Emriver Em2 Geomodel
Use and Care Manual
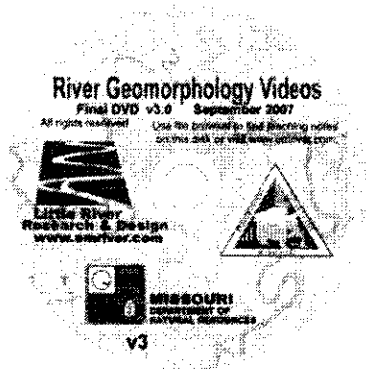
LITTLE RIVER
RESEARCH & DESIGN

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We're happy to send you a copy of our River Geomorphology Videos DVD.

The DVD contains 59 short movies showing river process and river conservation-related images, including Ozark fishes in their native habitat.

These videos were made in cooperation with Missouri State agencies and US EPA 319 funding. Many were made using our Emriver models.

Please use the teaching guide! You will have trouble navigating the DVD otherwise. A copy of the teaching guide can be found on the DVD (you'll have to use a file manager to find it—it's not accessible with a DVD player). You can download a copy at www.emriver.com/supportfaq as well. Use the teaching guide to locate your subjects of interest. All the video clips are numbered, and finding them on the DVD is easy using this system.

Note that the final edition has a "**v3**" notation as shown above. The final version contains many clips on bedload and gravel mining-related topics. Clips added to the final version are numbered 100 and higher. **Also note that there is no sound on the disk.**

If you need more disks for nonprofit use, you may make your own copies. Visit www.emriver.com to order copies at our cost of $15 per disk. For orders of more than 5 disks, contact us for bulk pricing.

Don't miss the hidden bonus videos! At the main menu, click on the upper half of our logo for the exciting short movie "River Dozer of Doom." Click on the bottom half for a short promotional trailer showing underwater and aerial video we've made.
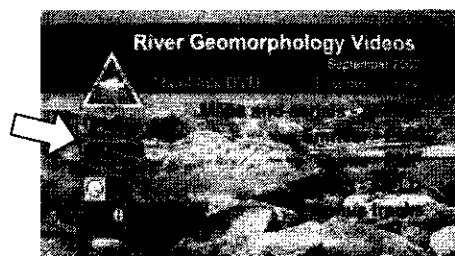
As of January 2018, all of these videos are now available on the **Little River YouTube Channel**. Please visit our website and follow the link to the Channel, then find the "Playlist" of River Geomorphology Videos.

How to care for your Emriver model and keep it sanitary

(Please read your manual thoroughly for additional information.)

DRAIN model and reservoirs after use

DO NOT leave water in the model or reservoirs

READ the manual, visit our support page at www.emriver.com

DO NOT use lithic (rock) sand in model

DO NOT use metallic objects in the model

DO NOT use solvents to clean plastic parts. Use only mild detergents.

ADD BLEACH ONLY IF NECESSARY

MAKE SURE the pump is circulating when you add bleach

- 6 ml max for Em2
- 12 ml max for Em3
- 21 ml max for Em4

TOO MUCH CHLORINE CAN DESTROY YOUR MODEL

Warranty Information and Replacement Parts

Little River will replace parts with manufacturer defects within one year of purchase. After the warranty period, replacement parts may be purchased from Little River or directly from a supplier.

To report defects, please call (618-529-7423) or email (info@emriver.com). Include a description of the problem, and a photo if appropriate.

To order replacement parts, please call (618-529-7423) or email (info@emriver.com). Include a list of the parts you need and we will provide a quote or direct you to a supplier.

YOU MUST READ AND UNDERSTAND THESE WARNINGS BEFORE USING THE EMRIVER MODEL

The Emriver model is very heavy when filled with water and sediment. A collapse of the model's supports could severely injure or kill a person. Be absolutely sure you understand how to use the supports.

Use only the supports provided with the Emriver geomodel. Despite weight-bearing claims, no standard production sawhorse is strong enough to safely support the model. Sawhorses and folding tables can collapse under dynamic or side loading.

Check all fittings on the aluminum supports before each use to be sure they are secure.

When setting up the box, the supports must be laterally level and aligned. They must also be aligned with the proper support point underneath the box. Otherwise the box could warp or collapse when loaded. Make sure spreader bars are fully engaged.

Never set the box up on a surface with a slope exceeding 8% (a 7-inch drop in 7 feet).

Never use more than 27 gal (102 L) of water in the model. Using more than the maximum amount of water and sediment could cause the box or supports to collapse.

Never use more than the provided 150 lb (68 kg) of sediment in the box, and do not place any heavy objects in the box.

Never allow people to sit or stand on or in the box. Never get underneath the loaded box.

Use only the pump and power supply provided with the Emriver Em2. Be certain to connect the power supply to a properly grounded outlet. Always use the Ground Fault Circuit Interrupter (GFCI) provided with the Emriver model (see Figure 18), and be sure to read the manual that accompanies the GFCI.

When using a 12-volt battery to power the model, always use the Emriver Battery Adapter from Little River Research & Design. Never bypass the fuses.

When powering the model with a 12-volt battery, be sure you understand the dangers associated with charging and using lead-acid batteries, and consider using safer spill-proof batteries.

The box should only be used for its intended purpose as stated herein.

If any part of the box or pumping system is damaged, if you have any doubts about the electrical or structural safety of the model, or if you do not understand these directions, do not use this model.

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RESEARCH&DESIGN
CARBONDALE, ILLINOIS, USA

This manual describes the safe use and maintenance of your Emriver Em2 river process simulator. It is very heavy when filled with modeling media and water, and could be dangerous if not properly supported, assembled, and operated.

Therefore, it is important that you read, understand, and abide by all the instructions and warnings in this manual to avoid damage to the model or personal injury. Updates to this manual and other support for the Emriver model may be found at www.emriver.com.
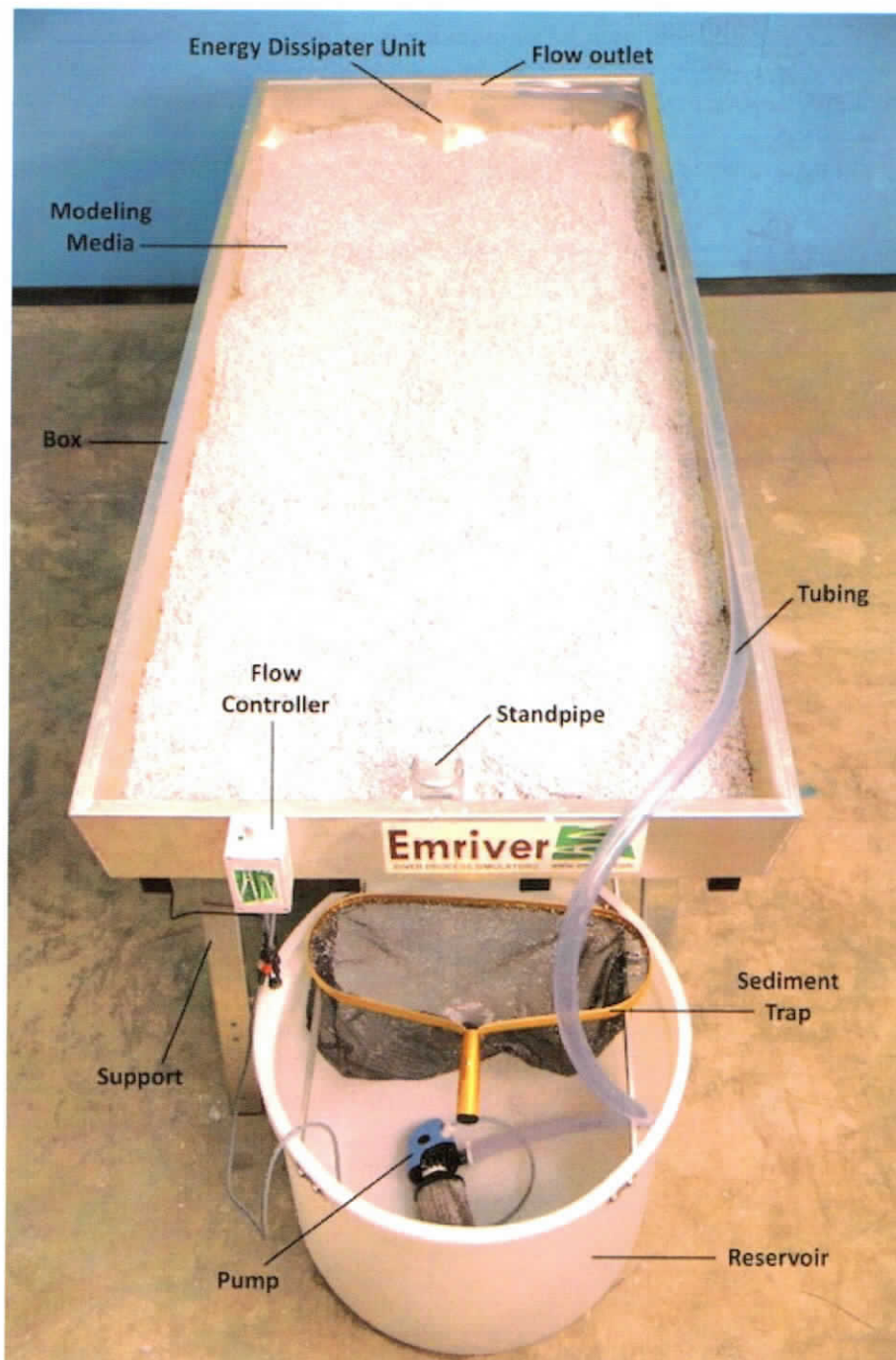
Figure 1. Parts of the Emriver Em2 river process simulator. Power supply is shown in Figure 2.

Figure 2. Power supply included with the Emriver Em2 model, shown attached to the downstream support.

Parts and Accessories Checklist

Emriver parts and accessories checklist:	Other parts and supplies you may want to have on hand:
☐ Emriver Em2 Box	☐ Paper towels and mop
☐ Modeling media in 5 buckets	☐ Shim materials
☐ Emriver Use and Care Manual	☐ Hand level
☐ Emriver Lab Materials	☐ Plastic buckets for sediment and water
☐ Standpipe	☐ Garden hose
☐ Emriver supports	☐ Scraper/trowel
☐ Reservoir	☐ Squeegee
☐ Sediment trap	☐ Notebook
☐ Pump and filter	☐ Household bleach
☐ ¾-inch-diameter tubing	☐ Small towels for drying hands
☐ Electronic Flow Controller	☐ Sieve
☐ Energy Dissipater Unit (EDU)	☐ Laser level (for use with Scientific/Academic Kit)
☐ Flow outlet	☐ 12-volt battery (for use with Emriver Battery Adapter)
☐ Power supply	☐ Battery charger (for use with Emriver Battery Adapter)
☐ GFCI-equipped outlet	
☐ Hydraulic shapes	
☐ Measuring tape	
☐ Solid scoop	
☐ Perforated Scoop	
☐ Riprap stones	
☐ Simulated riparian vegetation	
☐ Scrapers for moving media	
☐ Blue and green dye	

Accessories available for purchase from Little River Research & Design:	
☐ Digital Flow Controller	*Academic Kit:*
☐ Emriver Battery Adapter	☐ Emriver level rod and holder
	☐ Graduated cylinder (250 mL)
	☐ Graduated cylinder (1000 mL)
Structures Kit:	☐ Graduated beaker (2000 mL)
☐ Box culverts	☐ Stopwatch
☐ Walled culvert	☐ Coarse mesh hand sieve
☐ Double walled culvert	☐ Perforated scooper
☐ Model houses	☐ Hand size scooper (not perforated)

WARNING
When fully charged with water, the model can weigh in excess of 500 lb (227 kg). Dynamic loading during use, caused by someone leaning on the model, for example, can greatly increase this load. A collapse of the model's supports could be dangerous and seriously damage the model. You must be certain the model is adequately supported and that you have read and understand all warnings.

STEP 1 - Set up the supports

To assemble the model, begin by setting up the aluminum supports. The shorter support will hold the downstream end of the box, so keep in mind how you would like the model oriented when placing the supports.

If the supports are not properly aligned, the box will twist when fully loaded, which may damage the box. To check alignment, look across the support crossbars as shown in Figure 3. The supports must be both level and parallel.

The supports should be set up so that the crossbars are 49 in (1.25 m) apart and aligned as shown in Figure 3 to prevent damage to the box.

Figure 3. Incorrect (left) and correct (right) support alignment. Crossbars must be both level and parallel when viewed as shown.

On uneven ground, use shims made from ¾-inch plywood or 2-by-4 scraps under the support feet as necessary.

Be sure all four feet of each support are properly supported. One horse is modified to provide clearance for the reservoir (see Figure 9). Place the supports so this opening lies at the downstream end.

The Emriver supports have a difference in height of about 3 in (76 mm), yielding a box slope of 6%.

The slope of channels in the box will be determined by the position of the standpipe, so the exact box slope is not necessarily important.

Note: Labels on the supports display arrows that indicate proper placement and orientation, with the shorter support at the geomodel's downstream end. See Figure 4.
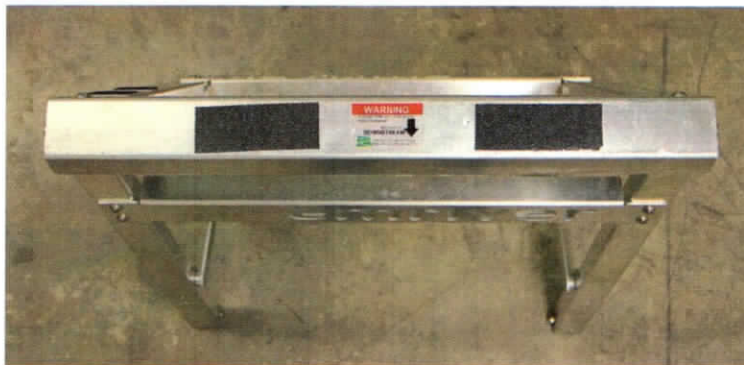

Figure 4. Labels on the supports indicate proper orientation, with the shorter support at the downstream end.

STEP 2 - Install the standpipe in the drain assembly

Install the standpipe by sliding it into the drain assembly from the **underside of the box**. Insert the handle first. The seal may be damaged if you insert the standpipe from above. For initial setup, the standpipe should extend into the box approximately 2 in (50 mm).

The standpipe will move much more freely in the drain assembly seal when wet — you may want to moisten the standpipe before inserting it.

The standpipe has been lubricated with a silicone grease to allow smooth action against the rubber seal. This lubricant is waterproof, nontoxic, and should last for many uses. As needed, apply a small amount to restore smooth movement. This silicone grease may be found at most hardware stores and is typically used for waterproofing electronics and o-rings. An extra tube of silicone grease has been provided with your model and can be found inside the red carrying case. **Keep the standpipe coated with a thin film of silicone grease** to ensure years of trouble-free operation.

