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Design and Construction of a Low-Cost Stream-Monitoring Shelter

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Abstract

The design and construction of a low-cost stream-monitoring shelter are discussed. Currently in use on the Fernow Experimental Forest in West Virginia, the shelter creates an environment for efficient sampling and chemical monitoring of small streams while protecting expensive equipment from weather extremes and damage from wildlife and vandals. Data accuracy and completeness with this shelter have exceeded levels obtained with other types of shelter.

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Introduction

As the sciences of hydrology and watershed management have become more advanced, the use of more sophisticated equipment has increased. However, sophisticated equipment often is more sensitive to environmental conditions than older equipment and can be the target of theft or vandalism. Because of its sensitivity and high replacement costs, state-of-the-art equipment usually must be housed in some type of structure that controls or limits environmental extremes while keeping it secure from vandals and wildlife.

We have combined a low-cost shelter with a relatively simple streambed alteration design to create an economical stream-monitoring facility. The water-monitoring facility houses sophisticated and expensive equipment for sampling and chemical monitoring of small streams while maintaining a relatively natural yet controlled stream environment from which these activities are accomplished. Streamflow is not monitored in the shelter; rather, it is monitored using a weir and weir house located just downstream from the shelter.

Although this paper emphasizes the design and installation of the shelter, details on the equipment housed in the structure are provided to explain how the installation was tailored to meet our equipment and sampling needs.

Methods

One of these shelters has been installed on each of two watersheds on the Fernow Experimental Forest near Parsons, West Virginia. A third has been installed on a stream approximately 15 miles northwest of Parsons. These are small headwater streams, with drainage areas ranging from 29 to 96 acres. Watershed characteristics are summarized in Table 1. The monitoring facilities were installed at the outlet of each watershed, just upstream from the weir, near points used during the past 20 years for sampling stream chemistry.

The equipment in each shelter consists of two ISCO[1] automatic pumping samplers (ISCO, Inc., Lincoln, NE), an electrochemical continuous monitoring instrument called a MiniMonitor (U.S. Geological Survey, NSTL, MS), an Omnidata data logger (Omnidata International, Logan, UT), and two 12-volt marine batteries (AC power is not available at these sites).

[1]The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any other product or service to the exclusion of others that may be suitable.

Table 1.—Characteristics for three streams on which water-monitoring facilities are located

Watershed[a]	Maximum measured flow[b]	Mean annual measured flow	Watershed area
	------ ft^3/s ------		*Acres*
3	25.62	0.26	85
4	25.52	0.27	96
9	9.56	0.06	29

[a]Watersheds 3 and 4 are on the Fernow Experimental Forest; Watershed 9 is northwest of Parsons, West Virginia.

[b]Measured during a 37-year period (1951–87) for Watersheds 3 and 4, and a 21-year period (1958–70 and 1981–87) for Watershed 9.

The ISCO sampler is a portable device that collects up to 28 discrete sequential samples from a liquid source. It pumps stream water up through tubing at predetermined times or flow changes into sample bottles contained within its base. These samples are returned to the laboratory for analyses. The MiniMonitor continuously measures *in situ* stream pH, conductivity, and temperature. Probes for each of these measurements are connected to the MiniMonitor by 150-foot-long cables. Each MiniMonitor can accommodate two pH probes, one conductivity probe, and one temperature probe. The MiniMonitor is interfaced electronically with the data logger so that digital readings from the MiniMonitor are recorded on the logger's data storage pack. One of the 12-volt batteries powers the ISCO sampler; the other powers the MiniMonitor and supplements the internal D-cell batteries in the data logger.

Our reasons for designing the Fernow water-monitoring facility were to provide a weather- and freeze-proof environment for our instruments without subsequently altering stream-water chemistry. The shelter had to be large enough to house all of the equipment described earlier and to provide sufficient space for maintenance, calibration, etc. Because the shelter had to be located in such a way that the MiniMonitor probes and ISCO tubing had easy access to the stream, it was necessary to create a stable pool that was large and deep enough in which to suspend the probes, even during low flows. Water velocity had to be minimized to reduce turbulence (causing streaming-potential pH errors) around the probes and to allow the probes to be stabilized in the pool. The pH probes also had to be protected from breakage caused by stones and debris transported during large storm events. Finally, the ISCO tubing had to be as vertical as possible to minimize freezing of the tube during the winter and sample cross-contamination during sampling periods.

