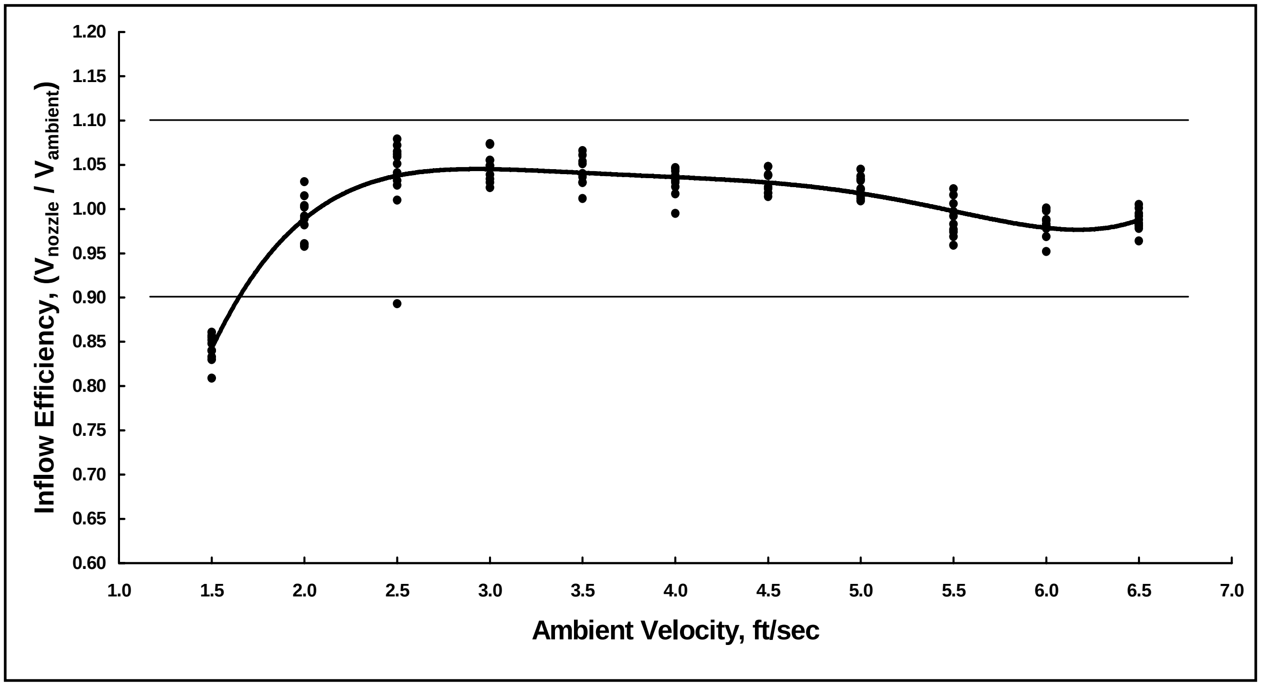


*Figure 9-- Inflow efficiency for the 5/16-in internal diameter TFE nozzle*

***Table 3--Summary of nozzle information***

| Nozzle | Taper depth, in | Useful velocity range, ft/sec |
|---|---|---|
| 3/16-in plastic | 2.250 | 1.75 to 6.50 |
| 1/4-in plastic | 1.556 | 1.60 to 6.50 |
| 5/16-in plastic | 0.875 | 1.50 to 6.50 |
| 3/16-in TFE | 1.920 | 2.25 to 6.50 |
| 1/4-in TFE | 1.670 | 1.75 to 6.50 |
| 5/16-in TFE | 0.937 | 1.60 to 6.50 |

## Transit Testing

As previously discussed, the theoretical depth limitation of a collapsible-bag sampler depends on the nozzle intake diameter and the volume of the bag. Based on a volume of 1 L and the maximum transit rate of 0.4 times the mean stream velocity, the 3/16-in internal diameter nozzle is capable of sampling to a depth of 35 ft, the 1/4-in internal diameter nozzle to a depth of 20 ft, and the 5/16-in internal diameter nozzle to a depth of 13 ft. A test scheme was devised to test the inflow efficiency of the US DH-2 with the three size nozzles while transiting to the operational depth of each nozzle. A crane system with an E-reel and an electronically controlled DC motor was used for the transit tests. The system was capable of precise control of the transit rate of the sampler.

