From **Dahm and Valett (1996), Hyporheic Zones, in Methods of Stream Ecology, 1996 Hauer and Lamberti (eds), Academic Press, NY.**

A. Sampling Pits

A straightforward way of sampling the hyporheic zone is to dig a hole with a shovel and crowbar into the floodplain near the active channel. This is a technique that was utilized by pioneering researchers interested in the interstitial biota. One advantage of this procedure is that it allows an accurate determination of the height of the water table. The elevation of the top of the saturated zone determines the location of the water table al that location. Continue to dig the hole to a depth of 30-50 cm below the water table. The pits may then be used to sample hyporheic water, sediments, chemistry, and biota. Additional holes or a trench should be dug close to the first pit for use in tracing the direction and velocity of groundwater flow. The distance from the main pit to the secondary sampling locations should consider the texture of the alluvium. Fine-grained alluvium calls for secondary sampling sites within 10-30 cm, whereas pits in coarse-grained alluvium may be placed 50-100 cm distant.

B. Minipiezometers

The vertical direction of groundwater movement can be measured with minipiezometers (Lee and Cherry 1978). Preparation and emplacement of minipiezometers is relatively easy with the proper tools. Minipiezometers also may be connected to a hydraulic polentiomanometer to measure differences in hydraulic head relative to surface water (Winter *et al* 1988, Boulton 1993). Vertical hydraulic gradient (VHG) measures pressure differentials between piezometers installed to different depths. A positive VHG (greater pressure in the deeper piezometer) indicates upwelling and a negative VHG (lower pressure in the deeper piezometer) indicates downwelling. Similarly, VHG across the ground water- benthic interface can be determined by comparing pressure differentials existing between a piezometer established beneath the active channel and ambient surface water pressure (Lee and Cherry 1978).

We suggest that minipiezometers be made of 1/2" (12 mm) PVC pipe. The minipiezometers are inserted into the sediments by placing the plastic PVC pipe around a steel T-bar with a sharpened tip and reinforced handle. A small sledge hammer is used to drive the T-bar into the sediments. In the active channel, minipiezometers are commonly inserted to a depth of 30 cm below the sediment-water interface. While holding the PVC pipe firmly, withdraw the T-bar carefully. Using a 60-ml syringe with the tip extended with Tygon tubing, remove the water from inside the minipiezometer. Check to see if the minipiezometer refills quickly after bailing to assure that it is not clogged. The minipiezometer can now be used for measurement of VHG and for hyporheic water sampling. Minipiezometers can be placed in transects across the active channel and into lateral alluvial sediments or on an upstream-downstream transect to measure either lateral or longitudinal patterns in VHG.

C. Wells

PVC wells of 2" (51 mm) diameter can be installed to provide permanent access points for sampling the hyporheic zone. Wells can be placed either beneath the active channel or in the fioodplain. Although the initial effort of well installation may be laborious and time-consuming, the wells provide sampling opportunities for many years with minimal maintenance. It is best to install wells at times of low discharge. Wells can be emplaced using crowbars and shovels, hand augers, power augers, or drilling equipment. Well depth should extend at least 50 cm below the water table during base flow discharge. Commercially available slotted screen with known slot size is attached with the use of collars to the bottom or segments of the PVC well. The length of slotted screen determines from what depth water will be sampled. For example if the bottom 50 cm of the well is slotted, ground-water will be drawn from that section of the well. The location and length of slotted well pipe which is used can be varied if samples are desired from specific regions of the groundwater. Before inserting the completed well (consisting of a bottom cap, slotted screen, and a solid PVC pipe), the base of tie excavated hole should be packed with a few centimeters of coarse silica sand (commercially available). The well can then be inserted into the hole and additional sand should be added to cover the length of the slotted screen. This prevents clogging of the well and efficient groundwater flow into the well. The remainder of the hole is then refilled with alluvial material removed during excavation. A surface seal of pelletized bentonite at [he top of the well ensures that surface flow will *not* enter the well from above. Pelletized bentonite is swelling clay which expands when wetted. Packing a few centimeters of bentonite around the well at the ground surface will prevent water from the surface to flow vertically along the outside of the pipe. Supplies for well installation (PVC pipe, slotted screen, connectors, bentonite, silica sand, etc.) are available from most well-drilling supply stores at reasonable prices.