The drain assembly nut should not be over tightened. Some water should leak from around the drain assembly, down the outside of the standpipe, and into the reservoir. This flow allows "groundwater" to exit the media and improves river modeling performance.
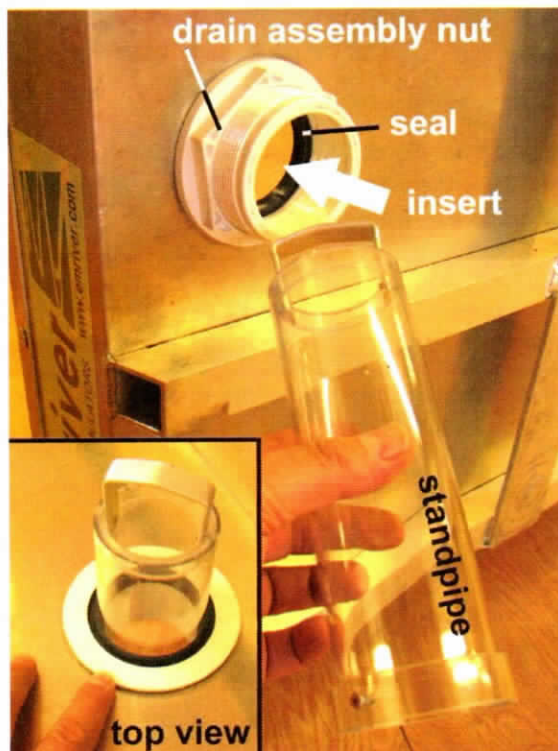
Figure 5. Insert the standpipe from the underside of the box to avoid damage to the seal. The standpipe will move much easier when the seal is wet. Never attempt to install the standpipe from the top of the box.

STEP 3 - Install the box

The box MUST be supported at the two reinforced ribs, and nowhere else. See Figure 6.
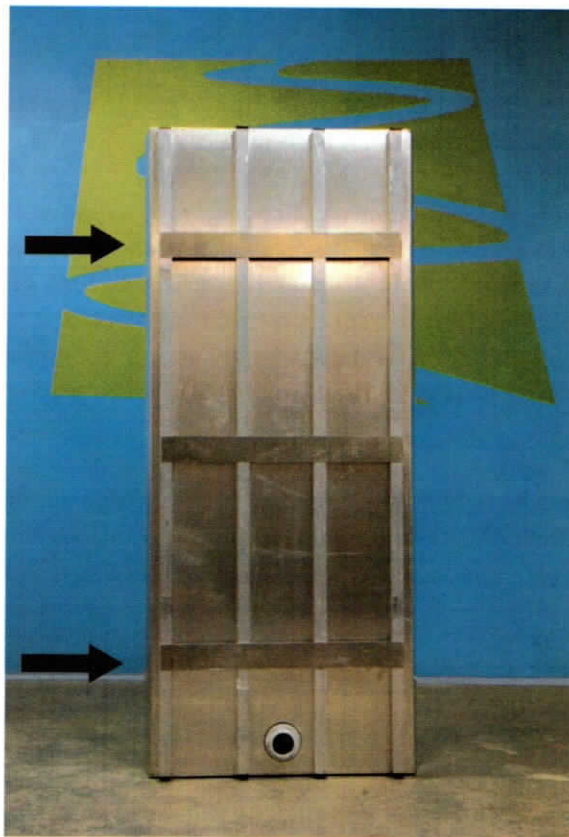
Figure 6. Support ribs on the underside of the box (indicated with arrows) are areas where the box must be supported.

CAUTION
The supports must be properly aligned with the support ribs on the box before any weight is added to the box. See Figure 8.

When the supports are level and aligned, place the box on them.

Note: Gaps of more than 0.25 in (6 mm) between the box's support ribs and the support crossbars indicate that the supports are **NOT** properly aligned.

Figure 7. Lift the box onto the supports. It is best to complete this task with two people.

Figure 8. Check to ensure that the support ribs on the box rest on the supports properly.

STEP 4 - Position the reservoir

Place the reservoir beneath the box at the downstream end. The reservoir should be located as shown in Figure 9 so that the standpipe will drain into the reservoir. Note that the support at the downstream end of the box has an opening for the reservoir.

Figure 9. Place the reservoir beneath the support at the downstream end.

STEP 5 - Position the pump

Attach one end of the tubing onto the arm of the pump. Place the pump, lying on its side, in the bottom of the reservoir, keeping the wire connectors outside of the reservoir. Check that the filter is securely attached to the pump. *Note that you may have a pump and filter that look different than those in the photo, but the setup is the same for each.*

Figure 10. Place the pump with filter in the bottom of the reservoir, lying on its side. The filter easily screws onto the pump. The tubing is attached to the arm on the pump.

STEP 6 - Fill the reservoir

Using the graduations on the reservoir, fill it with 27 gal (102 L) of water. The reservoir is graduated in U.S. gal. Position the reservoir before filling it with water. **Do not move the reservoir after it has been filled as this will cause damage to the reservoir.** <u>Do not fill the reservoir with more than 27 gal (102 L) of water.</u>

WARNING
Using more than 27 gal (102 L) of water could damage the box or cause it to collapse. Do not exceed this volume and **do not start the pump** until you have filled the reservoir and carefully measured the total volume of water in the system.

WARNING
When full of water, the reservoir weighs over 200 lb (91 kg). It will be damaged or destroyed if moved when full.

STEP 7 - Position the sediment trap

Place the sediment trap on the aluminum struts in the reservoir. Be sure the sediment trap sits directly below the standpipe.

Figure 11. Place the sediment trap on the aluminum struts in the reservoir.

STEP 8 - Attach and position the tubing and flow outlet

Connect flow outlet to the tubing as shown below in Figure 12.
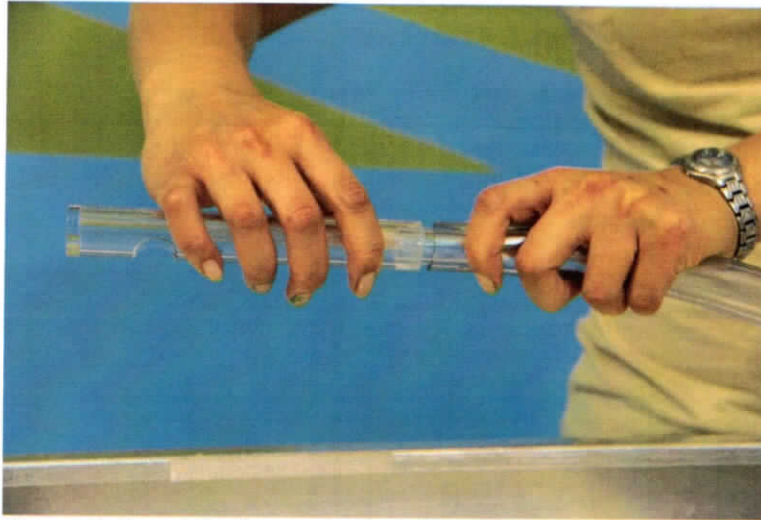
Figure 12. Insert the flow outlet into the tubing.

After the tubing is attached, align and attach the mushroom fasteners on the back of the flow outlet to the fasteners on the inside of the box at the upstream end, as shown in Figure 13. The outlet should snap into place.

Figure 13. Align the mushroom fasteners on the flow outlet with those on the inside of the box at the upstream end. Snap the fasteners together to secure the outlet to the box.

Place the tubing along the inside edge of the box, starting from the attached flow outlet. The tubing should run out of the box and into the reservoir, where it is connected to the pump (see Figure 1). Starting from the upstream end, roll the tubing under the lip of the box until you are near the standpipe. This will keep the tubing from interfering with demonstrations and media behavior. See Figure 14.

Figure 14. Tuck the tubing beneath the lip on the inside of the box.

STEP 9 - Position the Energy Dissipater Unit

Place the Energy Dissipater Unit (EDU) beneath the flow outlet. The flow outlet opening should line up with the innermost cylinder of the EDU. The EDU's Y-shaped opening should face downstream. See Figure 24 for a photo of the EDU while in use.
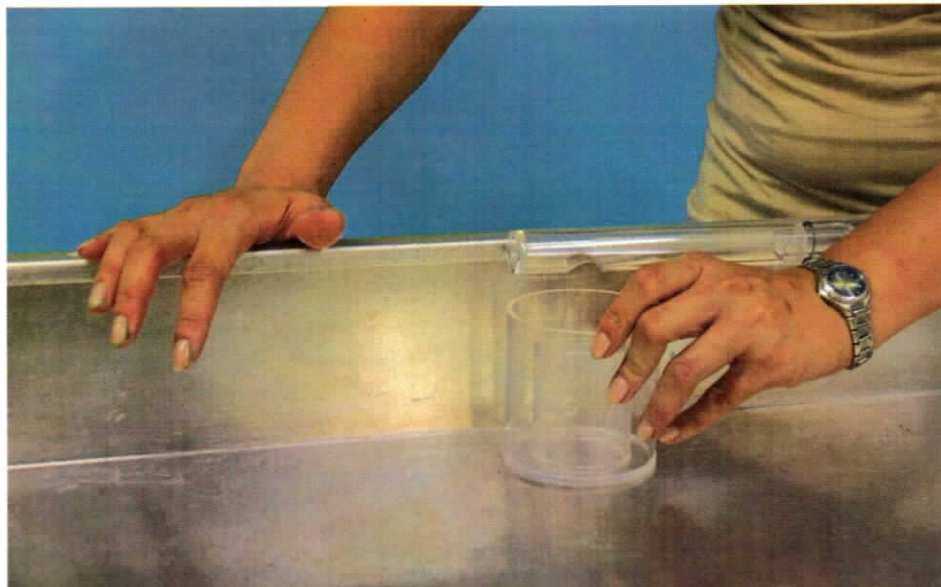
Figure 15. Place the EDU beneath the flow outlet.

STEP 10 - Fill the box with modeling media (sediment)

Pour the media into the box one bucket at a time. Spread the media using the scraper included with your geomodel to distribute it evenly throughout the box. See Figure 16.

Handling the media:

- During experiments and demonstrations, sediment leaving the box will accumulate in the sediment trap. The rate at which the sediment trap fills is highly variable, depending on activity in the box.
- When the sediment trap becomes full, use the perforated scoop included with the Emriver model to return sediment to the box.

Allowing sediment to accumulate in the reservoir will **NOT** harm the pump. The filter is sized to allow the pump to function normally even when completely buried in sediment. However, fine debris such as dirt, lint and pollen can accumulate in the media over time and clog this filter. Just give it a rinse now and then.

Figure 16. Pour the media into the box

STEP 11 - Power the pump

Attach the brick power supply to the leg of the shorter support using the mushroom fasteners on the support and the brick power supply. Wrap the Velcro® strap around the support leg and the brick power supply to fasten securely. See Figure 17.
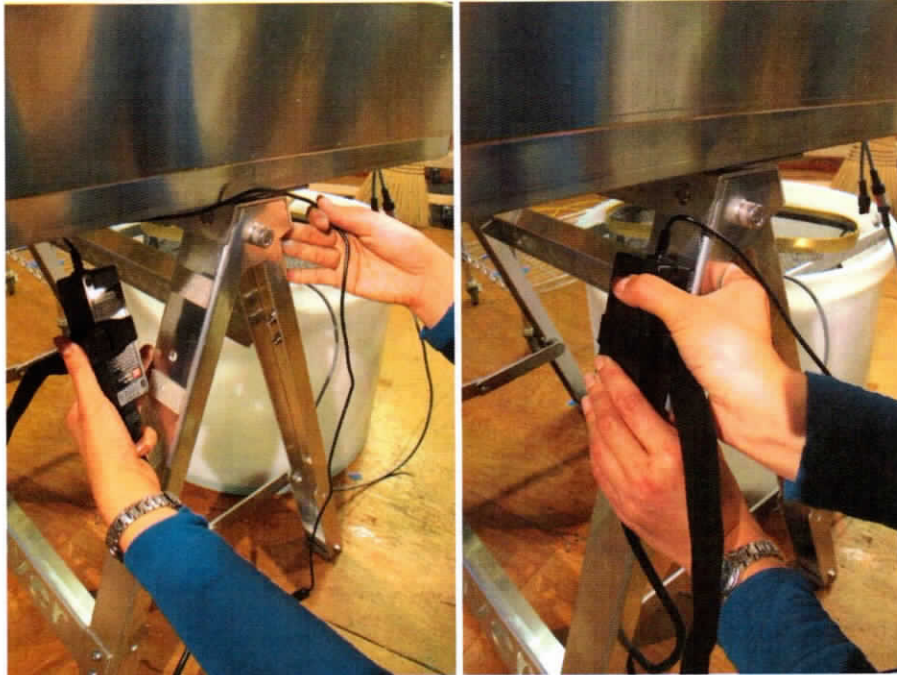
Figure 17. Attach the brick power supply to the leg of the downstream support.

Connect the power cord to the Ground Fault Circuit Interrupter (GFCI) (US users only). If you are using an extension cord, connect the extension cord to the GFCI. Do not plug the model's power cord directly into a wall outlet. **Always use the GFCI.**
If the red indicator light on the GFCI is on, it is ready for use and the model should be powered. If the red indicator light is off, press the red "Reset" button.
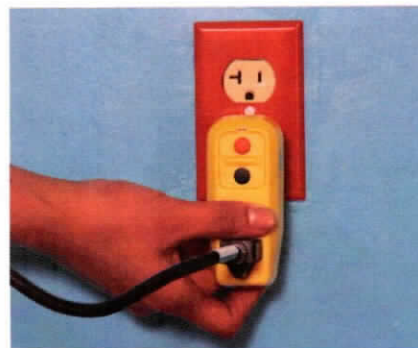
Figure 18. Always connect the power cord to the GFCI. Never plug the model's power supply directly into a wall outlet.

STEP 12 - Attach the Electronic Flow Controller (Model K28, or older *Crayfish*)

If you purchased the Digital Flow Controller (Model K500, or older *Alix*), see the separate instruction sheet. Attach the flow controller to the downstream end of the box using the hook *(note that some older controllers have a Velcro connection)*. See Figure 19.

Figure 19. Attach the controller to the downstream end of the box.

Connect the pump to the controller using the gray, blue, and orange connectors (note there is one red tab that is not a connector). Then, connect the controller to the power supply using the black and red connectors. See Figure 20. *Note that older models of the pump and controller have different connectors. The older models will not work with the new models as shown here. Simply match up the colors on the connectors.*
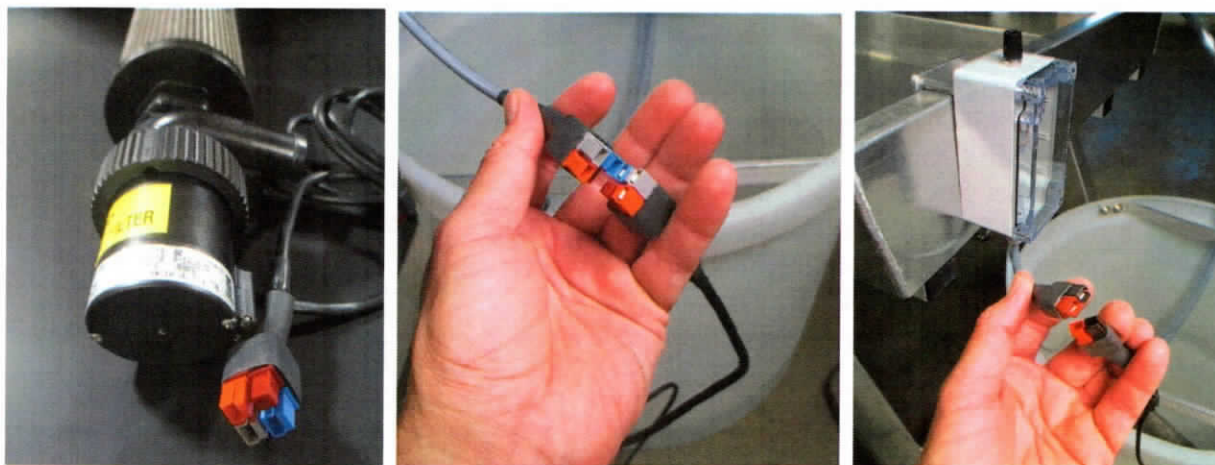
Figure 20. The pump, at left, connects to the flow controller, middle. The flow controller, right, connects to the power supply. The color-coded connectors on each component will match up.