Testing was conducted on a lake that could be characterized as a highland reservoir built for a city water supply. The flooded area of the reservoir had been cleared of trees, bridges, dwellings, and other structures before filling. The sampler could be lowered to depth while being towed without becoming entangled with any underwater obstacles. The test procedure was as follows:

- The boat velocity was set using the velocity reading from a current meter attached to a sounding weight.
- A transit rate of 0.4 times the boat velocity was calculated and set on the electronically controlled reel.
- The sampler was lowered to depth.
- At depth, the sampler transit immediately was reversed and the transit rate maintained.
- Approximately five observations were made at each velocity and depth.
- The velocity, volume of sample, and sample time were recorded and inflow efficiency calculated.

Transit tests were conducted with the set of plastic nozzles fabricated to the specifications determined from flume testing. The data were somewhat scattered as compared to flume test data. The scatter was attributed to the difficulty of precise boat velocity control, coordination of personnel operating the crane and timing the sample, and measuring the sample volume on a moving boat. Even with the data scatter, however, meaningful results were attained.

Figure 10 shows the results using a 3/16-in internal diameter plastic nozzle. The sampler was tested at tow velocities of approximately 2.5 to 6.25 ft/sec. The inflow efficiencies from the towed transit test were mostly in the acceptable range, but slightly higher in the 4 to 6 ft/sec range than flume tests result. Figure 11 shows similar results using the 1/4-in internal diameter plastic nozzle. Results for the 5/16-in internal diameter plastic nozzle are shown in figure 12. Although the data are more scattered than with the other nozzles, the inflow efficiency is mostly within the acceptable range, with a couple of outliers. Curves approximating the data are similar to the data curves for the flume test data. The conclusion of the transit tests is that the inflow efficiency of the sampler was not adversely affected by transiting.