SPECIFIC EXERCISES

A. Exercise 1: Dye Injection—Measuring Groundwater Flow and Velocity

1. This experiment will make use of the hand-dug sampling pits, the minipiezometer network, or (the well field. The direction and velocity of groundwater flow will be measured.
2. Inject a dye such as fluorescein or rhodamine WT into a center well or pit and record the time of injection.
3. Sample nearby wells, minipiezometers, or pits for appearance of the dye. Sampling times should be every 5-10 min except in very coarse sediments where sampling may need to be done every minute. Note the time that dye is detected in any of the adjacent sampling locations.
4. Measure the direction and distance of groundwater flow. Calculate the velocity in the appropriate distance and time (e.g., cm/day), and note the direction of flow.
5. Be sure to refill pits at the end of the experiment for the safety of wildlife and people visiting the stream.

B. Exercise 2: Measuring VHG in Minipiezometers

1. Carry out these measurements on all minipiezometers within the study reach. Sampling the height of the water within the minipiezometer can be done using: (a) a calibrated wooden dowel (cm) coated with chalk dust, (b) a voltmeter with leads attached to the base of a calibrated wooden dowel (cm), or (c) a commercial water level recorder.
2. For minipiezometers installed in the active channel, measure the distance from the top of the minipiezometer to the stream surface with a tape measure (cm).
3. Measure the distance from the top of the minipiezometer to the water level inside the minipiezometer. Repeat steps 2 and 3 for all minipiezometers at the study site.
4. For minipiezometers in the stream, calculate VHG for each minipiezometer,

$$VHG = (h_s - h_p)/L$$

where h_s represents the height of the top of the minipiezometer above stream surface (cm); h_p, height from top of minipiezometer to water in minipiezometer (cm); and L, depth of minipiezometer into sediment (cm). The resulting unitless ratio will be positive in upwelling (groundwater discharge) and negative in downwelling (groundwater recharge) zones.

5. Map out the pattern of upwelling and downwelling zones in the study section of stream. An example of such a map is shown in Fig. 6.2. Figure 6.2A shows the stream bed and surface water elevations, and Fig. 6.2B shows regions of upwelling and downwelling as measured by VHG (cm/cm).

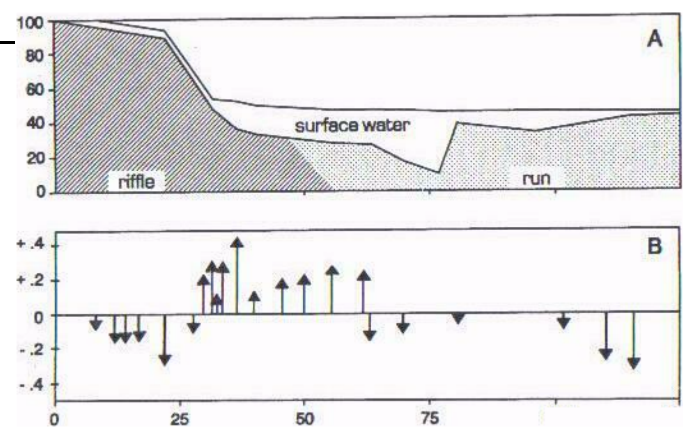

FIGURE6.2 (A) Longitudinal section of *3* 125-m study reach at Sycamore Creek, Arizona, illustrating downstream changes in stream bed elevation and morphometry. Riffles are steeper gradient sections where substrata are cobbles/boulders. Runs are lower gradient reaches where substrata are predominantly sand and gravel. (B) Magnitude of vertical hydraulic gradient (cm/cm) along a mid-stream longitudinal axis of the same study reach.

C. Exercise 3: Sampling a Well Field

1. This exercise is designed for those sites where a well field has been installed. A survey map with well locations and elevations is required for the exercise.

2. Measure the height of the water table in each well. This can be done using a commercial water level detector (e.g., Solinst), with a calibrated dowel with leads at the base connected to a voltmeter, or with chalk and a measuring line. Be sure to also measure the stage height of the stream at various locations within the well field.

