Teacher's Notebook

Suggestions for Low-Cost Equipment for Physical Geography II: Field Equipment

Patrick Pease, Scott Lecce, Paul Gares, and Mark Lange

ABSTRACT

Fieldwork and laboratory experiences have always been important components of physical geography education, at universities as well as secondary schools. However, the rising cost of necessary equipment and dwindling education budgets of most universities and secondary schools have placed such experiences in crisis. This is the second of two papers that present lab- and field-based items we have designed and built for student research. The equipment is easy to construct and made from low-cost materials like PVC plumbing pipe. Photographs, construction notes, and costs have been included for each of the pieces of equipment, as well as measured schematics for the more complex items.

Key Words: low-cost equipment, field equipment, lab equipment, student research

Patrick Pease is an assistant professor at East Carolina University. He is a geomorphologist with research interests in aeolian transport of sediment, mineral dust, the use of geochemical data to identify sediment sources and transport histories in geomorphic environments.

Scott Lecce is an assistant professor at East Carolina University. He is a fluvial geomorphologist with research interests in hydrological processes, transport and storage of heavy metals in fluvial environments, and flood hydrology and geomorphology.

Paul Gares is an associate professor at East Carolina University. He is a coastal geomorphologist with research interests in coastal dunes, beach processes, and environmental management.

Mark Lange is a doctoral student at University of Southern California. He is a coastal geomorphologist interested in microtidal estuarine beaches and high energy beach morphology.

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INTRODUCTION

Fieldwork and laboratory exercises have always been important components of an education in physical geography, and most instructors believe that at least some of the learning must take place with the environments that are to be studied. At many universities, colleges and high schools, however, growing class sizes and decreasing funds have made it difficult for teachers to maintain field experiences as part of their curriculum (Clark 1996; Fuller et al. 2000; Higgitt 1996; Jenkins 1994; Kempa and Orion 1996; Kent and Gilbertson 1997; Nairn et al. 2000; Tinsley 1996), and those pressures are likely to continue. One of the major problems is the growing cost of scientific equipment (Sane 1999), which makes it difficult for instructors to obtain the proper tools needed for meaningful experiences. In the first part of this paper (Pease et al. 2002) we discussed some of the pros and cons of constructing your own equipment, and gave examples of laboratory equipment that we have built and used. In this paper we continue the theme of low-cost, self-built equipment (cf. Jernigan and Murray1974; Wikle and Lightfoot 1997) and present six more examples of equipment that we have designed, this time for field-based teaching. As with the part I of this paper (Pease et al. 2002), we focus heavily on the use of PVC plumbing pipe as a construction material. Although not all of the pieces described in this paper are made of PVC pipe, we have an affinity toward it because of its low cost, durability, and ease of use (Pease et al. 2002). Construction information and photographs for each item are given, and measured schematics are included for some of the pieces.

FIELD EQUIPMENT FOR DATA GATHERING

Stilling Well for Pressure Transducers

The stilling wells are simple designs born out of simple needs. We use portable pressure transducers with built in data loggers (Water Level Loggers, produced by Global Water Instrumentation, Inc.) to obtain data for a variety of physical parameters, including stream stage level, water table height, and tide depth. To obtain the best results from the transducers for these purposes, they must be held at a constant level, submerged in calm water, and protected from debris and sediment accumulation. Construction of PVC stilling wells solves these problems. Examples of wells for tidal and fluvial applications are shown in Figure 1.

The well shown in Figure 1a is designed for monitoring tide heights and is made of 2-inch PVC about 9 feet long. A T-junction is placed on the end of the pipe, and the ends of the T are capped with PVC caps into which 1/2-inch diameter holes are drilled. The holes in the T are lined on the inside with a screen mesh to keep out sand. The T end is buried 6 feet into the beach as close to the low tide line as possible. The pressure transducer is lowered to the bottom of the well. As water level inside the pipe fluctuates in height with the tide, the transducer records the changing level. The data logger fits inside the top of the pipe and hangs from an end cap that was placed over the pipe.