A square, green indicator light in the circuit board displays when the power is on. Change flow rate using the knob on the controller. Pressing the knob resets the flow to zero. See Figure 21.

Troubleshooting: If the controller does not produce flow, and there are no lights on the circuit board, check the power supply to ensure that the cord is fully connected and that there is a light on the power brick.

If the power light is on, but there is no flow, check to see that the flow indicator LED is lit on the circuit board (round green light). If it is lit, check the connection between the controller and the pump. Also check for any obstructions or clogged filters. Expel all air from pump and hose. If the flow indicator LED is not lit, adjust the knob clockwise until the LED is lit and there is flow.

Figure 21. Turn on the pump and control flow with the knob.

Note: The knob does not turn the pump off completely; it merely stops flow. The pump is on as long as the power is connected. To completely turn off the pump, the power must be disconnected.

Note: If the pump is reluctant to prime when started, reorient or shake it a bit (while underwater) to remove air trapped in its intake. If necessary, clean any debris from the filter by unscrewing it from the pump and flushing it with water.

Flow Pathways

After the Emriver Em2 model has been assembled according to the instructions in this manual, it is ready for use. Figure 22 is a conceptual chart that shows flow pathways of water and electricity through a properly assembled Emriver Em2 model during use.

Figure 22. Flow pathways for water (solid line) and electricity (dotted line).

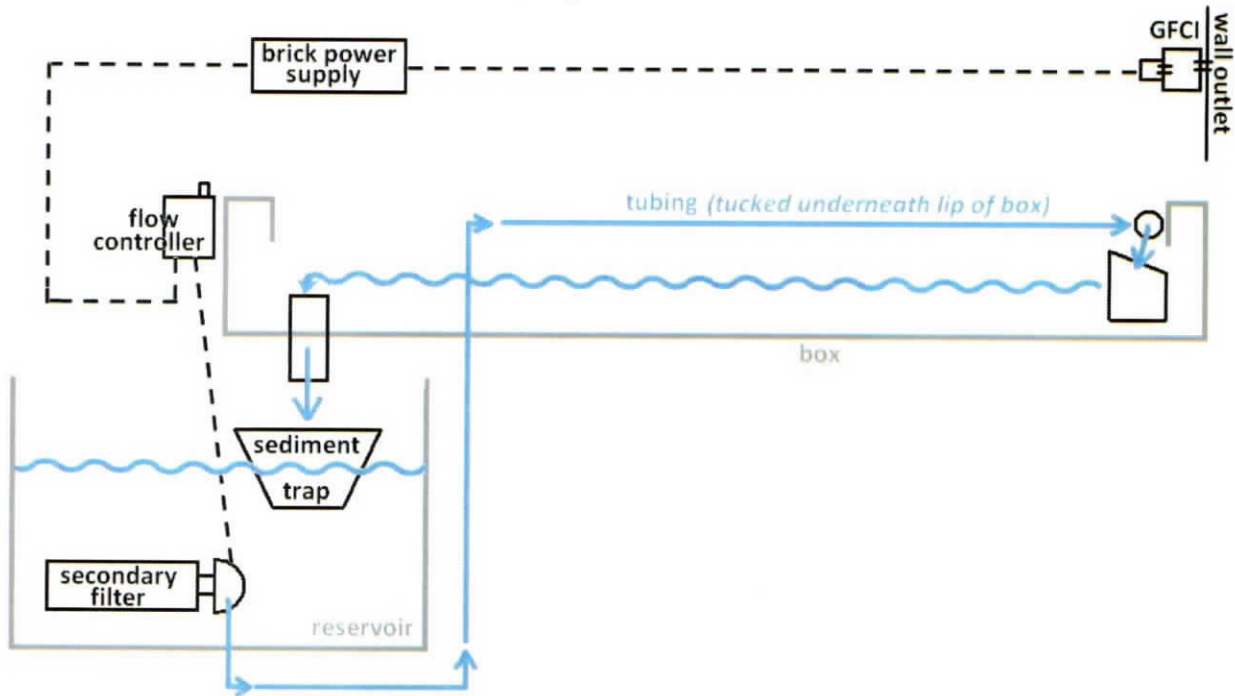© 2012 Little River Research & Design; updated July 2018

1. Read and understand all warnings in this manual.

2. Find a surface with a slope of less than 8%.

3. Set up supports so the crossbars are 49 in (1.25 m) apart. Check that the supports are aligned properly to prevent twisting of the box. **Check the supports for damage and loose connectors before setting up the model.**

4. One of the supports has an opening for the reservoir – be sure to place this support at the box's downstream end with the opening for the reservoir facing downstream. Labels on the supports display arrows that indicate correct placement and orientation. Use these arrows as a guide for proper support setup and reservoir placement.

5. Insert the standpipe in the drain assembly from the underside of the box so that the standpipe extends at least 2 in (50 mm) inside the box.

6. Place the box on the supports. Before adding any weight to the box, be sure that the support ribs on the box's underside rest directly on the supports, and that there are no gaps greater than 0.25 in (6 mm) between the support crossbars and the box support ribs.

7. Place the reservoir under the standpipe and place the pump in the reservoir, lying on its side. Check the pump filter for fine debris.

8. Fill the reservoir with 27 gal (102 L) of water using the graduations on the inside of the reservoir. **Do not exceed 27 gal (102 L).**

9. Place the sediment trap on the aluminum struts in the reservoir. Be sure the sediment trap sits directly beneath the standpipe.

10. Connect the tubing and flow outlet. Attach the flow outlet to the box. Place the Energy Dissipater Unit under the outlet. The innermost cylinder of the EDU must align with the mouth of the flow outlet and the EDU's Y-shaped opening should face downstream.

11. Fill the box with modeling media.

12. Fasten the brick power supply to the leg of the downstream support. Plug the model's power cord into the GFCI provided with the model and plug the GFCI into a wall outlet. **Never plug the model's power cord directly into a wall outlet.**

13. Attach the Electronic Flow Controller to the box.

14. Connect the power supply to the flow controller. Connect the controller to the pump. Match the color-coded connectors. Adjust the knob on the controller to desired flow rate.

15. Begin experiments and demonstrations.

Disassembly, Transport, and Storage

When breaking down the model, remember that **the reservoir cannot be moved while full of water.**
- It is easiest to use the pump and tubing to drain the reservoir.
- Remove the flow outlet from the tubing and place the tubing so that water drains into a container that can be carried when full of water (media buckets work well for this purpose) or directly into a proper drainage area. See Figure 23.
- Turn on the pump to move water out of the reservoir.

As much as 10 gal (38 L) of "groundwater" will remain in the media and box after the pump has been turned off and flow from the standpipe has slowed to a deceptive trickle. Before storage of the model, most of this remaining water must be drained from the sediment. This water can take several hours to drain.

Pile the media at the upstream end of the box to aid drainage. You can also remove the standpipe to speed along the process. You may also elevate the upper end of the model with a 2-inch shim between the box's support rib and the support.

The sediment is biologically inert and can be removed from the model and stored damp, though it is best to provide a means for drainage. A 40- or 50-gal container with a few holes in the bottom works well. A scrap of plastic filter cloth over the holes will keep sediment from being lost. Remember that the sediment may weigh well over 200 lb (91 kg) when wet.

Figure 23. Place the tubing so that it drains into a smaller, separate container if there is no drainage area nearby. Turn on the pump to move water out of the reservoir.

Note: To prevent growth of mold and bacteria, add about 10 ml of household bleach to the buckets if you plan to store them wet.

- Drain the model and reservoirs after each use; do NOT leave water in the Emriver models.

- To keep your model sanitary, change out the water every day and drain the table by lowering the standpipe all the way.

- If you cannot change the water every day, add about 6 ml of household bleach to the reservoir every day, and run the pump to distribute it through the system. This will prevent algae and bacteria from colonizing the model. You may also use widely available home water filters to remove contaminants. **Adding too much bleach or chlorine can damage the aluminum parts.**

- Never use lithic materials (i.e., sand) in the Emriver tables.

- Do not use metallic objects in the model.

- Power down the pump and controller after each use by disconnecting the pump from the controller, and disconnecting the controller from the power supply.

- Do not use solvents, which may dissolve or weaken the plastic tubing. If the tubing is left in the sun while wet, it may support algae growth and become cloudy. Routing a mild bleach solution through the tubing after use will minimize this problem. Removing all standing water in the lines will help as well. If tubing becomes cloudy you may purchase a replacement from us, or buy from your local hardware store, but that which is supplied with your model is a high quality type and is longer lasting and more flexible.

- All bolts on the supports should be periodically checked for tightness. Loose or missing bolts will affect the strength of the supports. The bolts should be as tight as possible while still allowing the supports to fold.

- Clean the filter on the pump periodically by unscrewing the filter from the pump and thoroughly rinsing it inside and out.

Quick Start Guide for the Emriver Em2

Some basic guidelines for using the Emriver are included here. Further instructions and exercises can be found in the **Emriver Lab Manual**. In addition, the guidelines and videos at the following places will help you begin.

- www.emriver.com
- http://serc.carleton.edu/NAGTWorkshops/geomoph/emriver/index.html
- Emriver DVD (located in front flap of this manual); all videos are also available as a Playlist on our YouTube channel. The link is available from our website.

General Tips

The primary independent variables imposed on your experimental channels are channel slope and discharge. To gain familiarity with the capabilities of the model, it is best to begin by exploring both of these variables at relatively low values.

Slope is controlled by the slope of the box (which is 6% when you use the support horses on a level surface) and by the elevation of the standpipe. A 6% slope makes for a fast-moving stream when the standpipe is lowered. Raising the standpipe to 2 inches will reduce the effective slope to 3%, and raising it fully will reduce the slope to nearly zero. This is the easiest way to control the slope of your model.

Slope of your channels is also dependent, of course, on their sinuosity. It is best to begin with lower slopes. A small laser level can be used to explore the relative elevations of the upper end of the channel and the standpipe. The modeling media is manufactured within a range of specifications and its specific gravity can vary from batch to batch. This may cause slightly different sediment behavior in different models.

As you are learning to use the model, begin with low flows (about 25 ml/s, as seen in Figure 24, left side). These flows may seem too low at first glance, but low flows often give the most interesting results. Higher flows (about 125 ml/sec, shown in Figure 24, right side) will mobilize all sediment in the channel, which, in many demonstrations and experiments, will make it difficult to see specific processes. Try forming a channel with moderate flows (less than 75 ml/s), and then lowering flow to find the point at which sediment transport in the channel ceases. Work up from this point.
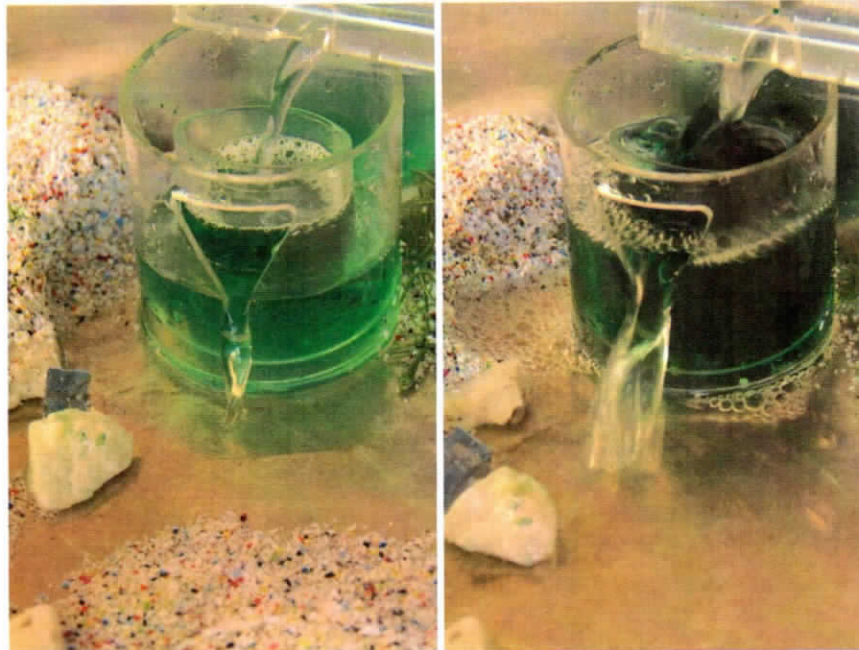
Figure 24. Low flow (left) and high flow (right) as it appears when looking at the EDU.

When you notice media being scoured from in front of the EDU, you may replenish it by pushing the banks closer together adjacent to the scour or by sprinkling media directly into the stream. If you pile the media excavated from your initial channel near the EDU, you will have a ready supply. Placing 8-10 pieces of limestone riprap directly under the outlet of the EDU will further calm the stream and reduce scouring.

A straight channel from the EDU to the standpipe in your river model will eventually form meanders, point bars, cutbanks, and other river features just as in nature, but it may take a couple of hours for these features to fully develop. Below are a couple of initial conditions that can produce features more quickly for teaching and demonstrating.

Meandering Channels

When forming experimental channels, mimic what you see in the field. For example, meandering gravel-bed rivers will have low point bars that slope gradually up to a floodplain, and relatively steep banks on the outsides of bends. Routing brief flood pulses (high flows of about 190 ml/sec, see Figure 24, right side) through your channels will give them more realistic characteristics. Remember that your modeled channels should be in a near-equilibrium condition in order to show the effects of disturbances.

Delta Building

To explore delta building and alluvial fans, move most of the media to the upstream 2/3 of the box and distribute it evenly. The downstream third of the box can have the aluminum 'bedrock' exposed, or may have a thin layer of media in it. You may wish to remove one 5-gallon bucket of media from the model.

Cut a straight or meandering incision in the media from the EDU to the beach and sculpt a gentle slope in the media away from your initial channel with the plastic scraper or the corner of a scoop. You may have media above the edge of the box at the upstream end of your model.

Raise the standpipe to 7cm (2.75") and start the pump, adjusting the flow to about 100 ml/s. The EDU will be about half-filled with water. Sediment will immediately begin moving downstream, and will be deposited in the forming lake at the downstream end of the model. As the lake fills, you will begin to see all the classic delta formation phenomena in the model. Periodically raising and lowering the standpipe will mimic rising and falling tides or sea level change and introduce layers of complexity to the delta. Raising and lowering the flow rate of the pump will further add to the dynamic qualities of the model.

Stratigraphy

If you have color-coded media in your model, examining the stratigraphy can give fascinating insight into the depositional history of your experiments. As in nature, the most complex stratigraphy is often the result of long-term deposition under dynamic conditions. Flood sequences, meandering channels, delta building, and other fluvial processes all leave different marks on the stratigraphic record.