To meet these requirements, we needed a medium-size structure that could be positioned directly over the streambed. We purchased a custom-built 8- by 10-foot barn-shaped utility building to use as the shelter. We had the building constructed on three 10-foot by 4-inch by 4-inch pressure-treated (0.40 retention) skids so that it could be transported to the site on a tilt-bed truck and readily moved into place. It was constructed with a gambrel roof to provide maximum head room. Pressure treated 2 by 6's (0.40 retention) spaced on 16-inch centers were used for floor joists, and pressure-treated 3/4-inch plywood was used for the floor. The roof and walls were insulated with 4-inch-thick fiberglass battens. The interior then was sheathed with 1/4-inch exterior AC plywood. A 36-inch insulated metal door was installed in one end of the building and a 24- by 36-inch double-paned screened window was installed in the wall opposite the door. An 8- by 16-inch screened vent was installed adjacent to the door to provide ventilation. The exterior of the building was sheathed with T1-11 plywood. Later, 29-inch-deep shelves were built along two of the walls to hold equipment.

The buildings were not placed directly over the streams until initial excavation work was done. The area of streambed over which each shelter was to be located was leveled and excavated to a solid base with a bulldozer. In addition, an 8- by 10-foot section was excavated about 16 inches deeper than the streambed. In this deeper portion, a 6-inch rigid plastic overflow pipe was positioned parallel to the original stream, and four rows of dry wall concrete blocks[2] were laid up to the level where the streambed was located initially (Fig. 1). After fill was placed around this block enclosure, a 2-foot high-density polyethylene culvert was centered on the block enclosure. The block walls were extended one block higher than the culvert, and a headwall around the upstream end of the culvert was constructed with native stone removed from the streambed during excavation (Fig. 2). The area around the block enclosure and culvert was backfilled with material that had been removed originally. After backfilling was completed, an emergency spillway to divert large peak flows around the shelter was constructed (Fig. 3). In the central Appalachians, the 2-foot culverts (15 ft^3/s capacity) used in these installations will carry drainage only from 50-acre and smaller watersheds at a peak-flow recurrence interval of 20 years (Helvey and Kochenderfer 1988). The spillway is designed to carry these rare peak flows that would exceed the culvert's capacity. To minimize erosion, the spillway was lined with rocks and seeded to grass.

Holes then were drilled into the sides and bottom of the culvert so that a portion of the stream water that flowed into the culvert was diverted into a high-density polyethylene tub (Fig. 4). The interior of the 4- by 6-foot block enclosure is shown in Figure 5.

The 4- by 2- by 1-foot polyethylene tub was inserted under the culvert so that half of the pan was under the culvert and the other half extended out to the side of the culvert. The tub was positioned so that there was a space between the

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[2]Tongue and grooved solid-concrete blocks 16 by 10 by 4 inches, each weighing approximately 46 pounds and designed to be used without mortar.

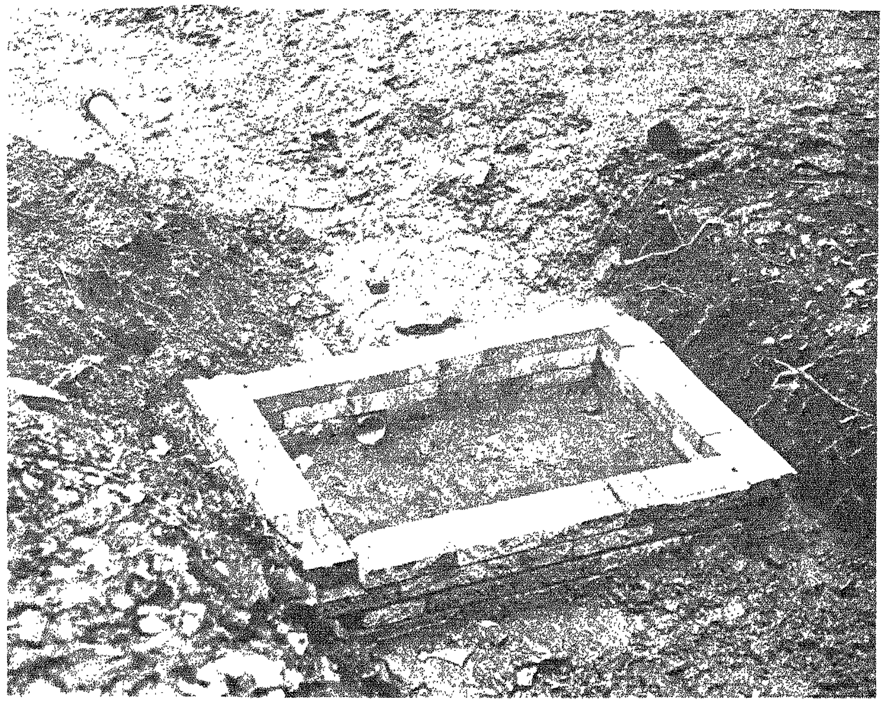


Figure 1.—First phase of construction shows block enclosure centered in 30-foot segment of stream channel excavated to a solid base. A plastic overflow pipe is then laid in the channel. A plastic culvert is laid on the four-block-high wall to provide sufficient room to insert a polyethylene tub under the culvert.