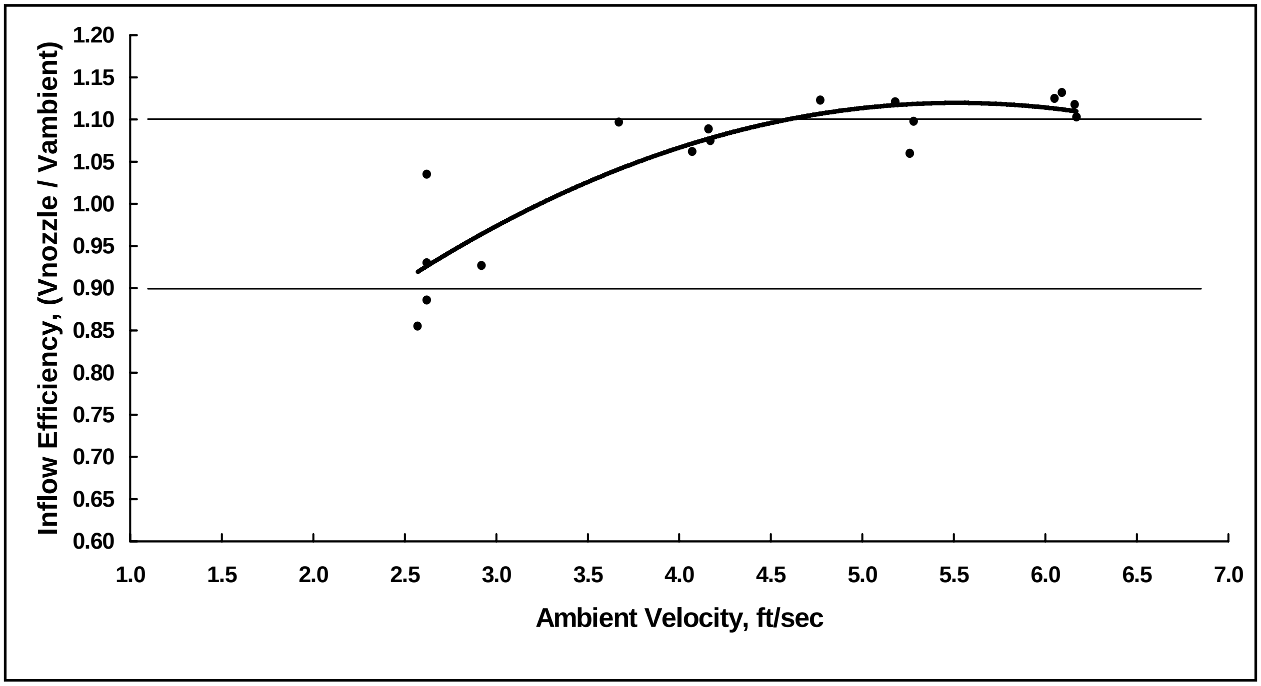


***Figure 10-- Inflow efficiency for transit test with the 3/16-in internal diameter nozzle***

Underwater Video

Concurrent with development testing, an underwater video system was used to observe and record the action of the sampler underwater while being towed by one of the FISP research boats. A small black-and-white underwater camera lens was mounted on a specially designed hanger bar and attached to a sounding weight. The lens was connected remotely by a co-axial cable to a video camera equipped with a digital screen for observation and recording. The sampler was suspended from one boat and the camera system from another boat. After various attempts and refinement of the technique, it was possible to position the sounding weight with camera lens so that the sampler was in the field of view. A streamer was attached to the hanger bar above the sampler so the horizontal attitude of the sampler could be recorded. The action of the sampler was recorded at velocities of 2 to 10 ft/sec at a depth of 10 ft. At depths greater than 10 ft and velocities higher than 10 ft/sec, it was impossible to keep the sampler in the field of view of the camera lens because of the drag on the camera cable. At all velocities observed