The best way to examine the stratigraphy in your model is to drain it overnight so the media can pack down. (Saturated media has lower cohesion than damp media.) Use the corner of a large scoop to cut V-shaped incisions laterally across the media bed. Cutting into the media this way magnifies the thickness of the layers and keeps the cut wall from collapsing.

Cleanup

When you are ready to put your Em2 away, dry the media as much as possible by fully draining the model and piling the media in the middle of the box for a day or so if possible. Scoop as much media as you can back into the buckets. If the reservoir is still full of water, remove the standpipe, pull the inlet tube from the end of the hose, and use the pump to wash all remaining media out of the box and into the sediment trap. A small squeegee is ideal for coaxing the last bits of media to the hole.

Emriver item		Specifications
Modeling media	modeling media material	particulate thermoset plastic
	modeling media (sediment) dry wt.	150 lb (68.2 kg)
	sediment specific gravity	1.55
	sediment particle size	0.02 - 0.09 in. (0.5 - 2.1 mm)
Box	box weight	approx. 38 lb (17.5 kg)
	box dimensions	77 x 33 x 5 inches (1.96 x 0.83 x 0.13 m)
Reservoir	water capacity	27 gal (102 L)
Pump	pump capacity	12V DC marine pump, rated 500 gph at 2.0 amps.
		Output ranges from 0 to 250 mL/sec
Entire system	wt. of entire system (dry)	approx. 260 lbs (118.2 kg)
	wt. of entire system (wet, @25 gal)	approx. 460 lbs (209.1 kg)
	min. floor space required for demonstration with 12 people	12 x 15 ft (3.6 x 4.6 m)

When forming experimental channels, mimic what you see in the field. For example, meandering gravel-bed rivers will have low point bars that slope gradually up to a floodplain, and relatively steep banks on the outsides of bends. Routing brief flood pulses (high flows of about 190 ml/sec, see Figure 24, right side) through your channels will give them more realistic characteristics. Remember that your modeled channels should be in a near-equilibrium condition in order to show the effects of disturbances. The guidelines and videos at the following places will help you begin.

- www.emriver.com
- http://serc.carleton.edu/NAGTWorkshops/geomoph/emriver/index.html
- Emriver DVD (located in front flap of this manual); all videos are also available as Playlist on our YouTube channel. The link is available from our website.

Quick Start Guide for the Emriver Em2

Be sure to read and understand the instructions contained in the Em2 User's Manual, especially the safety instructions at the front.

General Tips

The supports of the Em2 model create a slope of about 6%, which makes for a fast-moving stream when the standpipe is lowered. Raising the standpipe to 2 inches will reduce the effective slope to 3%, and raising it fully will reduce the slope to nearly zero. This is the easiest way to control the slope of your model.

Lower flow rates from the pump almost always give more interesting results than constant flood conditions, though an early flood followed by a return to normal will help establish terraces and strong banks. Intermittent flooding is part of life for just about any river.

When you notice media being scoured from in front of the EDU, you may replenish it by pushing the banks closer together adjacent to the scour or by sprinkling media directly into the stream. If you pile the media excavated from your initial channel near the EDU, you will have a ready supply. Placing 8-10 pieces of limestone riprap directly under the outlet of the EDU will further calm the stream and reduce scouring.

A straight channel from the EDU to the standpipe in your river model will eventually form meanders, point bars, cutbanks, and other river features just as in nature, but it may take a couple of hours for these features to fully develop. Below are a couple of initial conditions that can produce features more quickly for teaching and demonstrating.

Meandering Channels

Distribute the media evenly throughout the model, leaving a couple of inches in front of the EDU and the standpipe. Pack the media down somewhat with the scoop or even a mason's square trowel. Use the plastic scraper to cut an incision in the media with at least one full meander. (Draw the letter S with an inlet and outlet channel going to the EDU and standpipe, respectively.) Use the small, curved scoop or the corner of the large scoop to excavate a U-shaped channel profile to about half of the media's depth. Experiment with tighter and more gradual bends. Can you force the stream to abandon its channel and leave an oxbow lake?

Delta Building

To explore delta building and alluvial fans, move most of the media to the upstream 2/3 of the box and distribute it evenly. The downstream third of the box can have the aluminum 'bedrock' exposed, or may have a thin layer of media in it. You may wish to remove one 5-gallon bucket of media from the model.

Cut a straight or meandering incision in the media from the EDU to the beach and sculpt a gentle slope in the media away from your initial channel with the plastic scraper or the corner of a scoop. You may have media above the edge of the box at the upstream end of your model.

Raise the standpipe to 7cm (2.75") and start the pump, adjusting the flow to about 100 ml/s. The EDU will be about half-filled with water. Sediment will immediately begin moving downstream, and will be deposited in the forming lake at the downstream end of the model. As the lake fills, you will begin to see all the classic delta formation phenomena in the model. Periodically raising and lowering the standpipe will mimic rising and falling tides or sea level change and introduce layers of complexity to the delta. Raising and lowering the flow rate of the pump will further add to the dynamic qualities of the model.

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Cleanup

When you are ready to put your Em2 away, dry the media as much as possible by fully draining the model and piling the media in the middle of the box for a day or so if possible. Scoop as much media as you can back into the buckets. If the reservoir is still full of water, remove the standpipe, pull the inlet tube from the end of the hose, and use the pump to wash all remaining media out of the box and into the sediment trap. A small squeegee is ideal for coaxing the last bits of media to the hole.

Instructions for cleaning the GRI pump

Your GRI pump should be checked monthly as part of routine maintenance. If you notice flow reduction or a complete cease in flow, disassemble and clean the pump following the instructions below. If you have questions in the process, please call Little River at 618-529-7423.

1. Disconnect GRI pump from controller and power supply.

2. Unscrew retaining ring.

3. Pull threaded portion of pump housing to remove. Be careful not to remove the O-ring.
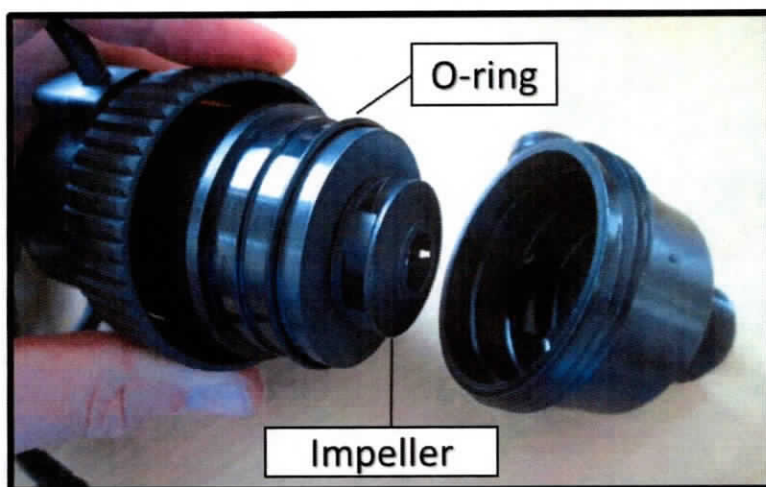
O-ring

Impeller

4. Remove the impeller by pulling it from the pump housing.
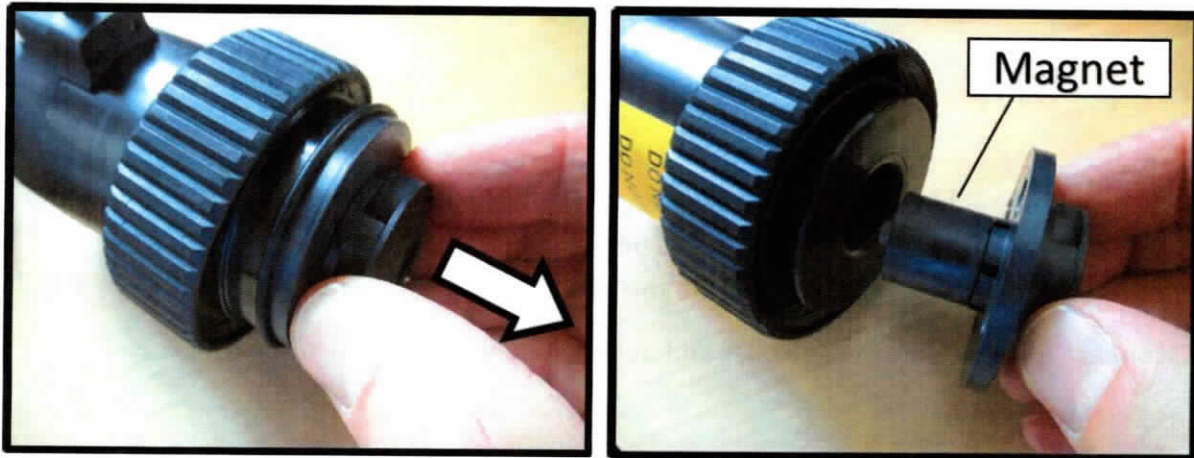
5. Clean all parts by rinsing with water. Make sure the narrow gaps around the impeller are clear of debris.
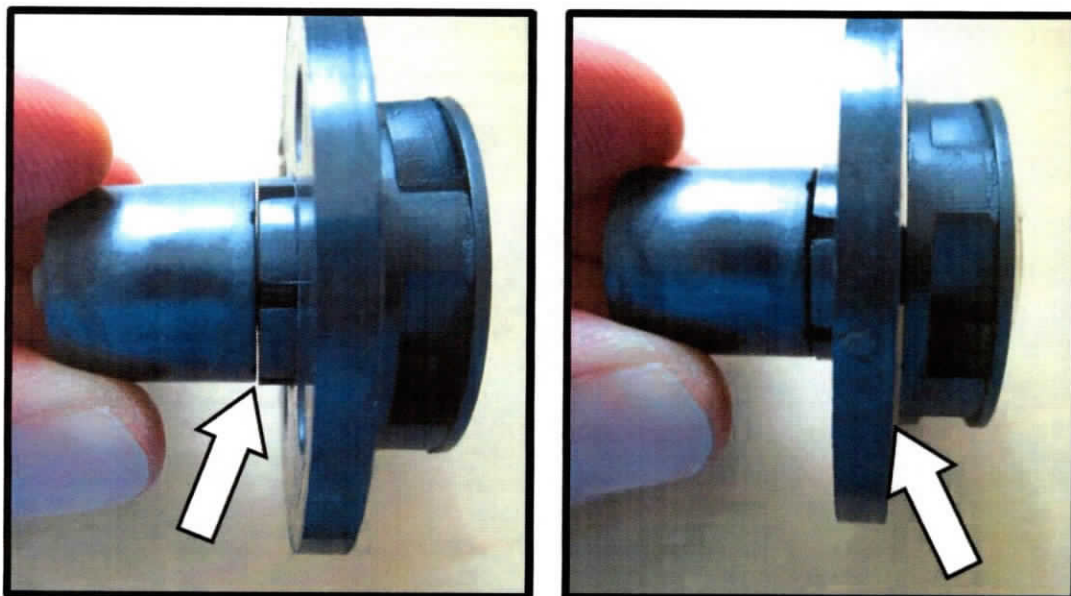
6. Moisten the whole unit to lubricate the O-ring and reassemble the pump by inserting the magnet and impeller into the housing. Make sure O-ring is in place and then press the threaded portion of the housing firmly onto the pump body. Tighten the retaining ring. When properly tightened, there should be no thread showing past the edge of the ring.

O-ring

No thread showing

7. Attach filter and tubing. Submerge pump fully before restarting. Agitating the assembly lightly in the water will help clear air from the filter and pump.

Emriver Lab Manual

Chapter 1

1 Safety and Lab Manual Contents

The Emriver Lab Manual goes beyond the basic information given in the Use and Care Manual to describe methods for advanced demonstrations and experiments.

This manual is a companion to the *Use and Care Manual*, and essential information in that manual is not repeated here. *It is vital that you read and understand the Use and Care Manual before using this Lab Manual.*

The Emriver model is capable of dozens of experiments and demonstrations, and new ones are constantly being developed. For the latest information on module development please contact us at info@emriver.com or visit our support page at emriver.com/supportFAQ/.

See Chapter 2 for detailed Setup procedures.

In this chapter

1.1 Safety

1.2 Emriver Lab Manual Contents

1.3 Introduction
1.3.1 Setting Up for Demonstrations

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1.1 Safety

YOU MUST READ AND UNDERSTAND THESE WARNINGS BEFORE USING THE EMRIVER MODEL

- The Emriver model is very heavy when filled with water and sediment. A collapse of the model supports could severely injure or kill a person. Be absolutely sure you understand how to use the supports.

- Use only the supports provided with the Emriver geomodel. Despite weight-bearing claims, no standard production sawhorse is strong enough to support the model. Sawhorses and folding tables can collapse under dynamic or side loading.

- Check all fittings on the aluminum supports before each use to be sure they are secure.

- When setting up the box, the supports must be laterally level and aligned. They must also be aligned with the proper support point underneath the box. Otherwise the box could warp or collapse when loaded. Make sure spreader bars are fully engaged.

- Never set the box up on a surface with a slope exceeding 8% (a 7-inch drop in 7 feet).

- Never use more than 27 gal (102 L) of water and the provided 150 lbs (68 kg) of sediment in the Em2, 40 gal (151 L) of water and 240 lbs (109 kg) of sediment in the Em3, or 60 gal (227 L) and 360 lbs (163 kg) of sediment in the Em4. Using more than the maximum amount of water and sediment could cause the box or supports to collapse.

- Do not place any heavy objects in the box and never allow people to sit or stand on or in the box. Never get underneath the loaded box.

- Use only the pump and power supply provided with the Emriver system. Be certain to connect the power supply to a properly grounded outlet. Always use the Ground Fault Circuit Interrupter (GFCI) provided with the Emriver model, and be sure to read the manual that accompanies the GFCI.

- When using a 12-volt battery to power the model, always use the Emriver battery adapter from Little River Research & Design. Never bypass the fuses.

- When powering the model with a 12-volt battery, be sure you understand the dangers associated with charging and using lead-acid batteries, and consider using safer spill-proof batteries.

- The box should only be used for its intended purpose as stated herein.

- If any part of the box or pumping system is damaged, or you have any doubts about the electrical or structural safety of the model, or if you do not understand these directions, do not use this model.

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1. Introduction
1.1 Safety
1.2 Lab Manual Contents
1.3 Introduction

2. Advanced Setup and Operation
2.1 Channel Slope
2.2 Slope Variables and Equations
2.3 Controlling Flow
2.4 Initial Conditions
2.5 Sediment Properties

3. Measurements
3.1 Thalweg and Other Horizontal Measurements
3.2 Vertical Measurements and Laser Levels
3.3 Water Discharge
3.4 Sediment Discharge

4. Demonstrations
4.1 In-channel Gravel Mining
4.2 Sediment Transport Measurement, Continuity, and Channel Stability

5. Exercises and Experiments
5.1 Channelization
5.2 Bank Armoring
5.3 Modeling Riprap

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1.3 Introduction

The first models similar to the Emriver that we know of were built in the late 1980s by river managers working for the Missouri Department of Conservation (MDC). These models were developed to meet a dire need: teaching private landowners about river geomorphology.