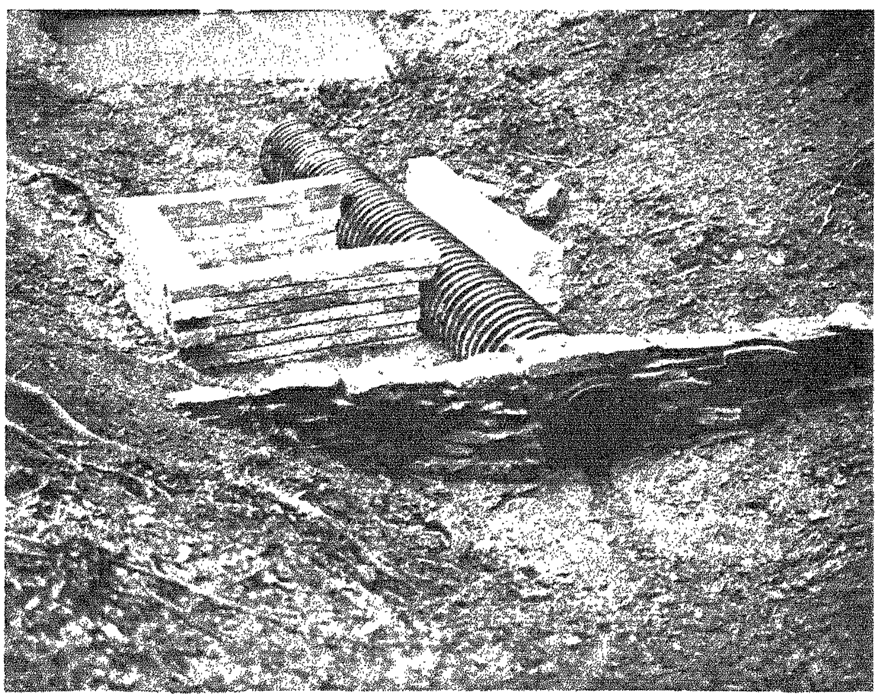


Figure 2.—Fill material is placed around the blocks and the culvert is laid on the enclosure. The culvert is positioned so that it is centered lengthwise on the upstream block wall and there is enough space to construct a block wall behind it. To avoid changes in stream chemistry, the headwall at the inlet end of the culvert (foreground) is constructed of native stone removed during excavation.

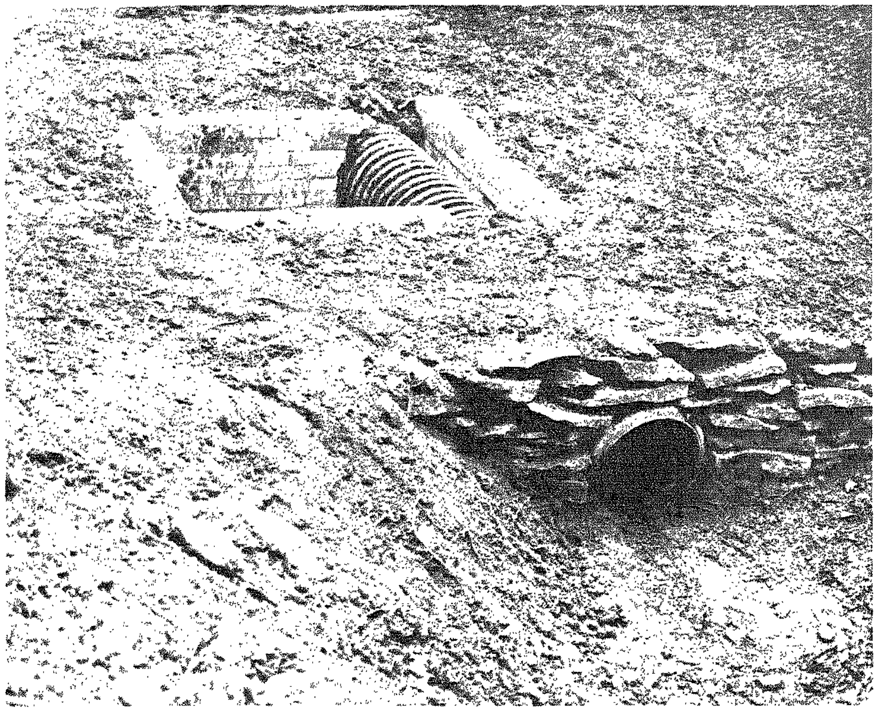


Figure 3.—Installation backfilled with material removed during excavation. An emergency spillway designed to divert occasional peak flows that exceed the culvert's carrying capacity was constructed around the block enclosure during backfilling.

tub and the block walls to prevent possible contamination. The upstream side of the pan was elevated so that overflow spills out from the downstream side and into the overflow pipe located at the bottom of the excavated hole. "Old" water is replaced completely by new within an average of 10 minutes. Turnover time decreases with increasing flow rates.