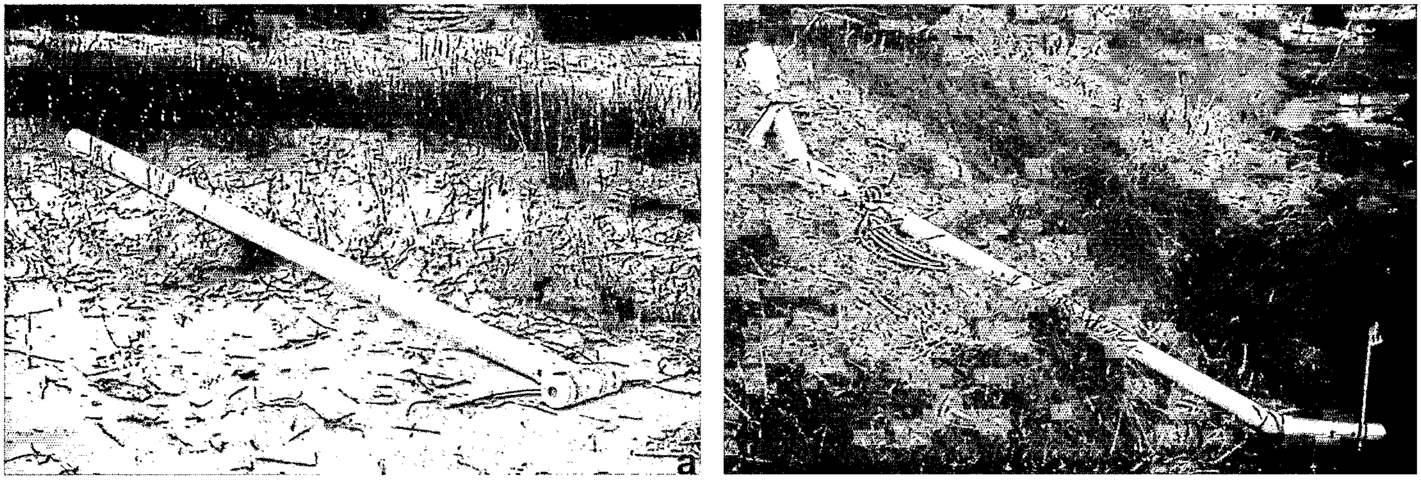

Figure 1. *Two configurations of stilling wells. The T-end of the well shown in Figure 1a was buried 6.5 feet (2 m) into a beachface and used to monitor tide height. The holes in the T-end are covered with a screen mesh to keep out sand. The pressure transducer with built in data logger was housed inside the PVC, which was then capped. Figure 1b shows a stilling well set in an agricultural drainage ditch. The holes seen just above water level allow water to enter the well. The transducer and dater logger are housed in the upper section of the pipe. Wood braces are used to hold the well in place.*