3. Bail all the wells and allow them to recharge. After recharging, the wells can be sampled for temperature, conductivity, pH, and dissolved oxygen. Measurements are best made with portable field probes inserted into the groundwater within the wells. If field probes are not available, samples can be drawn into large gas-tight syringes (60 ml) with Tygon extensions and measurements made using standard methods (e.g., APHA *et al.* 1992). The number of physical and chemical measurements should be guided by available instrumentation and questions being asked about the characteristics of hyporheic zone groundwaters.

4. Hydraulic conductivity of the sediments can be determined with the Hvorslev method (Hvorslev 1951, Fetter 1988). Water is withdrawn by bailing the well with a bailer. Water elevations then need lo be taken at various time intervals after bailing. Sampling intervals will need to be short (seconds) for high hydraulic conductivity substrata (i.e., coarse sand, gravel, and cobble) and longer for lower hydraulic conductivity material (i.e., fine sand, silts, and clays}. Compute the ratio fi/h_a, where *hi,* is the height the water level dropped below the static water level immediately after bailing and *It* is the water level drop at some time I. Plot the ratio hlh_a versus time on semilogarithmic paper; the lime-recharge data should plot on a straight line. Hydraulic conductivity *(K)* can be calculated with the following formula provided that the length of well screen is greater than 8 times the well screen radius ($L/R > 8$). For example with a 5-cm-diameter (2.5-cm-radius) well, the length of screened well should be at least 20 cm,

$$K=r^2 ln(L/R)/_{2LTo}$$

where K is the hydraulic conductivity (cm/s); r, radius of well casing (cm); R, radius of well screen (cm); L, length of well screen (cm); and TO, time for water level to rise to 37% of initial change after bailing.

5. Chemical and invertebrate sampling can also be carried out from groundwater wells. Bailers or syringes can be used to collect samples for chemical analyses. Standard methods for sample preparation and storage should be employed after samples are withdrawn (APHA *et al* 1992). Special care needs to be given to avoid contact with the atmosphere for samples collected for gas analyses. Sampling for invertebrates requires unscreened wells with open bottoms and sidewall slots, a high-volume diaphragm water pump, and a fine-meshed net (e.g., 45-^tm plankton net) lo collect the organisms exiting the pump. Sampling methods for hyporheic zone invertebrates from wells are presented in more detail by Stanford and Ward (1988) and Hakenkamp and Palmer (1992)

IV. QUESTIONS

1. What is the direction of flow for groundwater at your sampling site? What is the groundwater velocity?

2. What is the pattern of VHG values for the minipiezometers beneath your stream? Is this section of channel gaining or losing surface water due to exchanges with groundwater? Do the locations for upwelling (groundwater discharge) and downwelling (groundwater recharge) conform to the predicted relationship with bedform concavity and convexity?

3. How does VHG change with increasing stream discharge? What happens to the water table along the edges of the channel?

4. Are there measurable changes in water level in groundwater of the hyporheic zone during a diurnal cycle with no precipitation during that period of time?

5. Darcy's Law calculates the flux of groundwater (volume per unit time) with the equation

$$Q = -KA * (dh/dL)$$

where Q is the flux of groundwater (m^3/day); K, hydraulic conductivity *(mlday); A,* area through which flow occurs (m^2); and dh/dL, vertical hydraulic gradient (VHG is unitless). Given an area of 1 m^2, VHG measured with your minipiezometers, and K estimated by the Hvorslev method, calculate the vertical flux of groundwater through the sediment-water interface of your stream. How does this value compare to total surface water discharge through the reach of stream?

6. Are the groundwaters of the hyporheic zone supersaturated, saturated, or undersaturated with dissolved oxygen? Why'.'

V. MATERIALS AND SUPPLIES

Installation of Sampling Pits or Minipiezometers

1/2" PVC cut to required length (for minipiezometers)
Shovels, crowbar, work gloves
Sledge hammer
T-bar with reinforced handle for hammering

Sampling

Bailer
Biodegradable dyes
Hydraulic polentiomanometer or water level reader (e.g., chalk and calibrated line)
Sample preservatives/filtration apparatus Sampling bottles and nets
Stopwatch Syringe sampler Tape measure Temperature, conductivity, pH, and dissolved O_2 portable field probes