The shelter then was centered and leveled over the block enclosure with the downstream skid on top of the downstream row of blocks. A 30- by 30-inch wooden trap door was constructed in the shelter's wooden floor (Fig. 6). It was located above the portion of the pan which extends from the culvert and is large enough to allow the pan to be removed for maintenance or cleaning. It also provides access to the holes in the culvert that are reamed twice each week with a fiberglass rod to prevent plugging.

The monitoring and sampling equipment then was placed on the shelves (Fig. 7). The pan below the culvert was designed to dampen the stream water's current for efficient monitoring and automatic sampling. Consequently, the cables and tubing were routed to the trap door under the floor of the shelter via small holes cut into the shelf and floor directly beside and below the equipment. The ISCO uptake lines were cut to the required length necessary for sampling. However, the probe cables were much longer than necessary, so electrical clamps were nailed to the supporting boards at the perimeter of the trap door. The cables were suspended at the correct heights in the pan and clamped in place (Fig. 8).

A completed water-monitoring facility used on the Fernow is shown in Figure 9. Figure 10 is a schematic of the system. For the sake of space and clarity, only one ISCO sampler is shown. The cost of such a water-monitoring facility exclusive of costs for instrumentation and propane gas is approximately $3,600. The cost breakdown is as follows:

Item	**Cost** (Dollars)
Building	1,500
Excavation (450 JD Dozer $30/hr)	300
Plastic pan and drainage pipe	400
Plastic culvert	300
Concrete blocks	300
Labor ($8/hr)	800

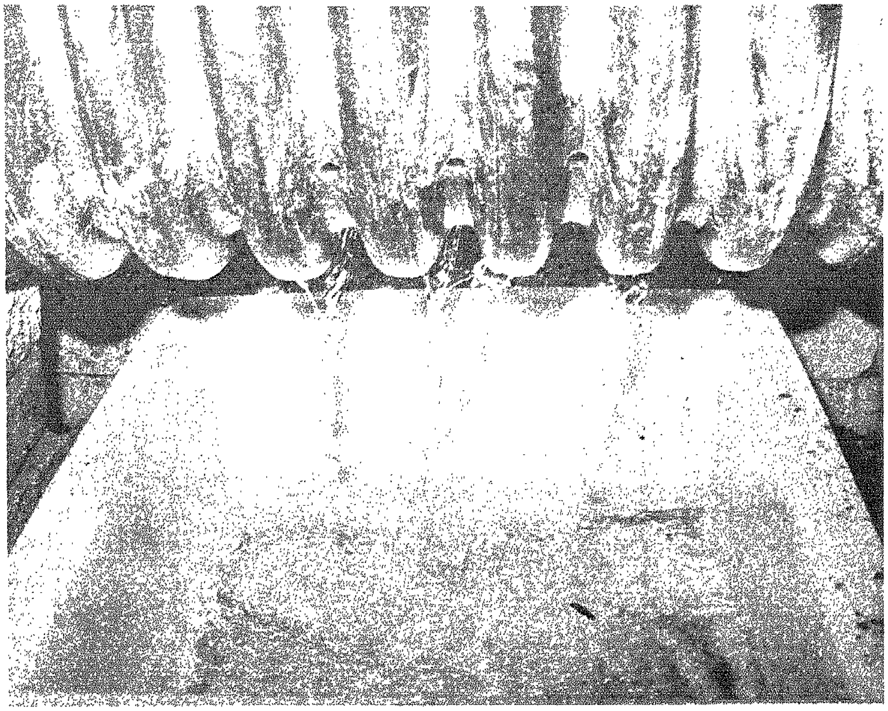


Figure 4.—Five 3/4-inch holes are drilled in the bottom of the culvert to divert water to the tub. Holes are drilled at the top of the corregations to minimize plugging. Additional holes are drilled higher on the sides of the culvert to divert stormflow should the lower holes become plugged.