Static drawings and talks had proven inadequate. There is a human tendency to oversimplify the morphologic response of rivers to practices like channel straightening or bedload mining, and attempts at education were frustrating. Miners, farmers and loggers who had observed river behavior all their lives were understandably reluctant to accept new ideas. But those early models built by MDC fisheries biologists proved to be very powerful tools for conveying the complicated processes and responses of rivers. Landowners and laypeople could clearly see, for example, how headcuts and incision can damage land upstream of a gravel removal operation.

Indeed, the Emriver geomodel and its ancestors are very powerful tools for teaching and understanding river processes and morphology for all ages. On seeing the model, experienced river observers invariably recognize morphological features and processes they have seen in the field. The strong similarities between channel behavior in the Emriver model and the behavior and morphology of real rivers is very convincing, even for the most skeptical observers. Observation of these processes is made easier by a greatly compressed time scale and expanded physical scale. Things happen faster in the model, and in the 2-meter Emriver Em2 one can see the equivalent of a few hundred meters of real stream. Thus we often see people make great leaps in understanding by observing the model. The Emriver model and its ancestors used by Midwestern river conservationists have proven to be very powerful tools in teaching landowners and other stakeholders how rivers function and respond to human impacts.

The Emriver model is also a powerful tool for education of professional river managers with backgrounds in fisheries, forestry, ecology, stream biology or civil engineering who may have little or no formal training in applied fluvial geomorphology, as well as children and laypeople through environmental outreach education. And, of course, the model is very useful to academic geomorphologists for more advanced demonstrations, research, and teaching.

1.3.1 Setting Up for Demonstrations

Teaching is an art. As with any teaching tool, your success with the Emriver model will depend on your understanding of fluvial geomorphology, the model, and your audience. Preparation is important. With a hostile or skeptical audience (say, a group of gravel mining advocates), your understanding the Emriver model and its operation will be particularly important. The model is not difficult or complex to operate, but small

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differences in how you use it can make big differences in your teaching effectiveness. In general, you should remember these guidelines:

- For field demonstrations, allow plenty of time for setup. The model can be set up and ready for use in as little as 30 minutes, but you should allow an hour, especially in unfamiliar settings. You should allow at least 10 minutes to start a model in which the groundwater has drained – it can take this long to replenish the groundwater so you can begin demonstrations.

- Understand channel slope and discharge and how they affect your demonstrations. It is tempting to use higher discharges for more dramatic (and faster) effect, but you will usually get better results by using lower flow rates. This chapter gives recommended starting slopes and discharges for demonstrations. Chapter 2 (*Advanced Setup*) gives detailed instructions on setting up the model. Those who use the model infrequently and only for a few demonstrations should standardize and write down their setup procedure to achieve the necessary box and channel slope with minimum hassle.

- At the start of your demonstration, tell your audience about the model and how it works. People are invariably curious about the modeling media (and almost never guess that it is plastic). For advanced groups, you may want to explain how the lower density of the plastic sediment accounts for scaling (see *Sediment Properties* in Chapter 2). If your audience is overly concerned with the mechanics of the model, they may miss parts of your demonstration.

- Limit your audience size so that observers can stand comfortably around the model and can see activity inside the box. You may have to split a large audience into smaller groups.

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Emriver Lab Manual

Chapter 2

2 Advanced Setup and Operation

This chapter is part of the Emriver Lab Manual, which is published in several chapters. Please see Chapter 1 for a complete listing of contents.

For the latest information on module development please contact us at info@emriver.com or visit our support page at emriver.com/supportFAQ/.

> This manual is a companion to the **Use and Care Manual**, and essential information in that manual is not repeated here. *It is vital that you read and understand the **Use and Care Manual** before using this Lab Manual.*

In this chapter

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2.1 Channel Slope

Channel slope in the Emriver model is controlled by the slope of the box and the elevation of the standpipe. For most setups, the slope of the box is determined by the relative height of its supports.

Unless you're investigating tectonic effects on channels, it's much more practical and realistic to control channel slope with the model's standpipe than to move the entire box. The slope of the box will determine the range of slopes attainable using standpipe adjustments, but, as in real rivers, the range of realistic slopes in the model is quite narrow – from zero to around 8 percent. You can set slopes throughout this range with only two or three box adjustments and the full range of standpipe adjustments.

Figure 2.1 and the equations that follow show the relationship between the box slope, standpipe height, and the maximum channel slope. Maximum channel slope is the straight-line distance divided by the vertical drop between the Energy Dissipater Unit (EDU) and the standpipe. You'll only see this channel slope in a perfectly straight channel.

Later in this chapter, you'll find a method for quick setups and approximate slope setting.

For experimental work and detailed study of fluvial geomorphology, you should directly measure slopes in the model using a leveling device. A self-leveling visible laser level is best for this, though other means can be used. See Chapter 3 of this manual for details on direct measurement of box and channel slope in the Emriver model.

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2.2 Slope Variables and Equations
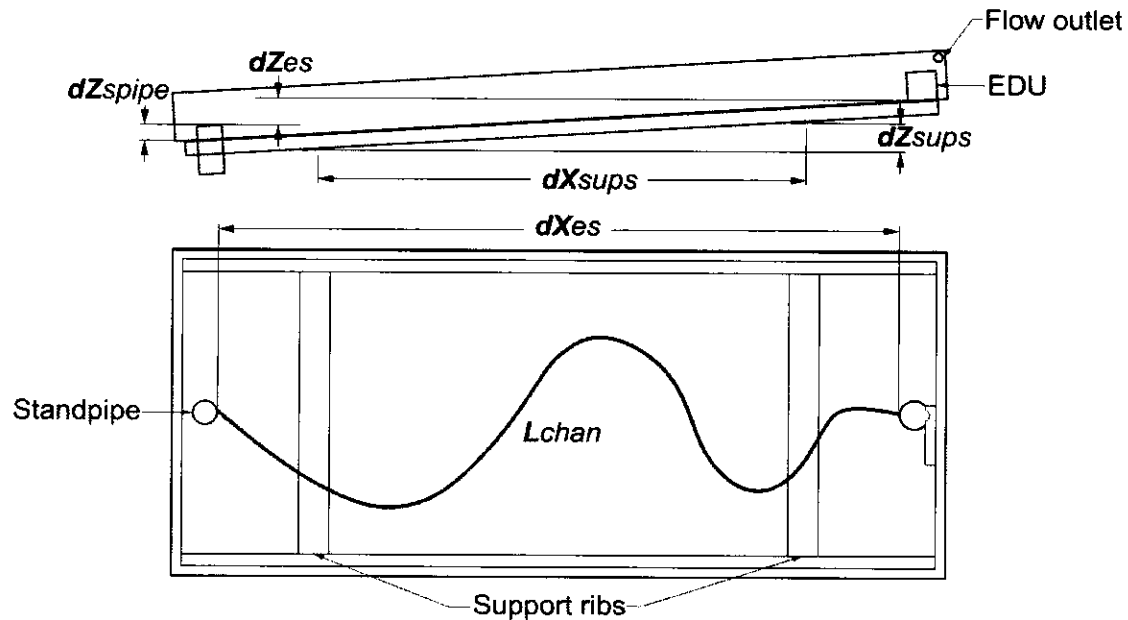
Figure 2.1 - Schematic longitudinal (top) and aerial (bottom) layout of the Emriver geomodel. Variables used in setting and calculating slope are listed in the table below.

Variable	Definition
dX_{es}	Horizontal (X) distance (d) between the Energy Dissipator Unit (EDU)(e) and standpipe (s). Constant; varies by Emriver model
dZ_{es}	Vertical (Z) distance (d) between the EDU (e) outlet and top of standpipe (s). Changes with slope change
dZ_{spipe}	Vertical (Z) distance (d) between top of standpipe and box floor (spipe); in other words, the height of the standpipe extending up from the bottom of the inside of the box
dX_{sup}	Horizontal (X) distance (d) between the box support ribs (sup). Constant; varies by Emriver model
dZ_{sup}	Vertical (Z) distance (d) between the box support ribs (sup). Can change by shims or tilt base
L_{chan}	Length (L) of channel (chan) measured along the thalweg, or the deepest part of the channel
S_{max0}	Maximum (max) possible channel slope (S) with a standpipe height (dZ_{spipe}) of zero. Can be calculated
S_{max}	Maximum possible channel slope for a given box slope and standpipe height (dZ_{pipe}). Slope of a straight channel running from the EDU to the standpipe. Can be calculated
S_{mc}	Slope of meandering channel. Can be calculated
Sinuosity	Ratio of channel length (L_{chan}) to straight-line distance from the EDU to the standpipe (dZ_{es}). Can be calculated

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2.2.1 Calculating Maximum Slope

S_{max_0} is the maximum possible channel slope in the box, given a straight channel and zero standpipe (dZ_{spipe}) elevation. If standpipe height is zero, then $S_{max} = S_{max_0}$, assuming leveled media. **As the standpipe is raised, S_{max} decreases**. S_{max} can be directly measured using a leveling device and equation 1 below:

$$S_{max} = dZ_{es}/dX_{es} \quad \text{(Rise over Run)} \qquad 1$$

2.2.2 Calculating Channel Slope

The slope of a meandering channel can be measured directly using a leveling device, measuring tape, and equation 2 below:

$$\text{(Slope of meandering channel)} \quad S_{mc} = dZ_{es}/L_{chan} \quad \text{(Rise over Run of Channel)} \qquad 2$$

Alternately, channel slope can be calculated by multiplying the reciprocal of the channel's sinuosity by S_{max}. Sinuosity is the channel length divided by the straight-line distance from the EDU to the standpipe:

$$Sinuosity = L_{chan}/dX_{es} \quad \text{(Ratio of channel length to linear distance)} \qquad 3$$

$$S_{mc} = \left(\frac{1}{Sinuosity}\right)(S_{max}) = \left(dX_{es}/L_{chan}\right)(S_{max}) \qquad 4$$

Reciprocal of Sinuosity times Maximum Slope   Rise over Run of Channel times Maximum Slope

2.2.3 Slope Calculation and Adjustment Methods – Quick Setup

For quick setups, slope can be adjusted using these steps. This method requires the model be set up on a perfectly flat surface.

1. Use equation 1 to measure slope of a straight channel, given standpipe height dZ_{spipe}:

$$S_{max} = dZ_{es}/dX_{es}$$

To determine S_{mc} you can measure it directly. If you do not have a level, you can measure L_{chan} and calculate sinuosity and then S_{mc} using equation 4:

$$S_{mc} = \left(dX_{es}/L_{chan}\right)(S_{max})$$

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For example: If S_{max} is 0.04, and $Sinuosity = \dfrac{L_{chan}}{dX_{es}} = 2.12$, then

$$S_{mc} = (1\ /\ 2.12) * 0.04 = 0.019$$

2. Alternatively, you may make up spreadsheets and charts that show S_{max} for given values of dZ_{es} or dZ_{spipe}. Figure 2.3 shows an example of such a chart. You will still need to measure L_{chan} in order to calculate the slope of meandering channels.
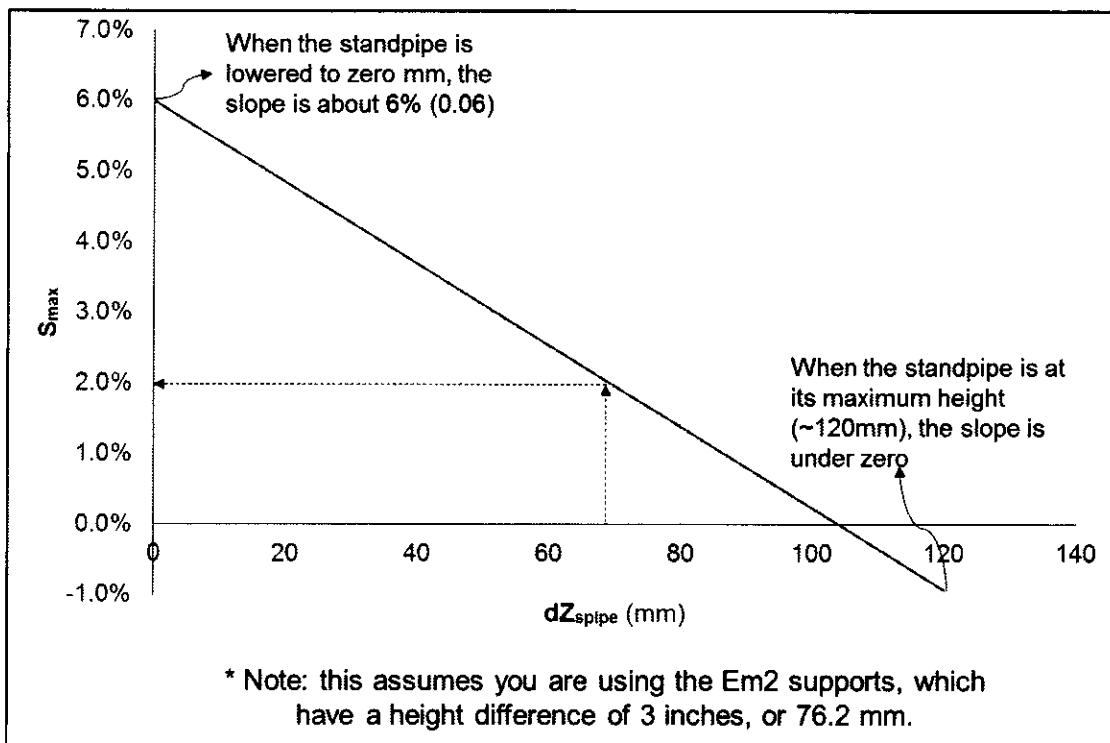
Figure 2.2 - A graph showing maximum channel slope (S_{max}) at a given standpipe height above the box bottom (dZ_{spipe}) and given known slope.

Figure 2.2 shows that
- Since the box slope of the Em2 geomodel is known to be about 0.06,
  - When $dZ_{spipe} = 0$ mm, it is possible for $S_{max} = 0.06$.
  - When the dZ_{spipe} maxes out at about 120 mm, S_{max} is just under 0.

- At any given standpipe height (dZ_{spipe}), S_{max} can be found.
  - For example, when $dZ_{spipe} = 67$ mm, S_{max} = nearly 0.02.

Note that such charts can be constructed using the formulas above for various typical model setups.

Note that the chart in Figure 2.2 is an example that depends on the known slope of the Em2. Em3 values differ.
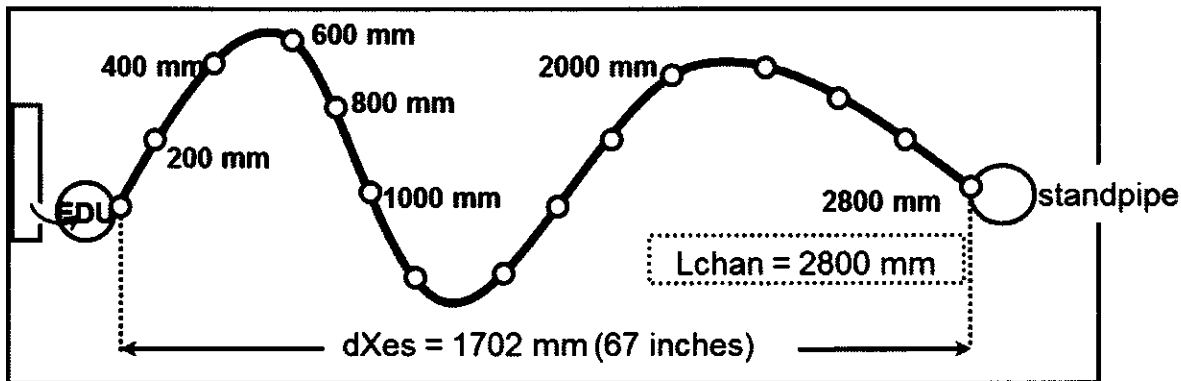
Figure 2.3 - A meandering channel in an Em2 model showing typical meander size and variables controlling sinuosity and slope. Round markers, which are 200 mm apart, represent channel length.