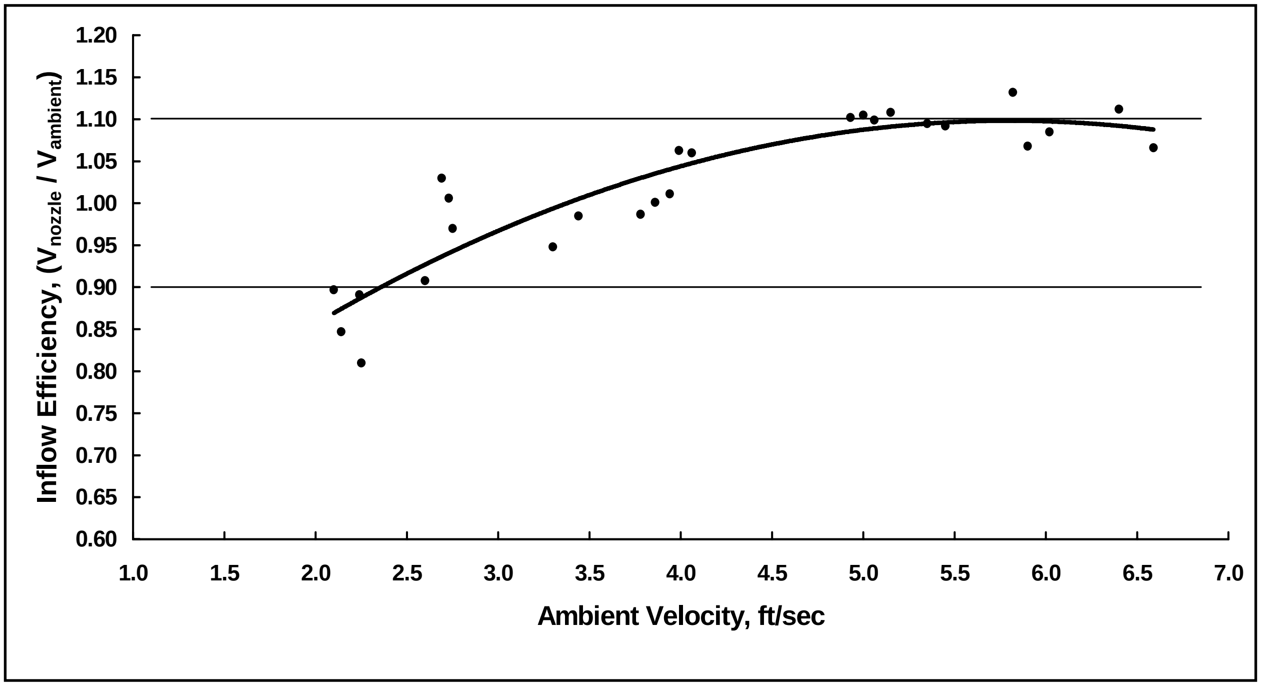


*Figure 11-- Inflow efficiency for transit test using 1/4-in internal diameter nozzle*

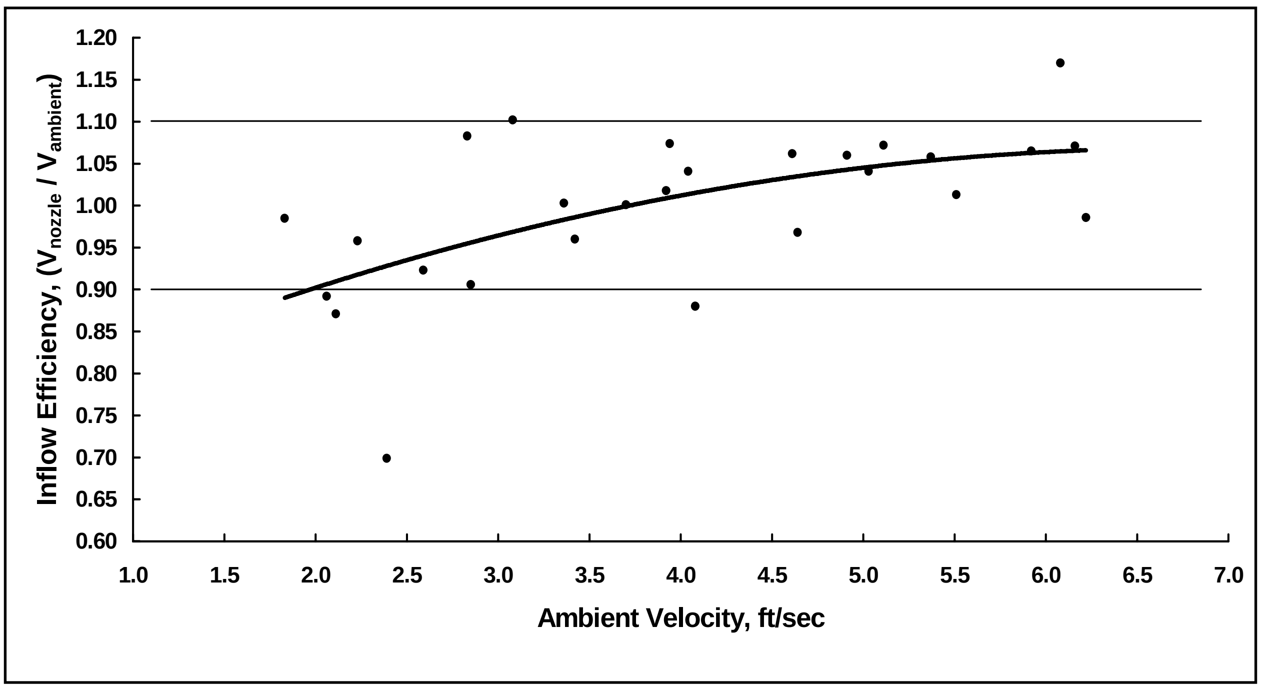


*Figure 12-- Inflow efficiency for transit test with the 5/16-in internal diameter nozzle*

and recorded, the sampler was very stable and remained horizontal throughout the velocity range.