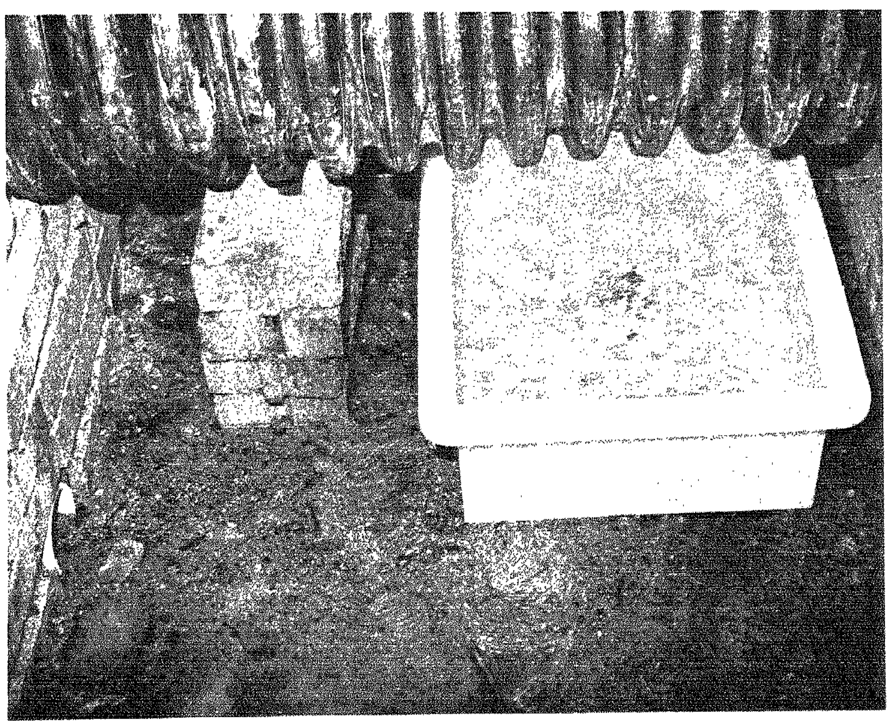


Figure 5.—Interior of block enclosure showing the placement of the culvert, tub, and overflow pipe.

Results and Discussion

The overall design worked well during the more temperate periods of the year. However, winter temperatures presented some problems for which design alterations were made.

Battery drainage accelerated in cold temperatures, which proved to be a problem for the MiniMonitor and data logger since they operated continuously. To compensate for the drainage, a solar panel (Solec International, Inc., Hawthorne, CA) with a voltage regulator that controls output to 12 volts (70 watts) was mounted on the roof of the shelter and connected to the MiniMonitor's 12-volt battery. The solar panel maintains battery voltage at a satisfactory level throughout the year. Removing snow from the solar panel with a long-handled wooden scraper is the only maintenance required.

The cold temperatures also caused the data logger to operate sluggishly, so a small propane light (Humphrey Products, Kalamazoo, MI) was mounted on one of the walls in each shelter. The lights produce 1,800 Btu per hour and have an illuminating capacity comparable to that of a 50-watt light bulb. The use of two 100-lb tanks connected with automatic pressure regulators that indicate when a tank is empty ensured that the lights burned continuously. The propane fuel tanks were positioned outside of the shelter, directly behind the wall holding the light. The fuel line was run through the wall.

The light burning continuously from October to April provides sufficient heat to maintain temperatures suitable for efficient data logging. It also provides needed illumination during short winter days. Approximately five 100-lb tanks of propane are required to operate each light for this period. Gas fumes do not pose a problem so long as the vent is kept open and the door is opened for a few minutes one or two days a week. Results from the air temperature probe in each shelter have shown that the internal shelter temperatures have not dropped below 36°F, even when minimum outside temperatures ranged between -8° and 0°F for 3 consecutive days.

The warmer, more humid air created in the shelter results in condensation on the shelter's ceiling and walls, so the vent in the shelter wall must be kept open during this period, though it generally is open all year. From October to April, the trap door also is kept open to allow the heated air to circulate down to the pan. Consequently, the water in the pan does not freeze and damage the pH probes. Additional protection during severe cold weather can be obtained by installing temporary covers over the culvert ends to prevent a draft through the culvert, and by installing another light in the shelter's cellar.

The trap door is closed from April to October to minimize the amount of light and warm air that reaches the water in the pan. Algal growth on the probes, which can affect the accuracy of the measurements, can be substantial during periods of low summer flows. Minimizing the light and temperature reaching the water retards the biological activity on the probes and in the pan. Algal growth has not been a major problem during periods with moderate flows, even during warm periods, but during drought periods when streamflow virtually stopped, algal growth has been substantial. However, we believe this problem would exist to some extent even without the controlled flows in the pan.