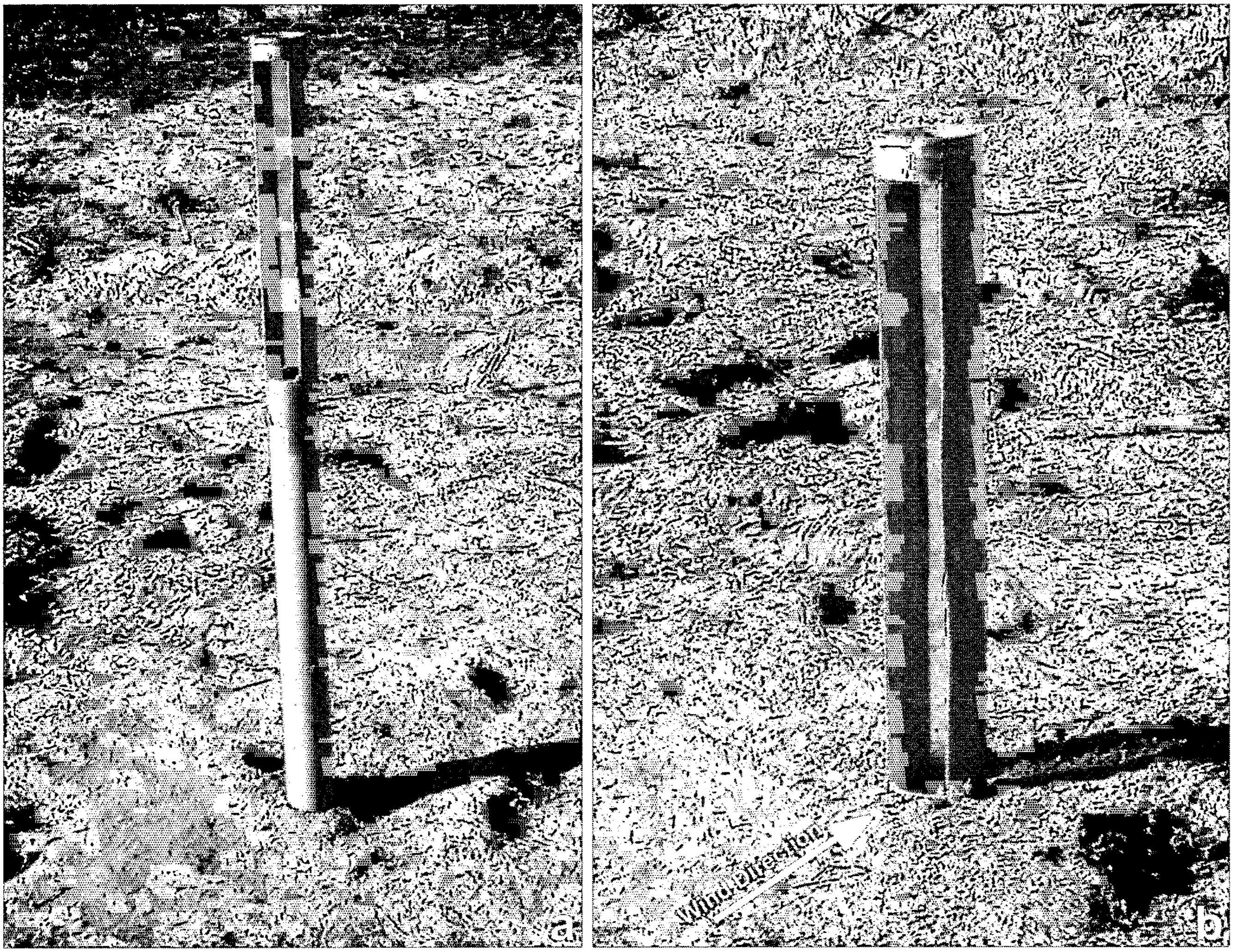

Figure 2. *The PVC aeolian sand trap. Figure 2a shows the trap prior to burial and Figure 2b shows the same trap in its deployed position. Notice how the upper portion has part of the front and back cut away. The back opening is covered with silk-screen cloth, duct-taped in place.*

The well shown in Figure 1b was installed in an agricultural drainage ditch to monitor stage for discharge calculations. The pipe can be made to closely follow the bank slope using angled connector pieces. The end of the pipe is capped and 3/8-inch or 1/2-inch holes are drilled in the lower part of the pipe. The transducer rests in the bottom, where holes allow water to fill the well. The data logger rests at the top and is held in place by the 45° bend. The Y-joint (just below the upper 45° bend) allows extra cable to be stored out of the way.

We have not yet used a similar stilling well for monitoring water table height, but that use would represent another purpose for such a well. The PVC pipe, capped at the end with similar drill holes, could be buried into the ground at a time when the water table is as low as it might be expected to get (during the summer for example). When the groundwater levels rise again, the pressure transducer would be in place to record that rise, and to monitor changes over time.

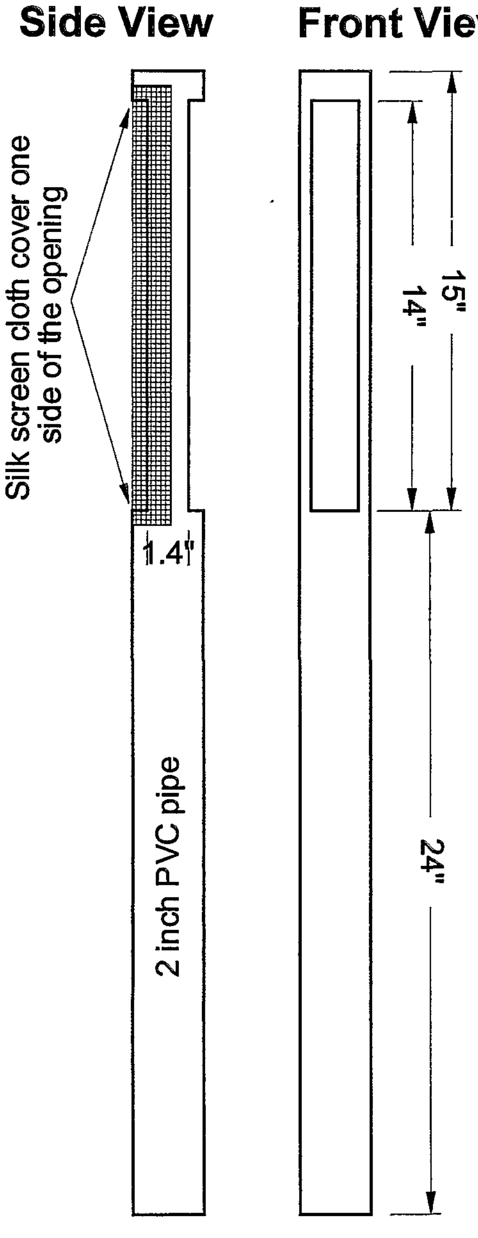

***Figure 3.** Front and side drawings of the PVC aeolian sand trap. Silk-screen cloth covers only one side of the opening and is held in place with duct tape.*

Stilling wells of the type shown in Figure 1 cost between $10 and $20, depending on the design and the diameter pipe needed for the type of transducer and data logger the user has. The primary consideration in their installation is to establish a baseline level against which future height, depth or stage levels can be compared.

PVC Aeolian Sand Traps

The PVC aeolian traps are used to measure the movement of sand-sized particles transported by wind. The original design is attributed to Leatherman (1978), but it has been modified for a variety of projects over the last 20 years. The design is very simple, as is the construction (Figures 2 and 3). A 40-inch length of 2-inch PVC pipe is used. The front and back portions of the pipe walls are removed from the top 14 inches, except for a 1-inch ring of solid pipe at the very top to maintain rigidity. One of the openings is covered with silk-screen cloth held fast with duct tape. The solid portion is buried in the ground so that the lip of the cut section is flush with the sand surface. Sand saltating along the surface strikes the back of the trap then falls into the holding chamber. The silk-screen cloth used for the mesh allows air to flow through with minimal obstruction, yet it blocks nearly all sand.