Drift Angle Tests

The drift angle is the angle between the vertical and the suspension cable as the sampler drifts downstream as a result of the stream current. Information is available for determining the drift angle, true depth, and wet-line correction for sounding weights in Buchanan and Somers[10], Rantz and others,[11] and Coon and Futrell[12]. FISP conducted tests to determine the drift angle of the US DH-2 while being towed by a boat. The drift angle of a towed sampler is not exactly the same as that in a stream because of the velocity distribution in a stream vertical. When towed in a lake, the entire wetted cable and sampler are subjected to the same velocity force. In a stream vertical, the velocity force varies along the wetted cable based on the velocity distribution in the stream. The information derived from tow tests, however, should give the user a good indication of the expected drift angle. The crane on the FISP research boat was modified to accept a bridge crane protractor. The sampler was towed at velocities ranging from 2 to 7.6 ft/sec and cable lengths ranging from 5 to 40 ft, measured from the water surface. The measured drift angles for cable lengths of 5, 10, 15, 20, 30, and 40 ft at velocities from 2 to 7.6 ft/sec are shown in figure 13. Figure 14 shows how the drift angle varies with wetted cable length for constant velocities of approximately 2, 3, 4.3, 5.4, 6.3, and 7.6 ft/sec. The results presented in figures 13 and 14 should give the user a good indication of the drift angle for most field situations. Based on the results of the drift angle tests, the practical operating upper velocity limit is 6 ft/sec.

