Table 11.5. Summary of Characteristics of Sampling Devices Available for Small Diameter Monitoring Wells

Device	Minimum Well Diameter	Approximate Maximum Sampling Depth	Typical Sample Delivery @ Maximum Depth	Flow Controllability	Materials[a] (Sampling Device Only)	Potential for Chemical Alteration	Ease of Operating, Cleaning and Maintenance	Approximate Cost for Complete System[b]
Bailers	½"	Unlimited	Variable	Not applicable	Any	Slight-moderate	Easy	<$8,100-$8,200
Syringe samplers	1 ½"	Unlimited	0.2 gal.	Not applicable	Stainless 316, Teflon or poly-ethylene/glass	Minimum-slight	Easy	<$8,100 (50 ml homemade) $81,500 (850 ml commercially available)
Suction-lift (vacuum) pumps	½"	26 ft.	Highly variable	Good	Highly variable	High-moderate	Easy	$8,100-$8,550
Gas-drive samplers	1"	300 ft.	0.2 gpm	Fair	Teflon, PVC, polyethylene	Moderate-high	Easy	$8,300-$8,700
Bladder pumps	1 ½"	400 ft.	0.5 gpm	Good	Stainless 316, Teflon/Viton, PVC, silicone	Minimum-slight	Easy	$81,500-$84,000
Gear-drive submersible pumps	2"	200 ft.	0.5 gpm	Poor	Stainless 304 Teflon, Viton	Minimum-slight	Easy	$81,200-$82,000
Helical rotor submersible pumps	2"	125 ft.	0.3 gpm	Poor	Stainless 304, EPDM, Teflon	Slight-moderate	Moderately difficult	$83,500
Gas-driven piston pumps	1 ½"	500 ft.	0.25 gpm	Good	Stainless 304, Teflon, Delrin	Slight-moderate	Easy to moderately difficult	$83,400-$83,800

Source: Nielsen and Yeates, 1985
[a]Materials dependent on manufacturer and specification of optional materials.
[b]Costs highly dependent on materials specified for devices and selection of accessory equipment.

Table 11.6. Advantages and Disadvantages of Several Types of Sampling Devices.