The bottom of the trap may be covered with a variety of materials. In his original design, Leatherman used window screening because he used the traps in a location where the water table was near the surface. The permeable screen allowed the water to rise in the pipe rather than push the pipe up out of ground as might happen if there was an impermeable bottom. If traps are to be used in place where the water table is not a concern, then PVC caps could be used on the bottom. We have also used plastic bags duct-taped in place that can be cut open to empty the traps. With care, the bags can be removed and the sand inside the trap can be transported in the bag.

Another concern is with the storage of sediment in the traps. Leatherman used a clear vinyl tube that slid down inside the trap. The tube had a string on the top end to enable it to be removed from the trap. The bottom of the tube was also covered with a fine mesh screen. Gares (1987) modified the design slightly, using a second PVC pipe as the inner tube. The rationale for using the inner tubes was to facilitate retrieval of samples. One tube could be withdrawn from the trap, and a replacement slid into place. This approach would permit the traps to remain in position while samples were collected, removed, and analyzed. Leatherman also felt that the clear pipe enabled the researcher to determine if there were sedimentary layers in the accumulation, although this has never proven to have much value.

A large soil auger works well to dig the holes for the traps. In fact, we discovered that using an auger allows the traps to be placed quickly enough that leaving the trap in place between wind events was not necessary. The ability to deploy the traps quickly obviated the usefulness of an inner pipe, and the trap could be emptied from the top into a sample container, or the bag on the bottom could be removed and used to transport the sample. The trap can easily be reset into the auger hole, or moved to a new location. Omitting the inner tube from the system also reduces the cost of each trap and the time it takes to build them.

The use of the PVC sand traps depends upon the requirements of the project and the sampling location. On bare sand surfaces in high wind conditions, these traps are best used for short-term, event studies because in the heavy saltation conditions that would result, they tend to fill quickly and thus require frequent emptying. However, they have also been used over weeklong periods in denser vegetation locations where sediment transport is low (Gares 1987). When placed in groups of four oriented in cardinal directions, they can monitor sediment movement under different wind conditions over a longer term and provide an overall picture of sediment transport patterns.

The main shortcoming associated with these traps is that they require an investment of time and field personnel to deploy and monitor during high speed wind events. Despite this, PVC traps are very appealing because they are easy to build and use, and cost only about $3.00 each, permitting the researcher to deploy many such traps to examine spatial variations.

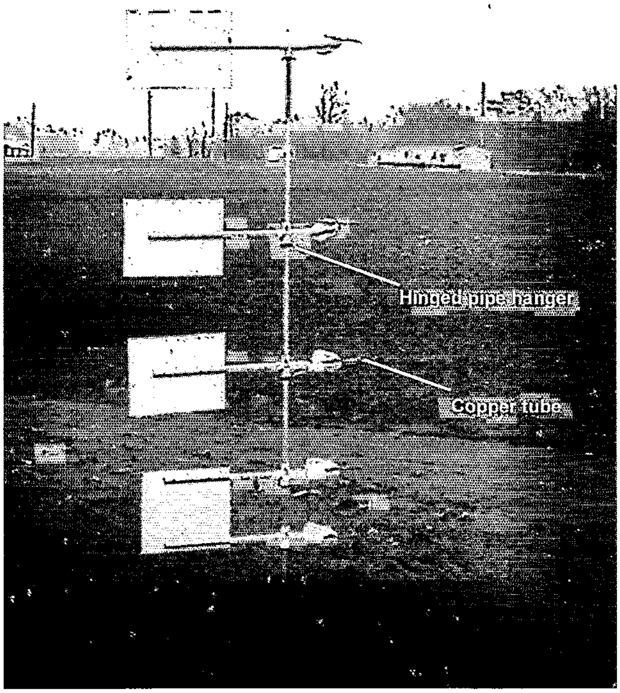

Figure 4. Dust traps mounted on a 7.5-foot (2.3 m) post at the edge of a tobacco field. Each vane rests on a pipe hanger that is clamped around the steel pipe just below the PVC T-joint. Notice that we attached the bottom two traps to a single wind vane because of their close spacing.

Dust Traps

Fine-grained soil particles can be eroded from bare fields by the wind and transported off-site. Monitoring this transport is frequently done with sophisticated samplers that involve suctioning air though filters or with light attenuation instruments. These samplers not only cost several thousand dollars but they often require the availability of AC current which is often difficult to access at field sites. The cost and difficulty with these samplers led us to devise simpler and cheaper dust traps (Figures 4 & 5). Our dust traps are modified Wilson and Cooke sediment catchers (Goossens and Offer 2000; Sterk and Raats 1996; Wilson and Cooke 1980). The traps are installed on posts and can be placed at any desired height. Several traps can be mounted on a single post to give a representation of the vertical distribution of dust. We used higher posts than previous authors and mounted each trap on an individual wind vane to keep the trap opening oriented into the wind (Figure 4).