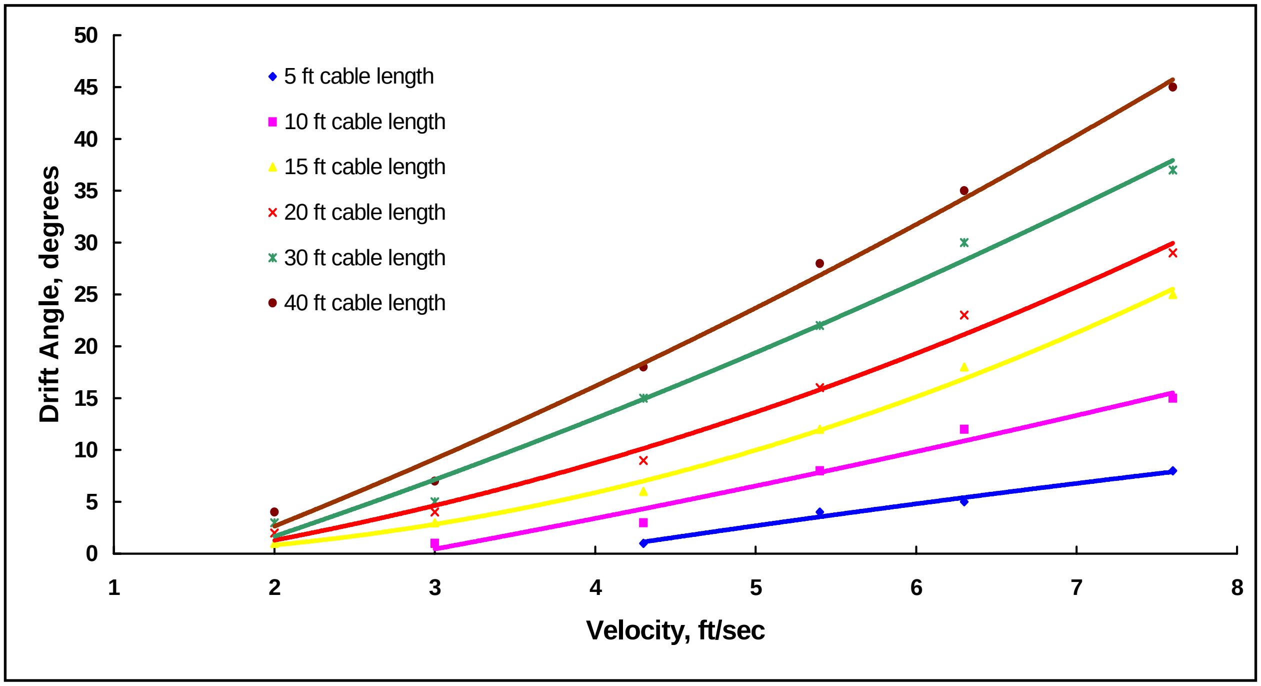


*Figure 13-- Drift angle for various wetted cable lengths*

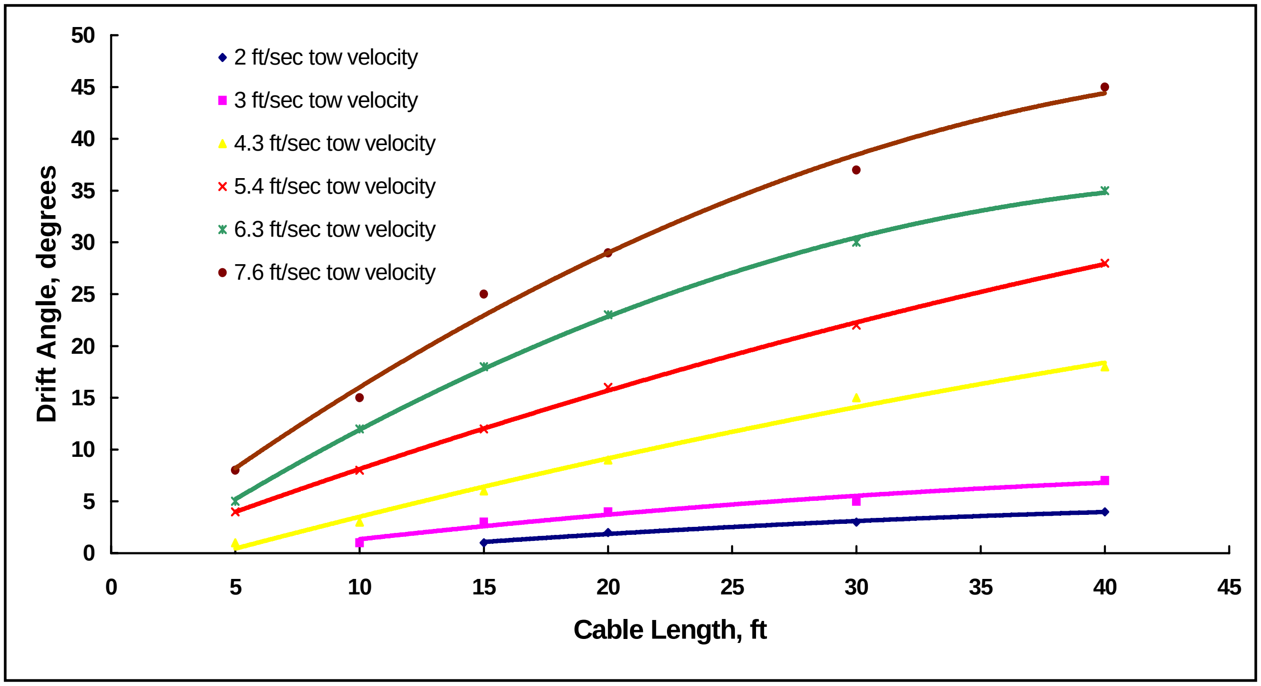


*Figure 14-- Drift angle for various constant velocities*

## OPERATING LIMITATIONS

### Depth

As previously discussed, the maximum theoretical depth at which the US DH-2 can be used is 35 ft with a 3/16-in internal diameter nozzle, 20 ft with a 1/4-in internal diameter nozzle, and 13 ft with a 5/16-in internal diameter nozzle. The maximum practical depth in field use depends on stream conditions. The maximum depth can be reached at low to medium velocities, but probably is not practical at high velocities because of the drift angle.