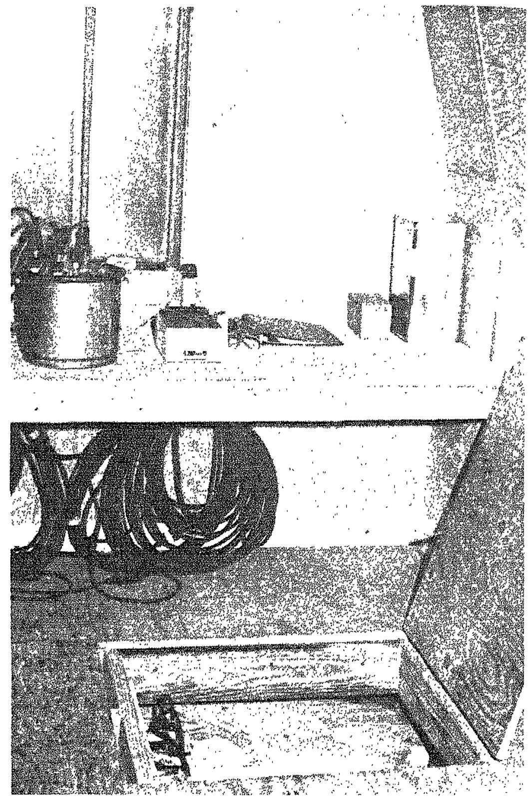
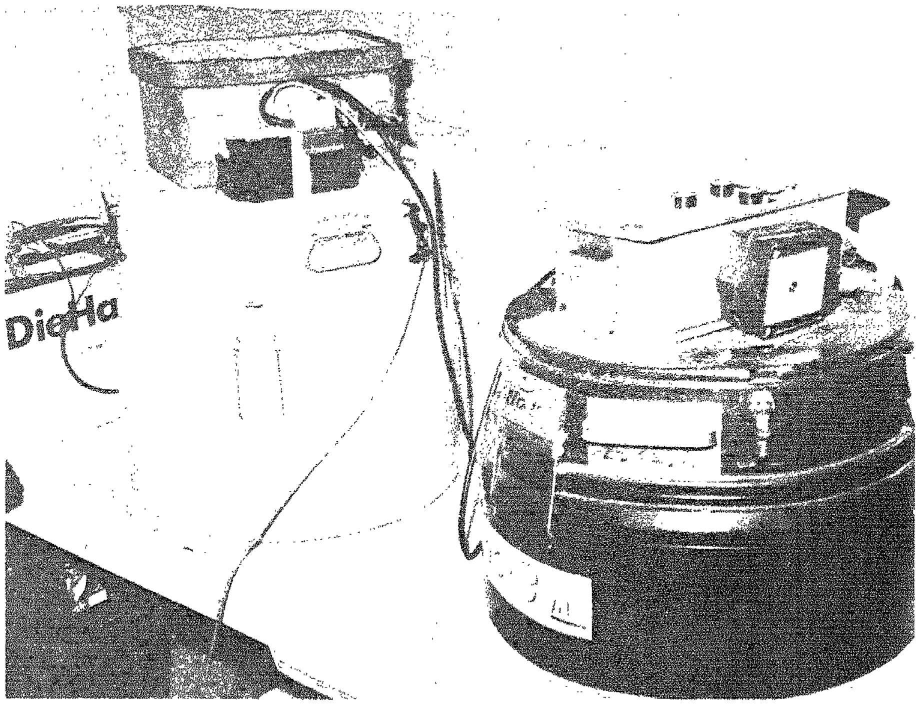


Figure 6.—Interior of a water-monitoring shelter showing the rear window, instrument bench, propane light, and trap door that provides access to the shelter's cellar.

Because stream-water chemistry could have been altered as a result of the excavation and installation of the culvert, the chemistry of water entering the culvert was compared to that exiting the culvert. Eleven months of testing showed that the culvert and excavation have had no effect on pH of stream water or on specific conductivity, which is a measure of total dissolved solids. Concentrations of suspended solids may have changed; however, turbidity was not measured so no conclusions concerning suspended sediment can be made.

The only changes we plan to make in future monitoring facilities are to make the cellars one block longer to facilitate pan removal, and to use solid-wood German siding