Figure 2.3 shows a typical meandering channel in an Emriver Em2 model. In this example we have:

L_{chan} = 2800 mm
dX_{es} = 1702 mm
Therefore, sinuosity = 2800 mm /1702 mm = 1.65

Box slope is thus:

$$S_{max_0} = dZ_{es}/dXes$$
$$= dZ_{es} \text{ (mm) } /1702 \text{ mm}$$
$$= 104 \text{ mm } /1702 \text{ mm}$$
$$= 0.06 \text{ or } 6\%$$

Maximum channel slope with the dZ_{spipe} set at zero (S_{max_0}) is thus 0.06. Let's set the standpipe about 2 in. (51 mm) above the box floor and calculate S_{max}:

$$S_{max} = S_{max_0} - dZ_{spipe} \text{ (mm) } / dXes \text{ (mm)}$$
$$= S_{max_0} - (dZ_{spipe} \text{ (mm) } / 1702 \text{ mm})$$
$$= 0.06 - (51 \text{ mm } /1702 \text{ mm})$$
$$= 0.06 - 0.03$$
$$= 0.03$$

In this case, the slope of a straight channel from the EDU to the standpipe would be 0.03. Raising the standpipe 2 in. (51 mm) reduces S_{max} from 0.06 to 0.03.

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Our meandering channel has a sinuosity of 1.65. We can determine its overall slope using equation 4:

$$S_{mc} = \left(dXes / L_{chan} \right) (S_{max}) \text{ or}$$
$$S_{mc} = \left(\frac{1}{Sinuosity} \right) (S_{max})$$
$$= (1 / 1.65)\ 0.03$$
$$= 0.018$$

2.3 Controlling Flow

A pump in the reservoir circulates water throughout the Emriver system. When the pump is first turned on, the water level in the reservoir will drop considerably before flow from the standpipe begins to replenish it. Interstitial spaces in the modeling media hold over 6.6 gal. (25 L) of water in an Em2, so water level will appear lower in the reservoir. If the standpipe is raised, several liters of water may accumulate in the lower end of the box before flow from the standpipe begins to refill the reservoir. Do not add more water to the reservoir, even if the water level appears diminished during demonstrations and exercises. Fill the reservoir with the amount of water outlined in the **Emriver Use and Care Manual** during initial setup and do not add or remove water during use.

Flow is controlled by the Emriver K28 Electronic Flow Controller or the Emriver K500 Digital Flow Controller. Assembly and use of flow controllers are covered in the **Emriver Use and Care Manual.**

2.3.1 Using the Emriver K28 Electronic Flow Controller

Figure 2.4 shows how water and electricity move though the Emriver Em2 system. Most demonstrations and experiments use only a fraction of the pump's full output.

To send the pump's full output to the box, turn the dial on the electronic flow controller several turns clockwise until flow no longer increases. From this setting, incrementally turn the dial counterclockwise to reduce flow rate. To completely shut off flow without turning off the pump, turn the dial on the controller counterclockwise until flow stops.

2.3.2 Flow Measurement

Discharge can be measured using a stopwatch and calibrated volumetric containers (available for purchase from Little River Research & Design as part of the Academic

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Kit). Simple measuring cups or more precise graduated beakers and graduated cylinders may be used for this purpose.

2.3.3 Discharge Ranges

When you are not measuring discharge as described above, you can estimate discharge by looking at the output from the Energy Dissipater Unit and activity in the box. However, estimating discharge in this manner depends on running the system at full capacity for a few seconds to remove air bubbles from the tubing. If you do not do this, flow rates can be altered.

The range of practical discharges in the model runs from about 25 ml/sec to 250 ml/sec.

- At very low discharges, much of the flow is moving through interstitial spaces in the model and not much will happen in the channel. When flow is slightly above a trickle, discharge is approximately 25 ml/sec.
- At flows above 75 ml/sec, channel beds begin to fully mobilize. This depends, of course, on channel morphology and slopes existing when the flow is increased.
- When water is nearly overflowing out of the mouth of the Em2's EDU, flow is approximately 250 ml/sec.
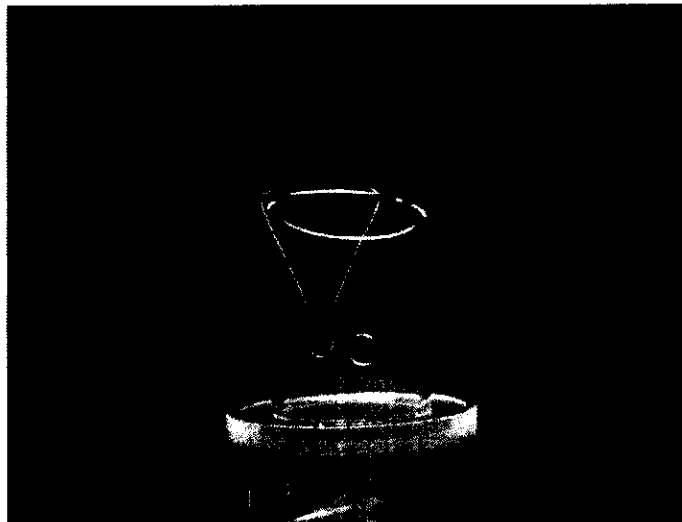
Figure 2.4 - A view of the Energy Dissipater Unit (EDU) in the Emriver Em2. Various output levels are marked as they correspond to flow rate.

When energy is controlled using grade control structures or other means in the model, the highest flows possible with the standard pump, around 350 ml/sec, can be used. Unless such structures are present in the model, flows above about 150 ml/sec will create large channels with high sediment transport rates and you will be very busy moving sediment from the trap in the reservoir back into the box.

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2.3.4 Creating Hydrographs

It's a simple matter to create hydrographs in the model. First, determine the range of flows and shape of your hydrograph. Set up a table with flow rates and times to maintain each rate. Creating the hydrograph will require at least two people, one to keep time and another to monitor and adjust flow rates using the flow controller.

Using a number of one or two liter containers (large plastic cups will work), it is also possible to measure both the water and sediment discharge at the lower end of the model. Simply catch the model's output in the containers over suitable time periods, recording the time period for each container. Then separate the water and sediment and measure both. Depending on your goals, you may want to dry the sediment before weighing. The sediment absorbs very little water.

In this manner students can produce both hydrographs and sedigraphs from the model. See Chapter 3 for more information.

2.4 Initial Conditions

At a given cross-section in an Emriver model's channel, sediment transport and channel morphology are dependent on the sediment and water regime imposed from upstream.

For many demonstrations, you will want sediment transport and channel morphology to be in an equilibrium condition – i.e., sediment transport will be relatively constant over most of the channel's length. When the model is in this state, perturbations to the channel will show fairly predictable responses. An excavation in the channel mimicking an inchannel mining operation, for example, will produce an upstream-migration headcut.

If the experimental channel is not in equilibrium, however, the channel's trend toward equilibrium will be imposed on your perturbation, and you may not see the response you expect. In general, demonstrations require that you form a channel and allow flow to produce equilibrium long profile and cross sectional conditions. For the most realistic channels, you should send a flood hydrograph through the system to form point bars and floodplains. Methods for flood hydrograph are discussed below.

If you purchased the K500 Digital Flow Controller, you can run a preset hydrograph. For further instructions about preset hydrographs and other use and care guidelines, see the K500 Digital Flow Controller Instructions for Use.

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After returning to lower flows you can visually examine sediment transport rates in the model. When these rates appear to be relatively even throughout the channel's long profile, you may assume continuity of sediment transport in the channel.
When this condition is reached, you may expect relatively predictable responses to channel perturbations.

2.4.1 Floods and Feature Formation

To form a classic meandering channel with a full complement of fluvial features, you may use the following steps:

1. Set box slope and standpipe slope. Send flow into the box to fill the groundwater table at whatever rate you like.

2. Form a meandering channel with at least a full meander wavelength within the box. Figure 2.3 shows an example.

3. Begin with moderate flows of 25 to 55 ml/sec and allow for groundwater table development and sediment transport continuity.

4. Increase flows to about 100 - 150 ml/sec for a short time. This higher flow will fully mobilize bed materials and you will see formation of point bars and small floodplain surfaces. Usually only 20 seconds or so of high flows will be sufficient.

5. Decrease flow to 55 ml/sec or less. As you decrease flow, sediment transport will decrease and you will be left with a compliment of features that includes point bars, floodplain surfaces, cutbanks, pools and riffles.

2.4.2 Valley Shape

For demonstrations of basic channel processes such as response to channelization and gravel mining, you will want to begin with typical natural channel morphology (if indeed there is such a thing). Sediment transport should be in equilibrium along most of the long profile (i.e., sediment transport continuity is present throughout the channel). This condition can be achieved by simply making a proto-channel by hand and then routing flows through the model until you can see that there are no reaches with net erosion or deposition.

In general, a shallow U-shaped valley, shown in Figure 2.5, will produce realistic features as the channel migrates through the model's sediment. As meander bends enlarge, cutbank heights will increase, and various cutbank and bluff heights will show how these features look and behave in nature.

You may form a U-shaped valley using the triangular scraper included with the Emriver model. Dig a thin, straight line through the sediment in the box, beginning at the headwaters and moving down to the standpipe. Once flow is turned on and water has saturated the interstitial spaces in the model, a U-shaped channel should form from water flowing through the proto-stream at intervals of low and high flow.
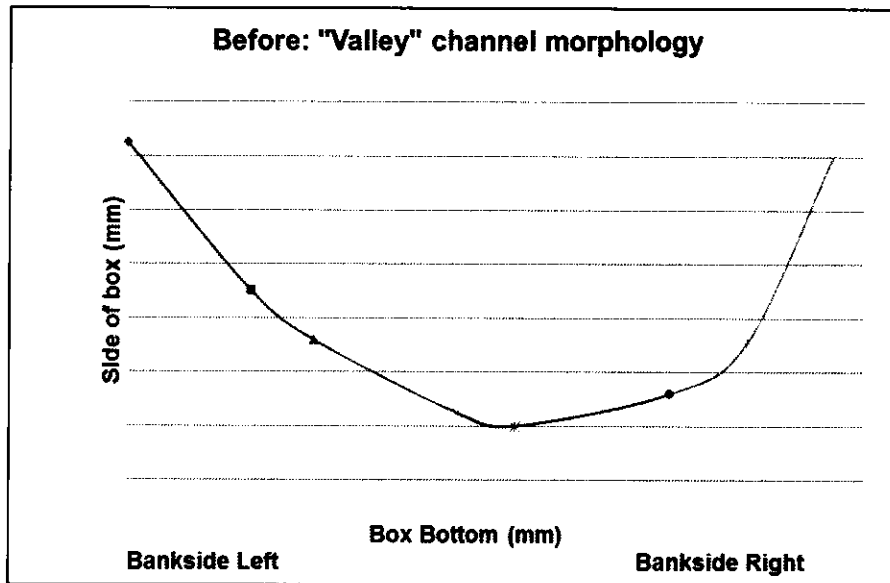
Figure 2.5 - Cross-sectional profile of a typical "valley" morphology formed at the beginning of a demonstration. As meanders in the channel migrate, they will tend to erode away the valley sides, producing steep bluffs. This is only an example. You should experiment with other shapes.

2.5 Sediment Properties

The modeling material used in the Emriver is ground thermoset plastic. Most of the material is the same dense, hard plastic from which countertops are made. Such thermoset plastic is difficult to recycle because it cannot be melted and remolded. The material we use is mostly recycled from industrial materials (it is not consumer-generated).

The material's specific gravity ranges from 1.4 to 1.6. By contrast, most rock-derived sediments in natural rivers have specific gravity values above 2.6.

Because the plastic sediment is less dense than rock, it moves more readily in the relatively low flows and velocities seen in the Emriver model. The material is highly angular, which allows it to hold shear faces and cutbanks that closely resemble those seen in the field.

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Only bedload transport is modeled in the Emriver; there are no sediment particles fine enough to be considered suspended sediment.

2.5.1 Modeling Media Sizes and Colors

The Emriver Em2 and Em3 geomodels come with non-color-coded ("Alpha") media. The Em2 uses 150 pounds and the Em3 240 pounds. The non-color-coded media is primarily white-based and has other colors speckled throughout the media. You may notice some relationships between size and color in this media, but these are strictly coincidental.

Sediment sizes of the non-color-coded media in the model range from 0.7 to 2.0 mm (0.028 to 0.080 in). Particle size distribution is weighted toward the larger particle sizes in the model.

Color-coded-by-size ("Carbondale" or "Memphis") modeling media is available for purchase from Little River Research & Design. The four colors in this modeling media represent specific particle sizes. Particle sizes of Carbondale mix are:

- Red: 0.4 mm
- Brown/black: 0.7 mm
- White: 1.0 mm
- Yellow: 1.4 mm

Memphis mix is finer than Carbondale.

2.5.2 Groundwater Behavior

Water moves freely through the interstitial spaces in the modeling media. If you use the media to build a dam from the material, for example, you will see seeps forming at the downstream base of the dam. You may also notice seeps forming on the downstream sides of valley walls in some situations.

You will notice that some groundwater movement processes in the model resemble those found in nature. However, the relatively rapid movement of groundwater through the modeling media is, at least for most geological settings, not necessarily representative of field processes.

After you initiate flow in the model, it takes a few minutes for dry sediment in the model to saturate (or for the groundwater table to rise to streambed level) before you can get normal channel flows through the length of the model. Until then, you will observe a "losing" stream.

For a typical setup, over 35 liters (9.25 gal) of water will remain in the Emriver's modeling media as groundwater after you turn off flow and discharge at the standpipe slows to a trickle. This water can take several hours to drain from the media.

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Chapter 3

3 Measurements

This chapter is part of the Emriver Lab Manual, which is published in several chapters. Please see Chapter 1 for a complete listing of contents.

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In this chapter

3.1 Thalweg and Other Horizontal Measurements

3.2 Vertical Measurements and Laser Levels

3.3 Water Discharge

3.4 Sediment Discharge

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3.1 Thalweg and Other Horizontal Measurements

Measurements of channel length are used in river research and management for many purposes, including hydraulic modeling and characterization of sinuosity. To determine channel slope, for example, we must begin by measuring a horizontal distance along a river channel.

In general, channel distance is measured along the deepest part of a channel (called the thalweg), though other paths can be used, including the centerline of bankfull or other characteristic discharge. Here we will use the deepest part of the channel.