Our design uses 500 ml wide-mouth plastic bottles with inlet and outlet pipes (Figure 5). Air flows through the upwind pipe into the bottle and excess air is exhausted out the downwind pipe by the increase in pressure in the bottle. The dust particles, carried with the flowing air, settle inside the bottle where quieter air conditions prevail. We used 3/8-inch copper pipe for the inlet and outlet (the original models used glass) because it is easy to bend, using a pipe bender, without crimping. Holes were drilled in the cap of the bottle so that the copper pipe would fit tightly; however caulking was needed in some cases to hold the pipe in place. The bottle caps were mounted to the wind vane arm instead of the bottle itself (Figure 5), which allowed us to change the bottles quickly, without disturbing the experiment. We simply unscrew the bottle, cap it (with another cap) and screw a clean bottle in its place. The offset in the arm, where the bottle is attached, centers the aerodynamic cross-section of the bottle, preventing it from altering the orientation of the trap normal to the wind.

The wind vane arm is built out of PVC because it is cheap and lightweight, and because we didn't have the appropriate sheet metal equipment needed to reproduce many of the vane designs that have been reported in previous literature (e.g. Fryrear 1986). The fin of the wind vane is constructed from foam core board and holds up well. A coat of paint might be useful if the traps will be out in the weather for a long time.

The traps were deployed on 7.5 foot posts, which consisted of 5/8-inch galvanized steel pipe (7/8 inch outside diameter) set 2.5 feet into the ground. At that height no guy lines are needed. We used 1-inch, hinged, split ring pipe hangers, clamped onto the galvanized pipe to hold

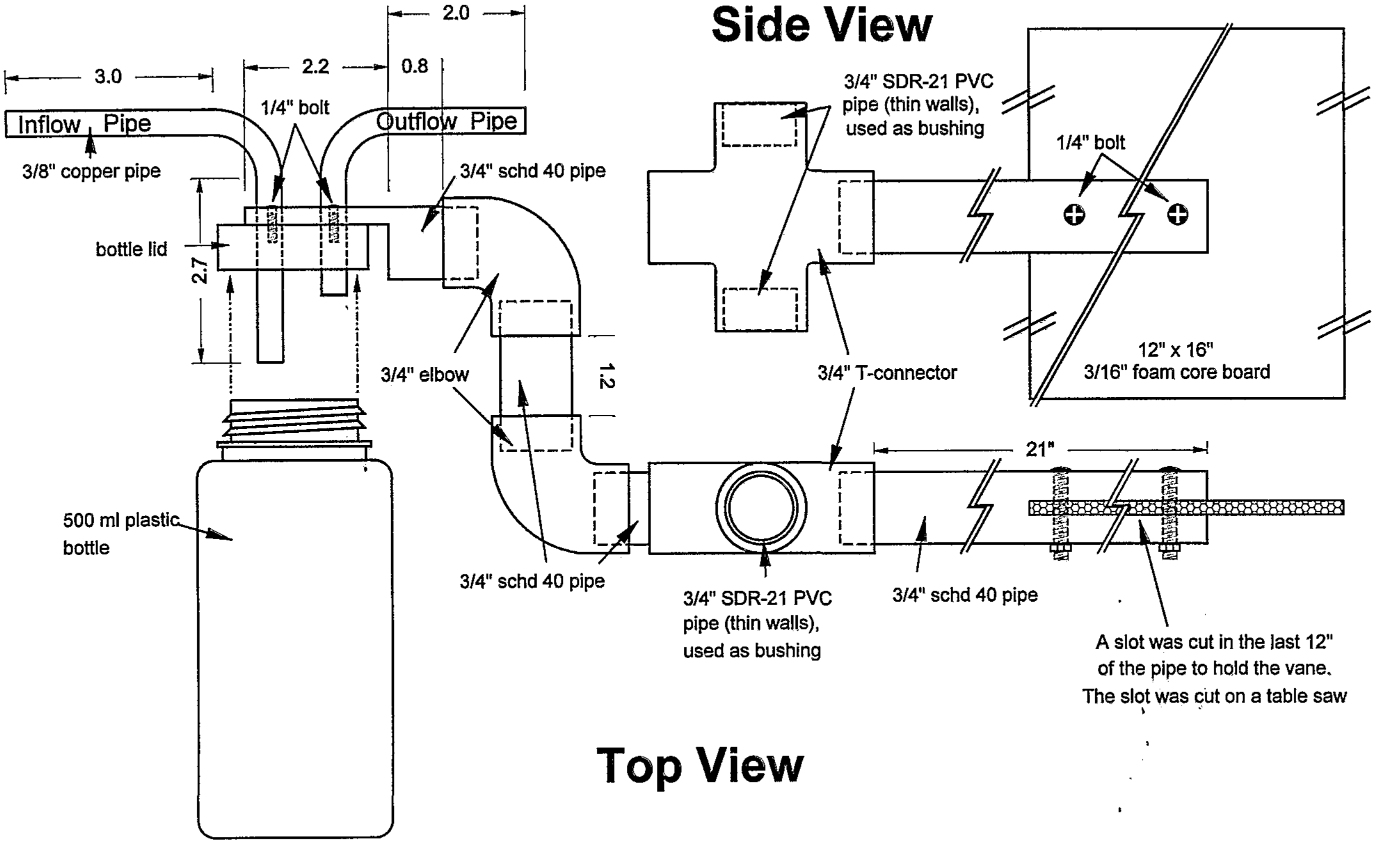

Figure 5. Diagram of the modified Wilson & Cooke dust trap. The side view shows the cross connecter that slides over the galvanized pipe post. The slot for the foam core wind vane was cut in a single pass on a table saw, although a handsaw could be used.

each trap at the correct height. The entire assembly shown in Figure 5, including the bottle, costs about $8.00. The galvanized pipe cost about $8.00 per 10-foot length, bringing the cost of the entire assembly shown in Figure 4 to about $48.00.