Advantages	Disadvantages
Bailers	
♦Bailers can be constructed of virtually any rigid or flexible material, including those materials that are inert to chemical contaminants. ♦Bailers are mechanically very simple, and thus are easily operated and disassembled for cleaning and repair. ♦Bailers are, in comparison with other sampling devices, very inexpensive, making them feasible for dedicated installation in monitoring wells. ♦Bailers can be used to sample water from wells of virtually any depth. ♦Bailers require no external power source, and are lightweight and highly portable. ♦Bailers made of flexible material will pass through nonplumb wells. ♦Bailers can be made to fit any diameter well, and can be made virtually any length to accommodate any sample volume. ♦Bailers can provide a "cut" of immiscible contaminants (i.e., petroleum, hydrocarbons) from the top of the water column in a well. Transparent bailers are usually used for this purpose.	♦In deep wells, well purging can be difficult and therefore labor-and time-consuming. ♦If the line used with the bailer is not a "noncontaminating" line and is not dedicated to a single well or is not adequately cleaned after each sampling event, cross-contamination between wells can result. ♦Aeration, degassing, and turbulence can occur while lowering the bailer through the water column or while transferring the sample from the bailers to the sample container. ♦The person sampling the well is susceptible to exposure to any contaminants in the sample. ♦Bailing does not supply a continuous flow of water to the surface. ♦It may be difficult to determine the point within the water column that the sample represents. ♦Bailer check valves may not operate properly under certain conditions (e.g., high suspended solids content and freezing temperatures). ♦The "swabbing" effect of bailers that fit tightly into a well casing may induce fines from the formation to enter the well, especially if the well has been poorly developed.
Syringe Devices	
♦The sample taken with a syringe device does not come into contact with any atmospheric gases and is subjected to a very slight negative pressure, thus neither aeration nor degassing of the sample should occur. ♦Samples can be collected at discrete intervals and at any depth. ♦Syringes can be made of inert or nearly inert materials. ♦Syringes are not restricted to the limits of suction lift. ♦The syringe can be utilized as the sample container, thus removing the possibility of cross-contamination between wells. ♦Syringes are inexpensive, high portable, and simple to operate. ♦Syringe devices can be used in wells as small as 1 ¼" inside diameter.	♦Syringes are inefficient for collecting large volume samples. ♦Syringes cannot be used to purge a well. ♦Syringes are relative new in the application, therefore they may not be as readily available as other sampling devices. ♦Sample contamination by components of "homemade" sampling devices is possible unless materials are carefully selected. ♦The use of syringes is limited to water with a low suspended solids content. ♦Some leakage has been found to occur around the plunger when syringes are used to sample water containing high levels of suspended solids.
Suction-Lift Pumps	
♦The flow rate of most suction lift pumps is easily controlled. ♦Suction-lift pumps are high portable and readily available. ♦Most suction-lift pumps are inexpensive in comparison to other sampling devices. ♦The pump does not contact the sample--only the tubing must be cleaned (peristaltic pump only). ♦Suction-lift pumps can be used in wells of any diameter, and can be used in nonplumb wells.	♦Sampling is limited to situations in which the potentiometric level is less than 25 feet below the surface. ♦A drop in pressure due to the application of a strong negative pressure (suction) causes degassing of the sample and loss of volatiles. ♦An electric power source is required for peristaltic pumps. ♦The gasoline motor power source used for most centrifugal pumps provides potential for hydrocarbon contamination of samples. ♦Pumping with centrifugal pumps results in aeration and turbulence. ♦Centrifugal pumps may have to be primed, providing a possible source of sample contaminations. ♦Low pumping rates of peristaltic pumps make it difficult to purge the wellbore in a reasonable amount of time. ♦Where the sample comes in contact with the pump mechanism of tubing, the choice of appropriate materials for impellers (centrifugal pump) or flexible pump-head tubing (peristaltic pump) may be restrictive.
Gas-Drive Devices	
♦Gas-drive devices can be utilized in wells of 1 ¼" in. inside diameter. ♦Gas-drive devices are highly portable for most sampling applications, and are inexpensive. ♦Discrete depth sampling is possible. ♦Gas-drive devices can provide delivery of sample at a controlled, nearly continuous rate.	♦If air or oxygen are used as the driving gas, oxidation may occur (causing the precipitation of metals), gas-stripping of volatiles may occur, or CO_2 may be driven from the sample (causing a pH shift). Consequently, air-lift sampling may not be appropriate for many chemically sensitive parameters.

Table 11.6. Advantages and Disadvantages of Several Types of Sampling Devices.