Your Emriver model comes with a measuring tape. To measure channel length, lay the tape in the center of your channel, following its curves as closely as possible. It is usually necessary to turn off flow in the model to do this. The tape disrupts flow and will cause channel changes in your model. The tape will closely follow curves if you lay it on the narrow edge as shown in Figure 3.1.
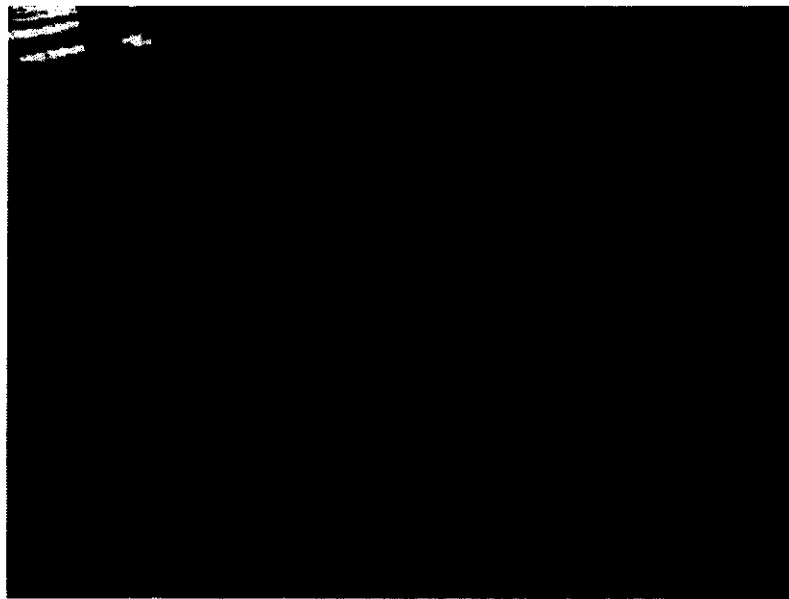
Figure 3.1 - The Emriver measuring tape will follow channel curves when placed on its narrow edge as shown here.

Always measure from a fixed point in the model. The standpipe makes a good reference point.

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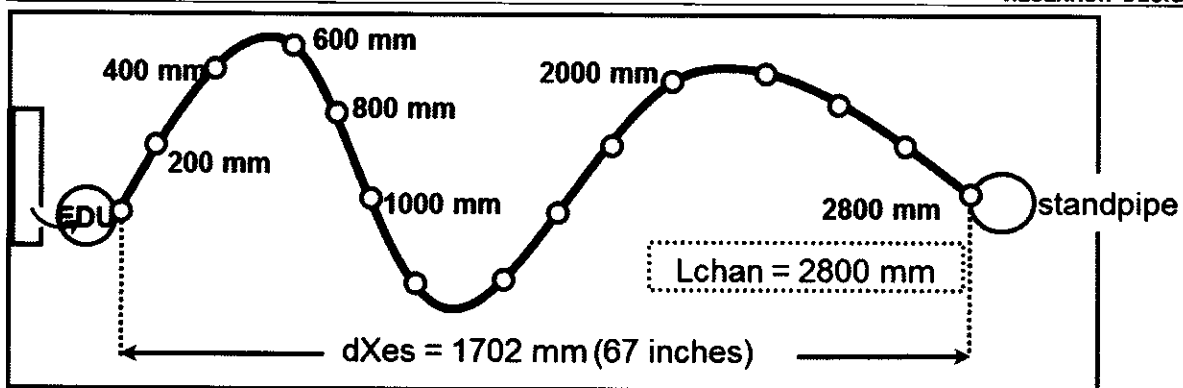
Figure 3.2 - A meandering channel formed in the Emriver Em2 geomodel. The channel is marked in 200 mm increments. Lchan and dXes, two variables used in calculating slope and sinuosity, are shown. See Chapter 2 for a detailed discussion of slope calculations.

3.2 Vertical Measurements and Laser Levels

The crossbeam level rod, part of the Emriver Academic Kit, is used to measure vertical distance from a reference laser beam to points in the model. The rod is used exactly as a surveyor's level rod, but on a smaller scale.

A small rotating laser with a visible beam works very well. Many surveying levels use an invisible beam and a receiver. These are poorly suited for use with this model because the receiver is too large to use with the Emriver small leveling rod. The rod is red because it allows the red-orange beam of a laser level to be visible in sunlight.

The bracket and beam are not meant as reference points – the gunwales (top rims) of the model are neither level nor straight enough to use as straight edges.

Figure 3.3 - The Emriver leveling rod, bracket, and crossbeam. Older models may use a slightly different design.

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The crossbeam should be near level, but is not reliable as a reference line. The crossbeam slides longitudinally on the box gunwales while the rod bracket moves side-to-side on the crossbeam, allowing measurement of most of the surface area inside the Emriver box. The level rod slides vertically on the rod bracket to allow careful positioning of its tip against the surface to be measured. The level rod is easily removed from the rod bracket for accessing other points. Figure 3.4 demonstrates how to assemble the rod and bracket.

To survey points within the model, set up your laser so that the beam is about 10 cm above the box gunwales. Verify that you can find the beam at all points in the box – at the corners and at the lowest and highest points you'll want to survey. Once you've done this, you can measure relative elevations of features throughout the box.

1. With your left thumb, depress the spring on the lower bolt.

2. Insert the bolt head through the opening at the top of the level rod.

3. Fit the same opening over the head of the top bolt and release the spring.
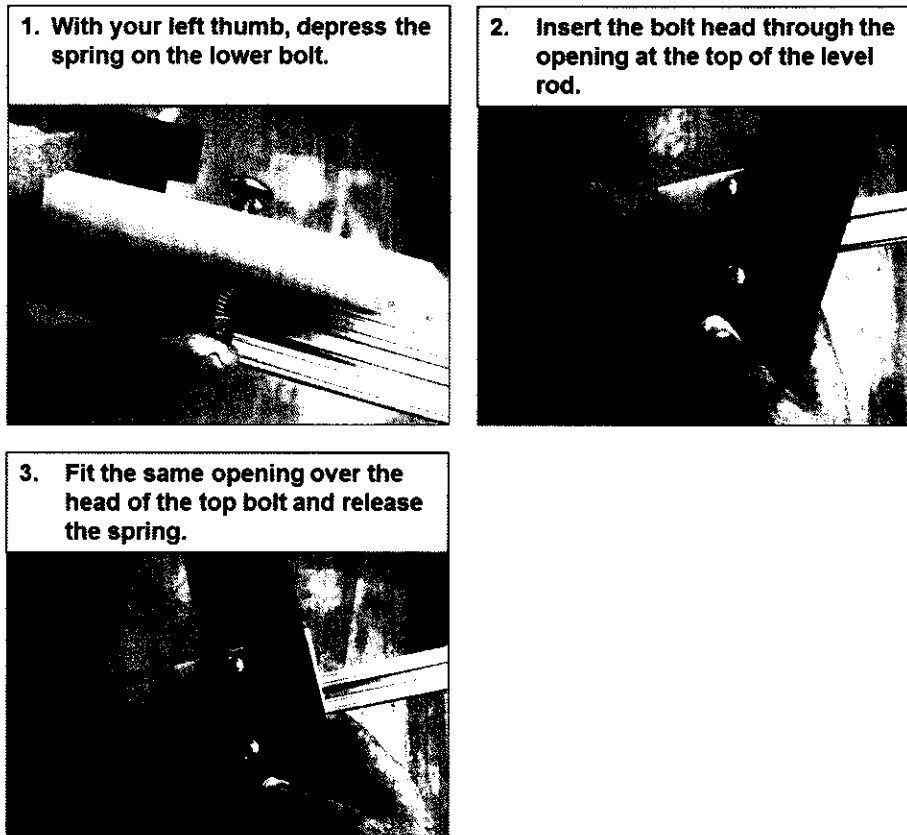
Figure 3.4 - Assembly of the level rod, bracket and crossbeam (available for purchase from Little River Research & Design).

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Figure 3.5 shows basic leveling setup. Emriver models make excellent teaching tools for field methods, especially when used with a rotating laser, because the surveying methods are essentially the same as those used in the field.
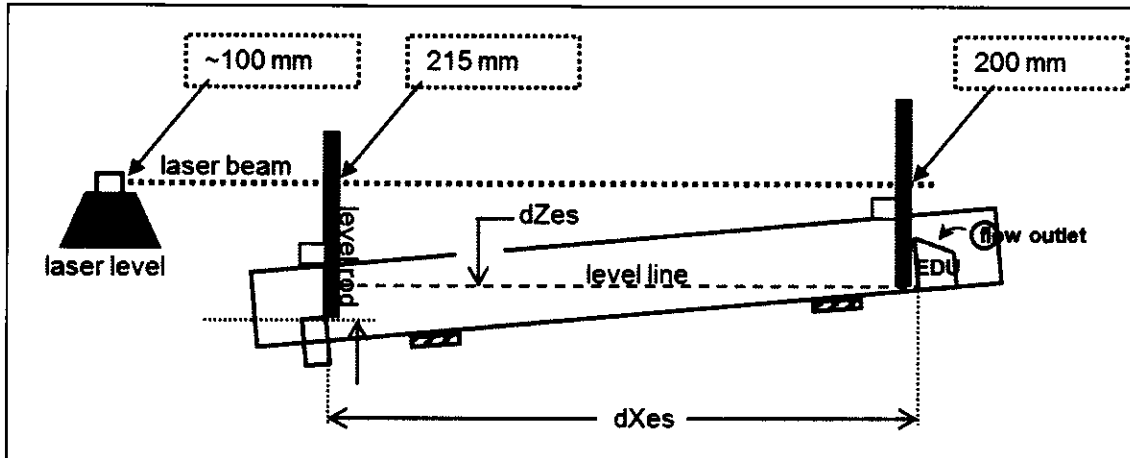
Figure 3.5 - Schematic showing basic leveling. Here a rotating level is set up and leveled so its beam is about 100 mm above the Emriver box. The level rod is depicted as a grey line at two different positions. Readings on the level rod show that dZes is 15 mm. If dXes is 1,320 mm, then slope for a straight channel between the two points would be 15 mm/1,320 mm = 0.011. The level reference line is drawn for clarification only.

Channel long profiles may be surveyed using the measuring tape and a laser level. Using the level rod, measure bed elevation at the thalweg (the deepest channel point) along the entire length of the channel. Be sure to also get elevations for the standpipe lip and any points where the box bottom is exposed by scour. Plot these data as shown in Figure 3.6. Some advanced exercises involve before and after long profiles in which you can see the effects of channel manipulations.
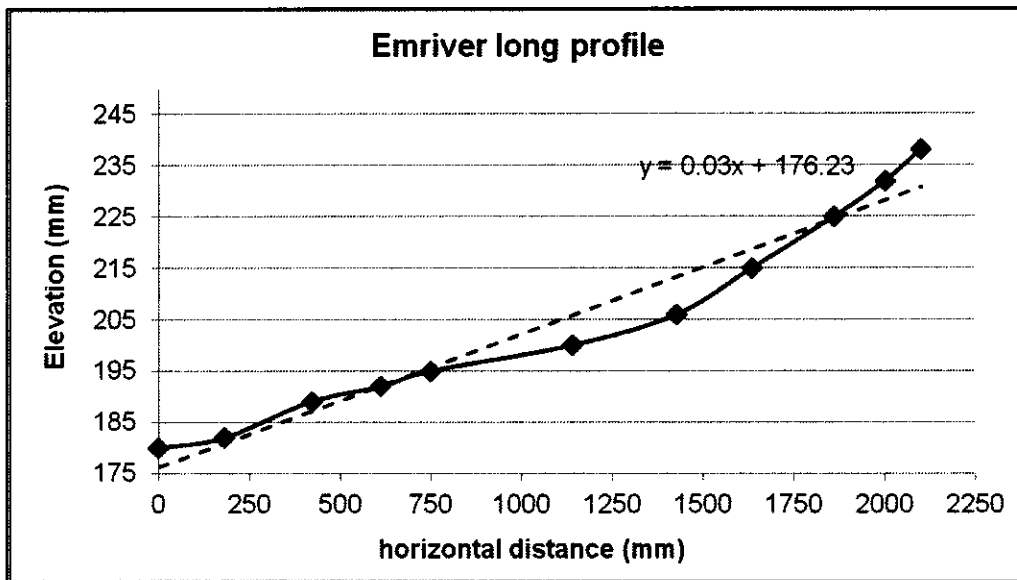
Figure 3.6 - Example of a long profile in a meandering channel in an Emriver model.

3.3 Water Discharge

Input of water through the model can be measured using a graduated cylinder and a stopwatch. Given the modeling media properties and Emriver Em2 box size, the usable range of discharge flows starts from about 25 ml/sec to 250 ml/sec.

Discharge from the standpipe can be measured using multiple timed captures. A stopwatch and graduated cylinder are required. You'll need at least two capture containers, two watches, and two people to capture discharge. To capture all discharge, you'll need to alternately switch containers without losing any flow as they become nearly full.

You may use fine screens to filter the sediment from captured flow before measuring its volume.

3.4 Sediment Discharge

By using a number of one- or two-liter containers it is also possible to measure both the water and sediment discharge at the lower end of the model. Simply catch the model's output in the containers over suitable time periods, recording the time period for each container. Then, separate the water and sediment and measure both. Depending on your goals, you may want to dry the sediment before weighing. The individual sediment

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particles absorb very little water. You can dry the sediment in an oven. The modeling media should only be oven-dried **until constant weight**. Recommended maximum oven temperature is **100°C** (212°F).

As an alternative to oven-drying the media to constant weight, it is possible to determine bedload discharge per collected volume of water. This method should work for simple exercises and classroom experiments, and the required calculations (and examination of assumptions) would provide a good learning experience.

- First, collect the sediment and water output at the model's standpipe within a given time period.
- Next, pour the collected sediment-water mixture into a large graduated cylinder and note the volume of each.
- Then, determine the volume of dry sediment collected in your wet sample. The pore volume of the wet sediment is approximately 50%. Based on this, you can calculate material volume of dry sediment.
- Mass of the sediment collected can now also be determined. The bulk density of the dry Emriver sediment is 0.75 g/cc. Based on this, you can convert volume to weight of modeling media and use this to calculate bedload transport.

Here is an example calculation:

- You collect a total of 100 ml of sediment-water mixture from the output at the standpipe.
- You then measure that 20 ml of the mixture is wet sediment.
- Based on 50% pore volume (50% x 20ml), you can calculate that 10 ml of dry model sediment were collected in the 100 ml sediment-water mixture.
- Since the bulk density of dry Emriver sediment is 0.75 g/cc (or 0.75 g/ml), you can also calculate (0.75 g/ml x 10 ml = 7.5 g) that 7.5 g were collected per the 100 ml sediment-water mixture. Therefore, the bedload transport rate is 0.075 g/ml.

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Emriver Lab Manual

Chapter 4

4 Demonstrations

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In this chapter

4.1   In-channel Gravel Mining

4.2   Sediment Transport Measurement, Continuity, and Channel Stability

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4.1 In-channel Gravel Mining

Although outlawed or heavily regulated in many parts of the world, mining of sand and gravel from stream channels is common in some regions. The Emriver model is particularly useful for demonstrating the effects of gravel removal from channels, especially the offsite impacts that are usually unknown to laypeople. These include channel downcutting (also called incision) upstream and downstream of the site, increased lateral migration, and bank erosion upstream of the mined area.