Aeolian Box Traps

We have not entirely limited ourselves to PVC construction. Other readily available raw materials have found a place in our classes, labs, and field sites. One example is an aluminum frame box sand trap (Figure 6). This trap is designed for aeolian environments and has been used in class-based research projects. The design principle is to have a container in which sand will be trapped, but which does not inhibit the airflow. The trap consists of a small frame made of 1inch by 1/16 inch and 1/2-inch by 1/16-inch aluminum flat stock. The flat stock was bent and connected to form 4-inch by 4-inch squares. The two squares were connected with four straight pieces 10 inches long creating a rectangular frame 4 inches by 4 inches by 10 inches. The aluminum is easily cut, bent and drilled. Pop-rivets are used to close the 4-inch by 4-inch squares, and to attach the straight pieces to the square ends. Pantyhose are used to enclose the trap and serve as the receptacle for the sand transported into the trap. We cut the legs off the pantyhose and stretched them carefully over the box, leaving one end open to face into the wind. Almost the entire surface area of the trap permits air to pass so that sand is easily carried into the box by the flowing air where it becomes trapped. The pantyhose cloth does not provide a single standard mesh size as one would expect with sieve mesh. Instead, the holes are randomly sized and unevenly distributed. The openings are seldom larger than 3.0 to 2.5 phi, smaller than most sand transported by wind. The nylon fibers are also "fuzzy" and have a three dimensional aspect which prevent most holes from passing through the cloth in a straight path. We have found that the pantyhose catch particles throughout the sand range and even trap silt size grains.

These box traps are particularly useful when stacked in groups of three to discriminate the height of the saltation cloud. If the researcher wishes to examine the vertical distribution of saltating sediment in more detail, it is possible to reduce the height of the opening to 1 inch or 2 inches and to stack six or more traps. The traps are lightweight enough that they must be held down using stiff, U-shaped wire hoops, similar to wickets used in a croquet game.

The box traps suffer from the same use issues as the PVC traps and care must be taken when they are emptied. They fill quickly in high wind conditions on bare surfaces. Also, they can only be oriented in a single direction.

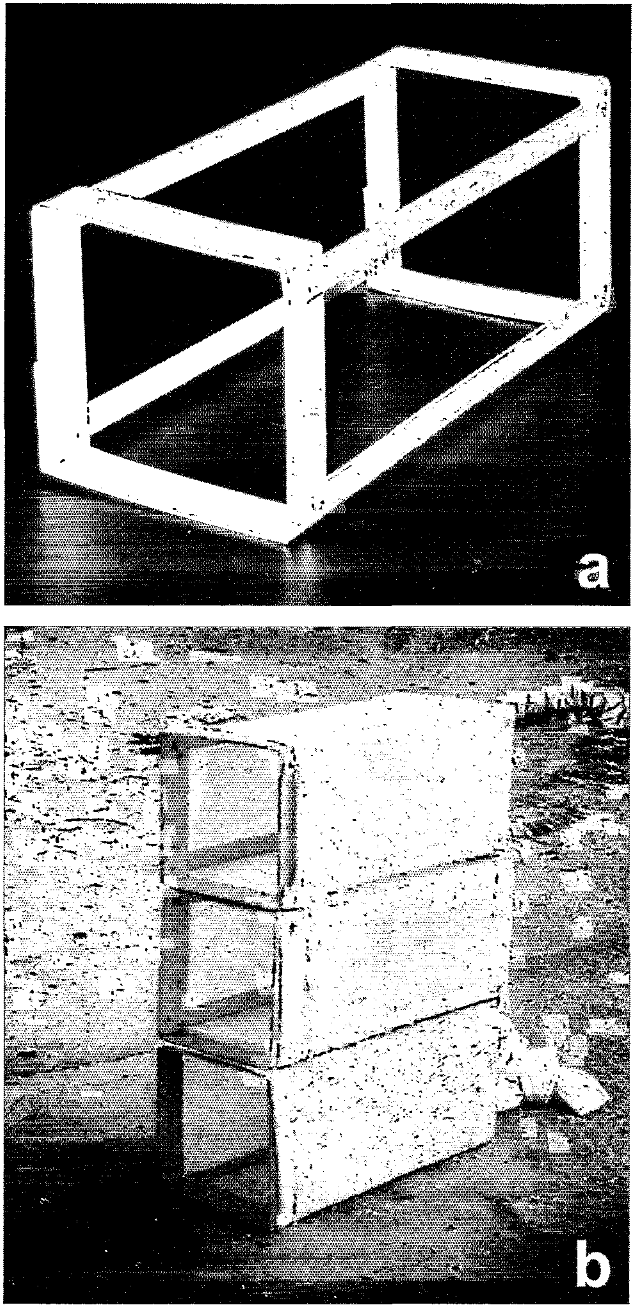

Figure 6. Aluminum frame aeolian box sand traps. Figure 6a shows the aluminum flat-stock bent and pop-riveted into a frame. Figure 6b shows three traps with pantyhose stretched over the frames.