Advantages	Disadvantages
Gas-Drive Devices (continued) ♦The use of an inert driving gas (i.e., nitrogen) minimizes sample oxidation and other chemical alteration. ♦Devices can be installed permanently in boreholes without casing. ♦Multiple installations can be achieved in a single well or borehole (either temporarily or permanently installed). ♦Gas-drive devices can be constructed entirely of inert materials. ♦The depth from which samples can be taken with gas-drive devices is limited only by the burst strength of the materials from which the device and tubing are made.	♦An air compressor or large compressed-air tanks must be transported to deep sampling locations, reducing portability. ♦Application of excessive air pressure can rupture the gas entry or discharge tubing. ♦Devices installed permanently in boreholes without casing are difficult or impossible to retrieve for repair; proper installation and operation may be difficult to ensure.
Gas-Operated Bladder Pumps ♦Most of these pumps have been designed specifically to sample for low levels of contaminants, so most are or can be made of inert or nearly inert materials. ♦The driving gas does not contact the sample directly, thus problems of sample aeration or gas stripping are minimized. ♦Bladder pumps are portable, though the accessory equipment may be cumbersome. ♦The relative high pumping rate (in comparison with other sampling devices) allows well purging and large sample volumes to be collected. ♦The pumping rate of most of these pumps can be controlled rather easily to allow for both well purging at high flow rates and collection of volatile samples at low flow rates. ♦Most models of these pumps are capable of pumping lifts in excess of 200 feet. ♦These pumps are easy to disassemble for cleaning and repair. ♦Most models of bladder pumps are designed for used in wells of 2-in. inside diameter; some are available for smaller diameter wells. ♦Large diameter bladder pumps (i.e., 3 ¼ outside diameter) are available for large diameter monitoring wells.	♦Deep sampling requires large volumes of gas and longer cycles, thus increasing operating time and expense, and reducing portability. ♦Check valves in some pump models are subject to failure in water with high suspended solids content. ♦Most currently available pump models are expensive, though prices are highly variable. ♦Minimum rate of sample discharge of some models may be higher than ideal for the sampling of volatile compounds.
Gear-Drive Electric Submersible Pumps ♦These pumps are constructed of inert or nearly inert materials; therefore, the are suitable for sampling organics when optionally available Teflon discharge line is employed. ♦These pumps are highly portable and totally self-contained, except when auxiliary power sources are employed. ♦These pumps provide a continuous sample over extended periods of time. ♦Models are available for both 2-in. and 3-in. (or larger) inside diameter wells. ♦High pumping rates are possible, making it feasible to use the pump for both well purging and sampling. ♦Reasonably high pumping rates can be achieved to depths of 150 feet, and depth range can be extended through the use of an auxiliary power source. ♦These pumps are easy to operate, clean, and maintain in the field, and replacement parts are inexpensive. ♦In comparison to other pumps offering the same performance, these pumps are inexpensive to purchase and operate.	♦There is no control over flow rates; therefore, it is not possible to adjust from a high pumping rate for well purging to a lower rate required for sampling of volatiles. ♦Sampling in wells with high levels of suspended solids may necessitate frequent replacement of gears. ♦The potential for pressure changes (cavitation) exists at the drive mechanism; however, this has not been adequately evaluated.
Helical Rotor Electric Submersible Pump ♦This pump is portable and relatively easy to transport in the field to remote locations. ♦This pump is well-suited for use in wells of 2-in. inside diameter. ♦Relatively high pumping rates are possible with currently available units, thus well purging is possible. ♦This pump has been specifically designed for monitoring groundwater contamination; therefore, it is constructed of inert or nearly inert materials.	♦The currently available pump unit is limited to 125 feet of pumping lift. ♦High pumping rates with this pump lead to creation of turbulence, which may cause alteration of sample chemistry. ♦Thorough cleaning and repair in the field may be difficult because the pump is moderately difficult to dissemble. ♦Water with high suspended solids content can cause aeration problems ♦The currently available model is expensive in comparison to other devices offering comparable performance. ♦The pump must be cycle on/off approximately every 20 minutes

to avoid overheating of the motor.
♦The flow rate cannot be controlled, so the pump may not be suitable for taking samples for analysis of chemically sensitive parameters.

Table 11.6. Advantages and Disadvantages of Several Types of Sampling Devices.

Advantages	Disadvantages
Gas-Operated Double-Acing Piston Pump	
♦Because the sample is isolated from the driving gas, no aeration of the sample occurs. ♦The pump provides a continuous sampler over extended periods of time. ♦This pump is relatively easy to operate and is easy to disassemble for cleaning and maintenance, though some maintenance problems (i.e., with the pump motor or valving mechanism) cannot generally be solved in the field. ♦Models of this pump are available for wells of 1 ¼ in. inside diameter and for well of 2 in. or greater inside diameter. ♦The pump uses gas economically. ♦Pumping lifts of more than 500 feet can be overcome with this pump. ♦Flow rate of the pump can be easily controlled by varying the driving gas pressure on the pump. ♦The pump can be made of inert or nearly inert materials. ♦The moderately high pumping rate at great depths allows for collection of large volumes of sample in a relatively short time.	♦Piston pumps are relatively expensive in comparison to other sampling devices. ♦The pump is not highly portable--it must be vehicle mounted. ♦Unless the pump intake is filtered, particulate matter may damage the pump's intricate valving mechanism. ♦The pump's intricate valving mechanism may cause a series of pressure drops in the sample, leading to sample degassing and pH changes. ♦Fixed-length tubing bundles may be inconvenient for shallow, low-yield monitoring wells. ♦The tubing bundles may be difficult to clean adequately to avoid cross-contamination.

Source: Nielsen and Yeates, 1985