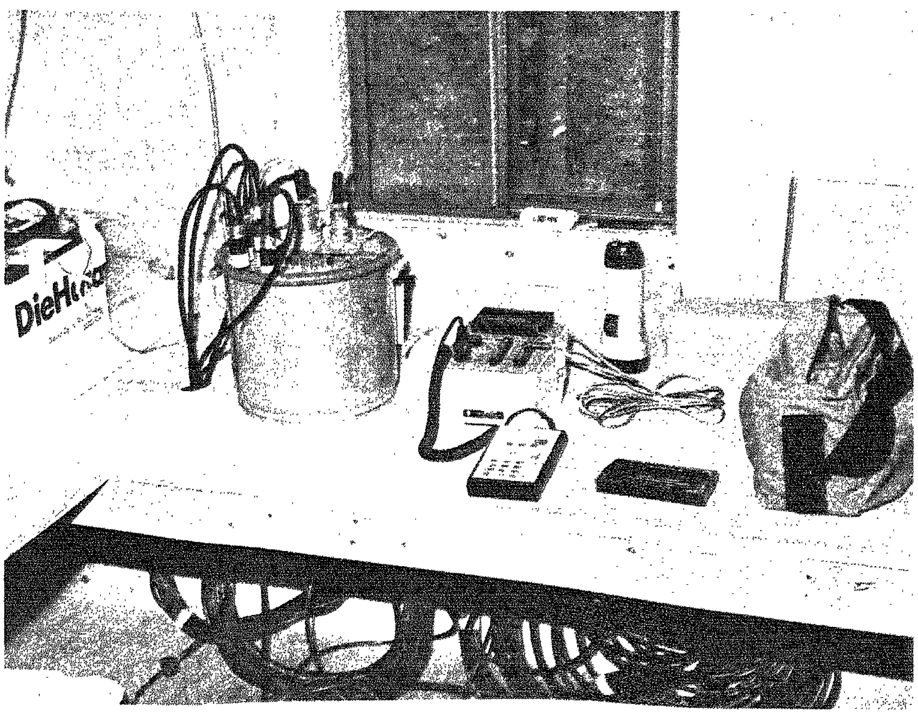


Figure 7.—Atop the instrument bench are two ISCO water samplers (top) and a MiniMonitor and Omnidata Easy Logger (bottom).

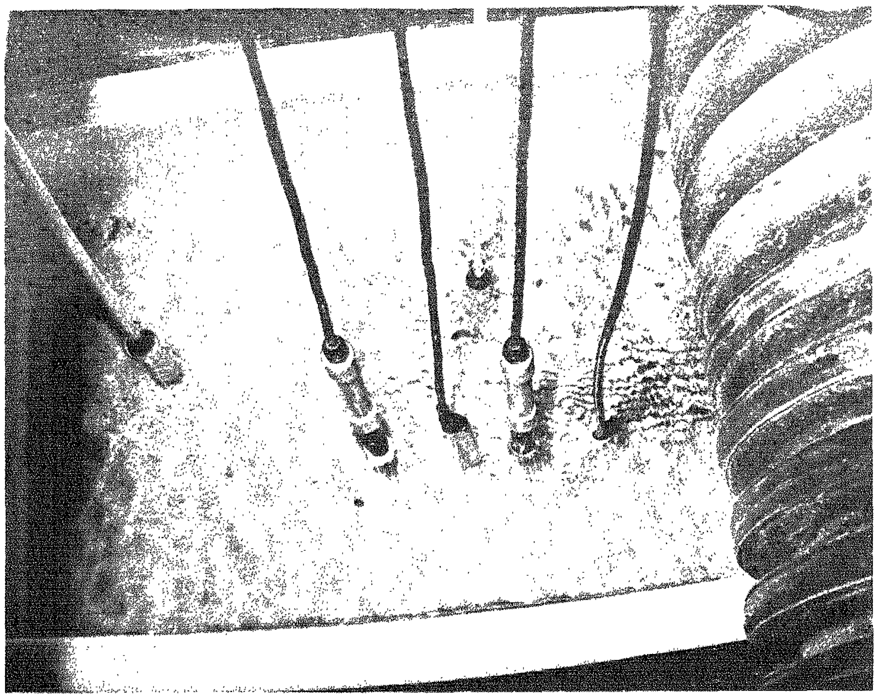


Figure 8.—Probes and ISCO suction lines are suspended in the tub.

on the exterior of the buildings. Plywood products seem to promote chewing damage from squirrels, porcupines, and groundhogs, whereas sawn lumber does not. We experienced substantial chewing damage on the T1-11 siding, forcing us later to cover the lower half of the shelters with metal sheeting (Fig. 9).

We believe that these installations have created an environment in which much more representative samples and accurate results are obtained than would have been possible otherwise. And we have encountered few problems even during extremely cold weather. In addition, calibrations and quality control checks are performed easily, and with minimal contamination. Data completeness for the MiniMonitors has exceeded 83 percent for all three sites, and the ISCO sampler uptake lines have not frozen.

The $3,600 cost for each water-monitoring facility is essentially a one-time expense for a structure that can be used for many years. The cost of the monitoring, logging, and sampling equipment at each site is approximately $20,000. We believe the initial construction costs are more than justified in that this sophisticated equipment is protected from environmental extremes and damage from wildlife and vandals.

Conclusion

While the overall system described here will accommodate only small streams, the design can be modified to operate on larger streams by diverting a portion of the stream water to the sampling or measuring point. However, for the purposes for which these installations were designed, we have found them superior to other low-cost shelters we have used. Equipment operation and data completeness and accuracy are better than we have experienced in the past, and we believe these results are due to the more tolerable environment created by the shelter. Not only do the instruments operate better, but the people performing routine checks, calibrations, and maintenance on the equipment operate more efficiently and accurately because they are not exposed to the elements.