However, like the PVC traps, they could be placed in groups of four and oriented in cardinal directions to monitor winds from different directions. They could also be used for longer periods in places where vegetation limits sediment transport. An additional concern is the removal of the pantyhose when sampling is completed. One is tempted to simply slide the hose off the box and to carry the sand in the hose, but as the hose stretches, the openings may expand a little and allow finer grains to escape. We recommend placing the whole trap in a plastic bag when removing the pantyhose so material is not lost.

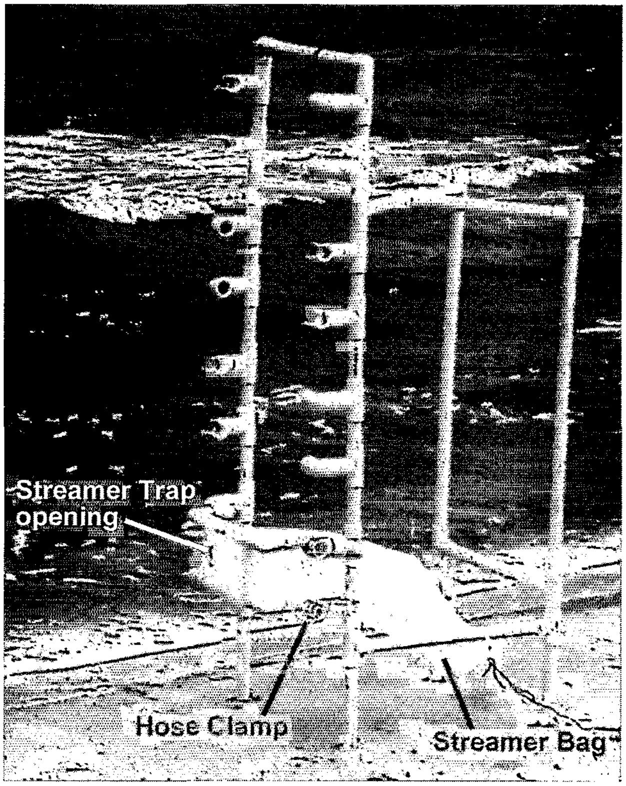

Figure 7. The streamer trap for measuring sediment movement in a surf zone transported by wave induced currents. The frame is built so that the streamer can be mounted at four different heights. The opening of the streamer is oriented in the direction of desired measurement and the netting acts similar to a windsock, trapping sand but allowing water to pass through.

The major advantages of these traps are their very quick deployment and the low cost, only about $3.50 for the frame. The pantyhose can be expensive, especially if numerous traps are being used to distinguish the height of the saltation cloud distribution in more detail. It is possible to reduce the cost by contacting companies for seconds and rejects. We had a graduate student do that, and he received several cartons full of hose at no cost.

Streamer Trap

The streamer trap is used to measure sediment movement in a coastal surf zone (Figure 7). The design shown in Figure 7 is modified from the streamer trap designed by Krause and Dean (1987). The trap design is similar in concept to a Helley-Smith bedload trap (Druffel et al. 1976). A fine-weaved cloth is sewn into a tub, with one end sewn into an open position onto a PVC frame. PVC is a good choice for coastal as well as fluvial work because of its non-corrosive properties and it higher density than water prevents floating. We used a cloth that captured grains larger than 4.5phi (coarse silt). This design creates an open tube with the streamer trailing behind, much like a windsock. The trailing end of the streamer is tied shut during a run, and untied to empty sand. The streamer is attached to a larger PVC support frame with

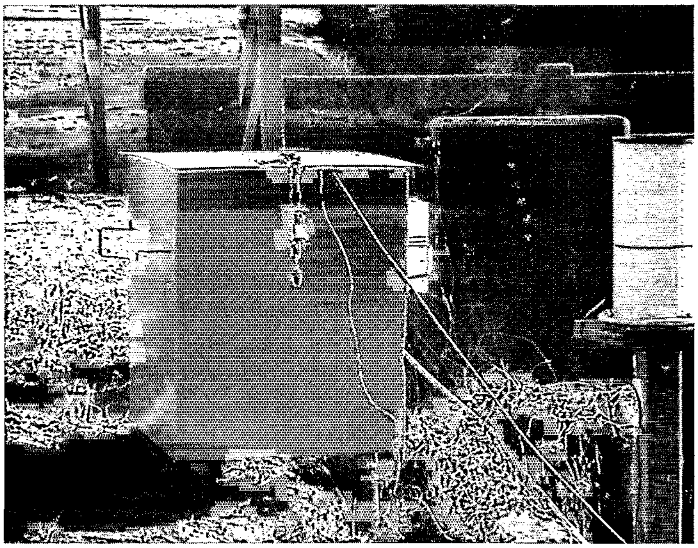

Figure 8. Steel box welded together to hold an automated water monitor/sampler. The box is water-proof to the top. The lid overhangs the body so that rain will not leak in. Weather stripping seals the lid to keep insects out. Both the chain and the steel flange that the chain drops through are welded to the box. The legs are buried 2.5 feet into the ground. Lengths of 2 by 2 lumber are slid into the square loops on the sides to carry the box.