### Stream Velocity

The minimum stream velocity at which the US DH-2 sampler will collect an acceptable isokinetic water-sediment sample is 2 ft/sec. The sampler maintains an acceptable inflow efficiency at velocities up to 6.5 ft/sec, the highest tested. The actual upper velocity limitation in field practice, however, depends on stream conditions. For example, the sampler could be used in a shallow high-velocity stream but may not be practical at the same velocity in a deeper stream because of the severe drift angle. Based on drift angle tests, the FISP recommends an upper velocity limit of 6 ft/sec. Safety and the operating platform will determine the actual upper velocity limit for which the sampler should be deployed.

### Transit Rate

The US DH-2 is not subject to the same transit rate limitations as rigid-bottle samplers. The minimum transit rate is one at which the sample volume does not exceed 1 L. The sampling time to collect 1 L of sample for the three internal diameter nozzles at varying stream velocities is given in table 4. The minimum transit rate can be calculated using the sample time from the table and the total distance to be transited. For example, if the total sampling time is 30 seconds, then the minimum transit rate should be such that it takes 15 sec to descend from the surface to the bottom, and 15 sec to return to the surface. If the stream is 15 ft deep, then the total distance transited is 30 ft in 30 sec for a transit rate of 1 ft/sec.

The maximum transit rate is 0.4 times the mean stream velocity, which results from the apparent approach angle of the nozzle as the sampler moves vertically in the stream. The transit rate should never exceed 0.4 times the mean stream velocity.

### Unsampled Zone

The unsampled zone for the US DH-2 is 4 in. The unsampled zone is the distance between the centerline of the nozzle and the bottom of the sampler. Care should be taken if the sampler is allowed to touch the bottom of the stream so that unconsolidated material is not overly disturbed, possibly biasing the sample.

Additional information about how to properly use sediment samplers can be found in Edwards and Glysson's USGS TWRI, Book 3, Chapter C2[13].

## FIELD EVALUATION

FISP fabricated four US DH-2 samplers for field evaluation by four USGS State Water Science Centers. The purpose of the evaluation was to determine if there were any major problems in the design or use of the sampler. Operating instructions, a field data form, and an evaluation were sent with each sampler. The samplers were sent to offices in Alaska, Arizona, Arkansas, and Louisiana. Figure 15 shows the sampler being deployed on the Colorado River in the Grand Canyon. Feedback from users was positive and no problems were identified that would preclude the FISP from proceeding with production and recommended use of the US DH-2 sampler.

***Table 4--Time to collect a 1-liter sample,*** seconds

| Stream Velocity, ft/sec | Nozzle Dia., 3/16 in | Nozzle Dia., 1/4 in | Nozzle Dia., 5/16 in |
|---|---|---|---|
| 2.0 | 92 | 52 | 33 |
| 2.2 | 84 | 47 | 30 |
| 2.4 | 77 | 43 | 28 |
| 2.6 | 71 | 40 | 25 |
| 2.8 | 66 | 37 | 24 |
| 3.0 | 62 | 35 | 23 |
| 3.2 | 58 | 32 | 21 |
| 3.4 | 54 | 30 | 19 |
| 3.6 | 51 | 29 | 18 |
| 3.8 | 49 | 27 | 17 |
| 4.0 | 46 | 26 | 17 |
| 4.2 | 44 | 25 | 16 |
| 4.4 | 42 | 24 | 15 |
| 4.6 | 40 | 23 | 14 |
| 4.8 | 38 | 22 | 14 |
| 5.0 | 37 | 21 | 13 |
| 5.2 | 35 | 20 | 13 |
| 5.4 | 34 | 19 | 12 |
| 5.6 | 33 | 19 | 12 |
| 5.8 | 32 | 18 | 11 |
| 6.0 | 31 | 17 | 11 |

## CONCLUSIONS

Based on the success of the previously developed FISP collapsible-bag samplers, a need for a lightweight version was identified. A FISP concept has evolved through the design, fabrication, testing, and evaluation of a 30-lb, 1-L collapsible-bag sampler. The sampler is designated the US DH-2 and can be used in streams up to 35 ft deep and at stream velocities ranging from 2 to 6 ft/sec.

*Figure 15-- Deployment of the US DH-2 in the Colorado River*

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