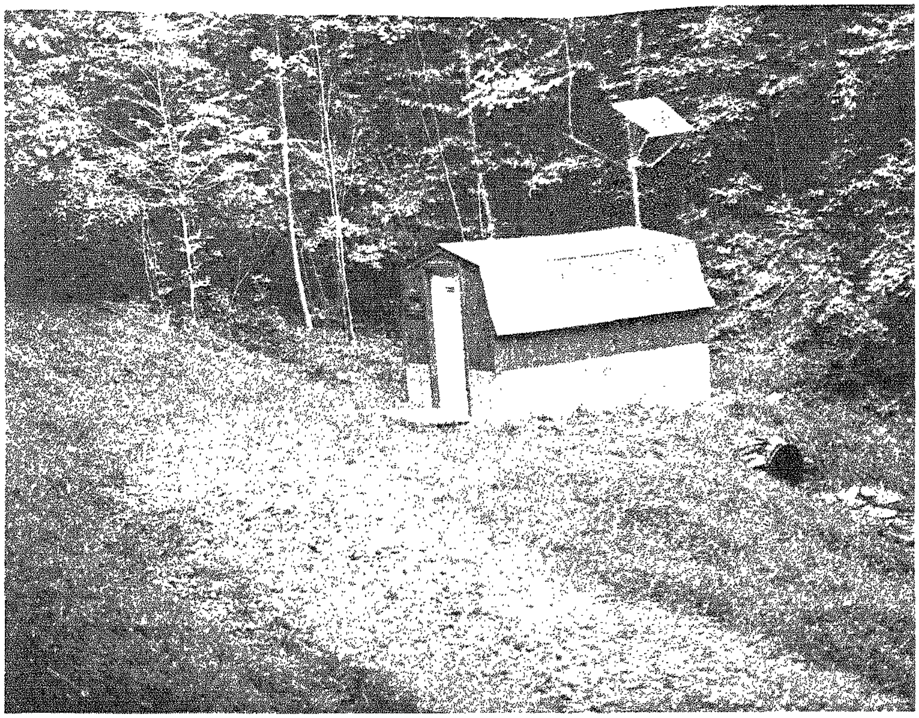


Figure 9.—A completed water-monitoring shelter in use on the Fernow Experimental Forest. The rock-lined emergency spillway is at the rear of the shelter.

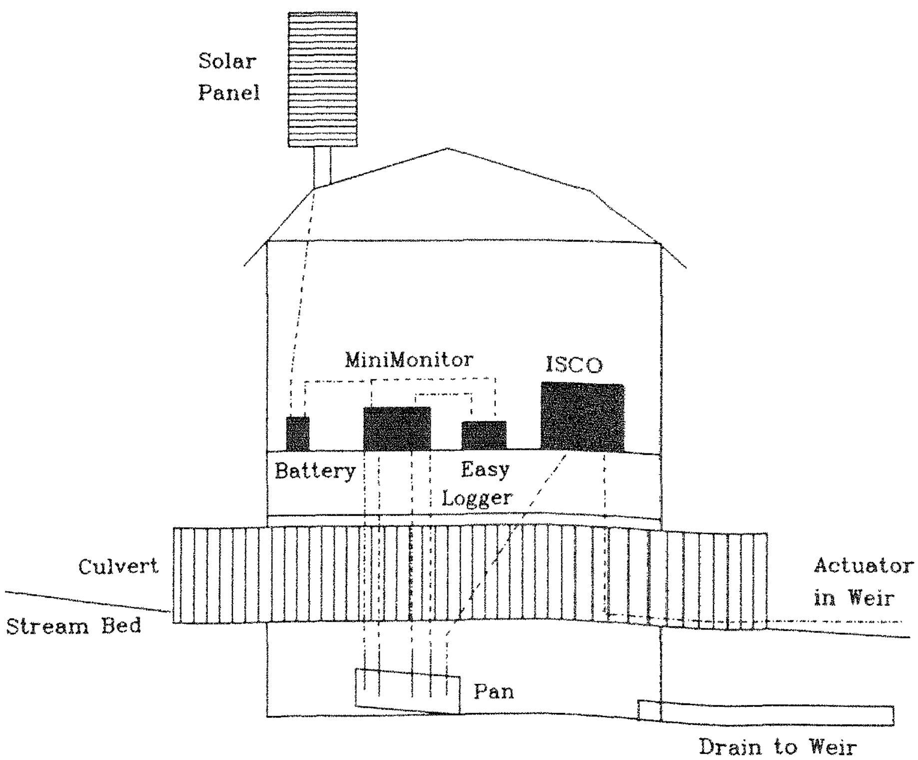


Figure 10.—Schematic of water-monitoring shelter designed for use on the Fernow Experimental Forest.

Acknowledgment

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