four legs that are driven into the sand bed. The support frame was constructed so that the streamer can be mounted at four different heights above the bed. The streamer trap measures sand movement in only one direction and if you want to measure multiple directions the frame must be rotated and redeployed. Some thought has been given to a multidirectional streamer trap, but one has not yet been constructed. The trap shown in Figure 7 cost about $33.00 and was used as part of a graduate thesis. Its use and results are well documented by Lange (2000).

Equipment Security Box

Another important, but often overlooked, aspect of field research is the protection of equipment from natural and human elements. We have ongoing research that requires some rather expensive monitoring and automated water sampling equipment to be left at a field site. We had three problems with the equipment. It was originally locked in a plywood box, to protect it from direct exposure to the elements, and for security. However, recognizing that a rusty hammer or fist-sized rock would easily yield access to the box, we felt obliged to hide the box in a low-lying area. During large discharges, however, the instrument would be flooded and samples lost. We also had an unpleasant time keeping mice (which chew holes in equipment), wasps, ants, and other wildlife out of the equipment.

We decided to build a steel box (Figure 8) that would solve all of these problems. The new box had to be waterproof so that rising water would not flood the equipment. It had to seal tight enough at the lid to keep out mice and most insects. It had to be tamper/bullet resistant enough so that we could safely set it up high enough above the bank (and in plain sight) so that it would not flood, even in large, overbank events. Given the plethora of bullet holes in just about everything more than two feet off the ground, we had reason for concern regarding the last criteria. We constructed the steel box sturdy enough to withstand a .22 caliber rifle round, which by all qualitative indicators appears to be the ammunition of choice for late-night vandals and intoxicated saboteurs.

A chain, welded to the lid and passed through a hole in a plate fixed to the box is used to lock the box. Detachable legs were attached to the bottom by brazing 1 1/2-inch threaded plates and screwing in lengths of steel pipes. The legs are buried 2.5 feet into the ground and partially in concrete to prevent the entire box from being taken or knocked over.

The project was not as complex as it might appear. We had our steel supplier pre-cut the 1/8-inch steel sheets to the correct dimensions for a nominal fee. Although some knowledge of welding is required, it is not a particularly hard skill to learn at the level required for this type of project. We did the welding with an oxygen/acetylene system, although an arc welder would likely work better. If you do not have access to the equipment or skills, local metal shops can do the welding, or perhaps for more cost effective labor, check with local high school shop classes that are often open to students practicing on outside projects.

DISCUSSION AND CONCLUSIONS

In this paper, and its complimentary piece (Pease et al. 2002), we have presented several designs for field and laboratory equipment that can be used in projects for physical geography or earth science courses offered in high schools and colleges. The equipment designs presented are not without limitations. There are issues to consider in designing devices such as those described, including the quality of the equipment, which may not be good enough to allow it to be used for publication purposes. The quality of the data obtained can only be determined by calibrating the devices in controlled conditions. Calibration can be very difficult to do if one does not have access to laboratories with the kind of sophisticated equipment necessary. One solution is to find equipment in the literature that can be duplicated or modified to cut down on production costs. Such devices will have gained some acceptance by the community of scholars through the review process, which may offset the inability to actually test the devices you build. Thus, for example, neither of the aeolian traps presented here has been officially tested in this fashion but they have been presented in the literature and have been used widely for field research (Gares 1987; Leatherman 1978). Likewise, the streamer traps and the dust traps are modifications of devices that have been used for fieldwork that has been reported in the literature (Goossens and Offer 2000; Kraus and Dean 1987; Wilson and Cooke

1980). Laboratory apparatus may be developed in much the same way. The filtration device presented in part one of this paper (Pease et al. 2002) used cheaper materials while replicating a similar device seen in a laboratory supply house.

We believe strongly in the value of experience-based learning and think field and lab time is crucial to the synthesizing of information presented in classrooms. One way to incorporate such experiences into the curriculum is with the use of research exercises that help students gain an understanding of how scientific research is conducted (Kent and Gilbertson 1997). It is often difficult, however, to undertake research projects because of the high expense of commercial research equipment. Despite the limitations of self-built equipment, we believe that many of the limitations of equipment expense that faculty face can be overcome with a little bit of ingenuity and initiative. To that end, we hope that the designs presented in this paper are useful and that they inspire additional ideas that will solve your specific needs.

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