Setup for gravel mining demonstration

(Maximum slope) **Smax**	variable, about 0.020 (2%)
(Slope of meandering channel) **S**	approx. 0.015
Planform	gentle meanders, at least a full meander wavelength, sinuosity about 1.3; alternatively, a straight channel
(flow) Q	35 - 55 ml/sec
Initial conditions	consistent sediment transport continuity, meanders with point bars and well-formed channel features; high banks will show erosion processes more strongly

Begin with a standard meandering channel with a sinuosity of about 1.3. Alternately, you can begin with a straight channel. In either case, route flow pulses of about 150 ml/sec through the model for at least 15 seconds to form channel features. In the straight channel, you should allow alternate point bars to form. Adjust flow discharge (Q) to 35 - 55 ml/sec. After decreasing the flow, make sure that the channel is metastable and sediment transport continuity is consistent throughout the channel.

You may want to mark the water surface elevation upstream of your mining site to better visualize the incision that usually takes place. If you purchased the Academic Kit from Little River Research & Design, you may use the leveling rod to do this. By setting the rod tip just at the water surface elevation, you can observe and measure upstream incision. Without a reference point like this, most people will tend to underestimate the degree of incision that occurs. Use a sieve, perforated scoop, or your bare hand to remove sediment from the center of the channel. Remove about 250 ml of material (about one cup).

You should observe several processes, which are shown in Figures 4.1 and 4.2 below.

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- Sediment continuity is completely disrupted as the mined area becomes a sink for bedload. Note that little or no bedload moves through the mined area.

- The increased bed slope at the mined area will encourage increased sediment transport, causing a headcut to form and migrate upstream.

- The banks and bed of the channel upstream of the mined area will erode. This part of the channel will show a net export of sediment. You will usually see relatively high bedload transport rates in this reach compared to the reaches farther upstream. This increase in transport rate is balanced by erosion of the banks and beds. You can thus visually observe the downstream changes in sediment transport rates that show the discontinuity. In a sense, you can say that gravel is being mined from reaches upstream of the actual removal area.

- As headcutting occurs, you may see sharp edges (or "scarps") form in the bed, usually in gravel bars. We see these features in the field, and they can be strong indicators of rapid incision.

- One or more dunes will form in the mined area, with downstream slipfaces. The slipfaces will migrate downstream as the hole is filled. As shown in Figure 4.2, the channel will tend to restore the original bed grade as it seeks sediment transport continuity.

- The downstream end of the mined area will erode as sediment is removed by the channel to regain sediment transport continuity. At real-world mines, we often see downstream riffles destroyed in just this manner.

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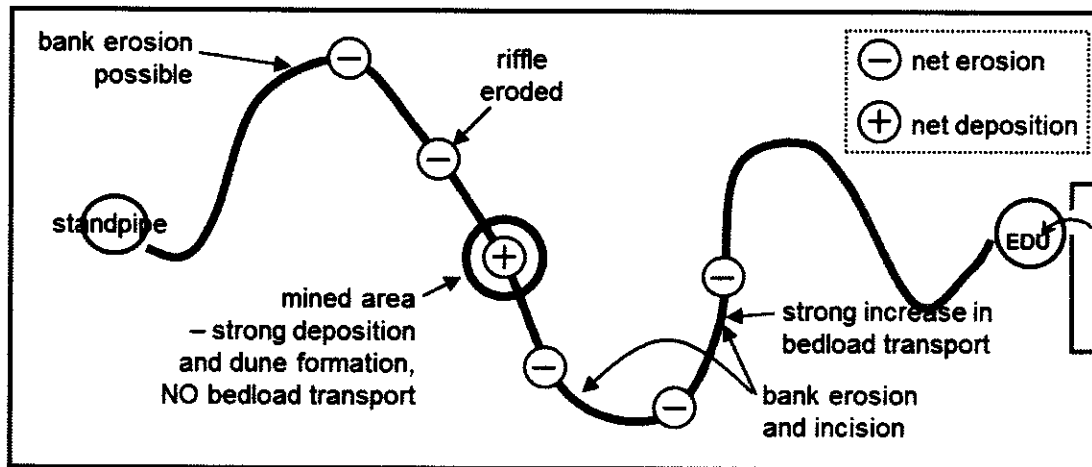
Figure 4.1 - Expected response to removal of bed material in an inchannel mining simulation. Usually, you can see a very strong increase in bedload transport rates upstream of the mined area. This net increase in transport is balanced by erosion of the channel's bank and beds.
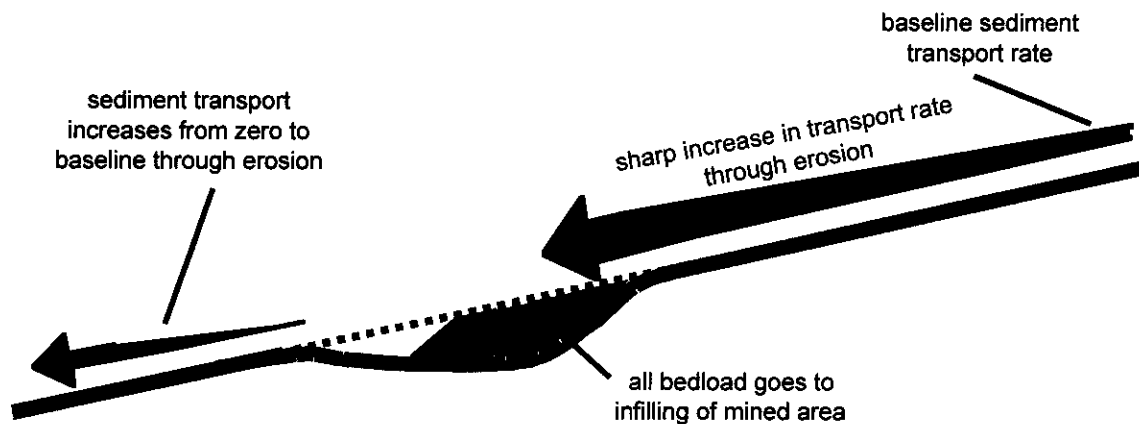
Figure 4.2 - Schematic showing an Emriver long profile after bed material has been mined. Width of the arrows corresponds to sediment transport rates, which (usually) are clearly observable in the model. Note how the original grade and sediment transport rate tend to be restored by deposition as the channel seeks continuity in sediment transport.

You may remove sediment from the mining site again to show the effects of repeated removals from a given area, as is often the case with real-world operations. You will usually see the processes shown in Figures 4.1 and 4.2 continue, with bank erosion and incision worsening.

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If you begin with relatively high banks on the outside bends, you will see dramatic bank slumping in the incising bends. This effect tends to make a strong impression on observers, and also illustrates geotechnical processes – the banks slump not only from toe scour, but also from increased bank height caused by the incision.

4.2 Sediment Transport Measurement, Continuity, and Channel Stability

River morphology is a product of both water and sediment flows. This experiment centers on sediment transport processes and their measurement.

Much interest in river systems focuses on stability. Most people consider a river stable if its morphology and position in space do not change over time. This is a logical assumption, but it is an unrealistic condition. Instead, alluvial rivers are products of the sediment and water they transport, and almost always change over time. Sediment is eroded from the channel bed and banks, and unless the channel's cross-section changes, it is deposited as well. If erosion and deposition in a reach are equal, then we can say that the reach is stable at least by one definition. In other words, if the sediment entering a reach equals the sediment leaving, the reach is stable. The channel may still migrate across its floodplain, but it is, in a geomorphological sense, stable.

You can observe these processes in the Emriver model. Sediment in the model moves as bedload, bouncing off the bottom of the channel. There are no particles in the model fine enough to move as suspended load. We can observe this movement and visually compare the sediment transport rate in one reach to that in another. It is possible to measure the transport rate only by capturing sediment leaving the standpipe. This problem demonstrates real-world difficulties in measuring bedload transport.

In this exercise, you will build on the procedures given for the inchannel gravel mining demonstration above.

Steps
1. Set up the model using the initial conditions and instructions given for the gravel mining demonstration. Form a meandering channel and use a flood pulse to form small floodplain surfaces (bar tops). Then reduce flow to about 55 ml/sec to establish an equilibrium channel.

2. Once you have established an equilibrium channel (in which sediment transport appears to be about the same throughout your experimental channel), record the discharge value. Then measure the sediment discharge rate from the standpipe. For this exercise, you may use either the drained weight of sediment or a volumetric measurement. The latter will be easier.

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3. Next, turn off the water flow. With the flow turned off, survey the channel long profile. Use a spreadsheet program or graph paper to plot the long profile. Leave your measuring tape in place – you will be using it again to resurvey part of the channel.

> Option: In addition to the thalweg survey, record the elevations of bank heights and bar tops. Plot these as well, using different data groups for the thalweg, banks, and bar tops.

4. Calculate channel slope and sinuosity.

> Option: Photograph the channel, using a camera mounted on a tripod or other fixture that will allow you to take photos from exactly the same vantage point later in the experiment.

5. Remove sediment from the channel using the guidelines for the inchannel gravel mining demonstration. Record the volume of the sediment to within at least 10% of the total using a graduated cylinder or beaker.

> Option: Take a photograph (as part of your series) of the channel to show the excavation.

6. Resurvey the section of the channel from which you removed the sediment. Plot this on your previous long profile plot.

7. Study the expected responses to the excavation. These are given above. You will have to quickly observe these processes as flow is restored. Video clips demonstrating these responses in an Emriver model can be seen on the River Geomorphology DVD included with this manual.

8. Restore water flow, carefully increasing flow so that groundwater is restored (if it was depleted during your surveying). Then, reestablish the water discharge value recorded in Step 2.

9. As flow is restored, carefully observe sediment transport processes. You should observe most or all of the processes shown in Figures 4.1 and 4.2.

Record your observations, comparing them to the expected responses given above.

Run the model at this flow until it appears that sediment transport continuity has been restored throughout the experimental channel.

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Option: As soon as sediment is exported from the standpipe, begin to sample sediment discharge and continue until the channel again reaches equilibrium. Plot these values against time, also noting changes in the excavated area so you can correlate these with sediment transport rates at the standpipe.

10. Shut off water flow. Again survey the long profile, plotting it against the other two. Calculate channel slope and sinuosity.

Option: If you surveyed bar tops and banks, resurvey these as well. Take another photo.

Questions

1. Did you observe the expected responses to the excavation? In particular, how was sediment continuity affected throughout your experimental channel?

2. Defenders of inchannel gravel mining (now illegal or highly regulated in most of the United States) often say these mines remove only a very small portion of the total bedload.

   • In your experiment, how would this argument hold up? How does the amount of sediment you "mined" compare to the transport rate you measured?
   • Is the mined volume a very small fraction of the transport rate?
   • How do you reconcile the responses you saw with the transport rate and the volume (or weight) of "mined" sediment?
   • Could you recommend a volume rate of sediment "mining" that would cause no change in channel morphology?

3. If you saw changes in the long profile plots, how do you explain them? If you plotted bar top and bank elevations, compare thalweg elevations to corresponding bar and bank elevations. Can you see evidence of incision?

4. Based on all your measurements and observations, can you make a schematic sketch of your experimental channel showing areas of net sediment deposition and erosion during your run?

   Considering the base or equilibrium transport rate (which you measured in Step 2), and your long profile plots, how much sediment do you think was eroded from the reach upstream of the mine? This will be an estimate, but will give an idea of the magnitude of disruption in sediment transport continuity. If this were a real world situation, it might tell you how much gravel a mine owner got from his upstream neighbor's stream channel.

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Chapter 5

5 Exercises and Experiments

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5.1 Channelization

"Channelization" is commonly used as a catch-all term for channel modification. Channels may be both realigned and enlarged through channelization. Often channelization means removal of a meander bend. Other projects simply enlarge the channel in attempts, often misguided and unsuccessful, to increase flood flow conveyance through the reach. Channel enlargement almost always fails, or at least requires frequent maintenance through sediment removal when channels carry significant coarse sediment loads.

The Emriver model is particularly useful for showing the processes that result in the failure of both channel relocation and enlargement projects.

5.1.1 Straightening

In the United States, thousands of miles of river channels have been straightened in attempts to control flooding, increase farmland drainage, and realign channels that conflicted with bridges and other built structures. Often sediment transport processes are not considered in these projects, which is one reason they often fail or cause serious offsite impacts.

In the Emriver model, we can straighten a stable meandering channel to observe typical processes that occur in real-world rivers after straightening.

Setup for channel straightening demonstration. Also see Figure 5.1 below.

(Maximum slope) **Smax**	variable, about 0.020 (2%)
(Slope of meandering channel) **S**	approx. 0.015
Planform	gentle meanders, at least a full meander wavelength, sinuosity about 1.3; alternatively, a straight channel
(flow) **Q**	45 – 60 ml/sec
Initial conditions	well-established sediment transport continuity, meanders with point bars and well-formed channel features

As before, begin with a meandering metastable channel. Visually check sediment transport continuity. Discharge should be set at about 45 - 60 ml/sec.

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Pick a meander bend in the middle of the model. You will want to observe channelization impacts both upstream and downstream of your straightening. Figure 5.1 shows a typical setup. Use the level rod and bracket (optional accessory, part of the Emriver Academic Kit) to mark the water surface elevation upstream of the channelization site. Place the rod tip just at the water surface and leave it there throughout your demonstration.

Note the difference in streambed elevation above and below your proposed channelization site (points H and J, Figure 5.1). You may also want to note or measure the thalweg distance between these two points. These two values give you the channel slope.

Next, use a scoop to excavate the new channel. Put this material in the old channel as shown in Figure 5.1-C.

As shown in Figure 5.1, the straightened channel will show the same elevation drop, but over a shorter distance. The new channel will thus have a steeper slope, sometimes twice the slope. This change in slope will produce a "step" in the long profile (as illustrated in Figure 5.1-B). This steeper section is out of equilibrium with sediment transport processes up and downstream, and is thus unsustainable. The increase in slope will result in higher flow velocities (which is often the rationale for straightening – to increase flood flow conveyance) and erosion in the channelized reach. The long profile tends to adjust to achieve sediment transport continuity by eroding upstream and depositing sediment downstream of the straightened reach.

In summary, you will usually see:

- Velocity within your channelized reach will be higher than in adjacent reaches, because the channel is usually narrower, and because it has been made much steeper by the straightening.

- Sediment transport rates will be high within the reach, making it a net exporter of sediment.

- A headcut will form within the reach and will usually migrate some distance upstream. As the headcut moves upstream, sediment will be sent downstream and you will see bank failures as banks are undermined.

- Downstream reaches are flooded with sediment. The channel will gradually reclaim sediment transport continuity by forming the long profile shape shown in Figure 5.1-D. In general, the downstream reach is graded and the upstream reach is incised. You will usually see very high sediment export rates at the standpipe during this demonstration.

A. Form a meandering channel with a channelization site well away from either end of the model. Note the difference in elevation between the points H and J.–Dig the straight channel as shown and block the old channel.

B and C.-The new channel drops the same distance between H and J, but is much shorter, and therefore steeper. An unsustainable "step" is formed in the channel's long profile. The unaltered channel is depicted as a solid line.

You will usually see increased current velocity and sediment transport in the straight reach, and a headcut will move upstream.

D.As adjustment continues, the channel attains sediment transport continuity by eroding upstream reaches and depositing sediment downstream. Notice the "step" has been eliminated.
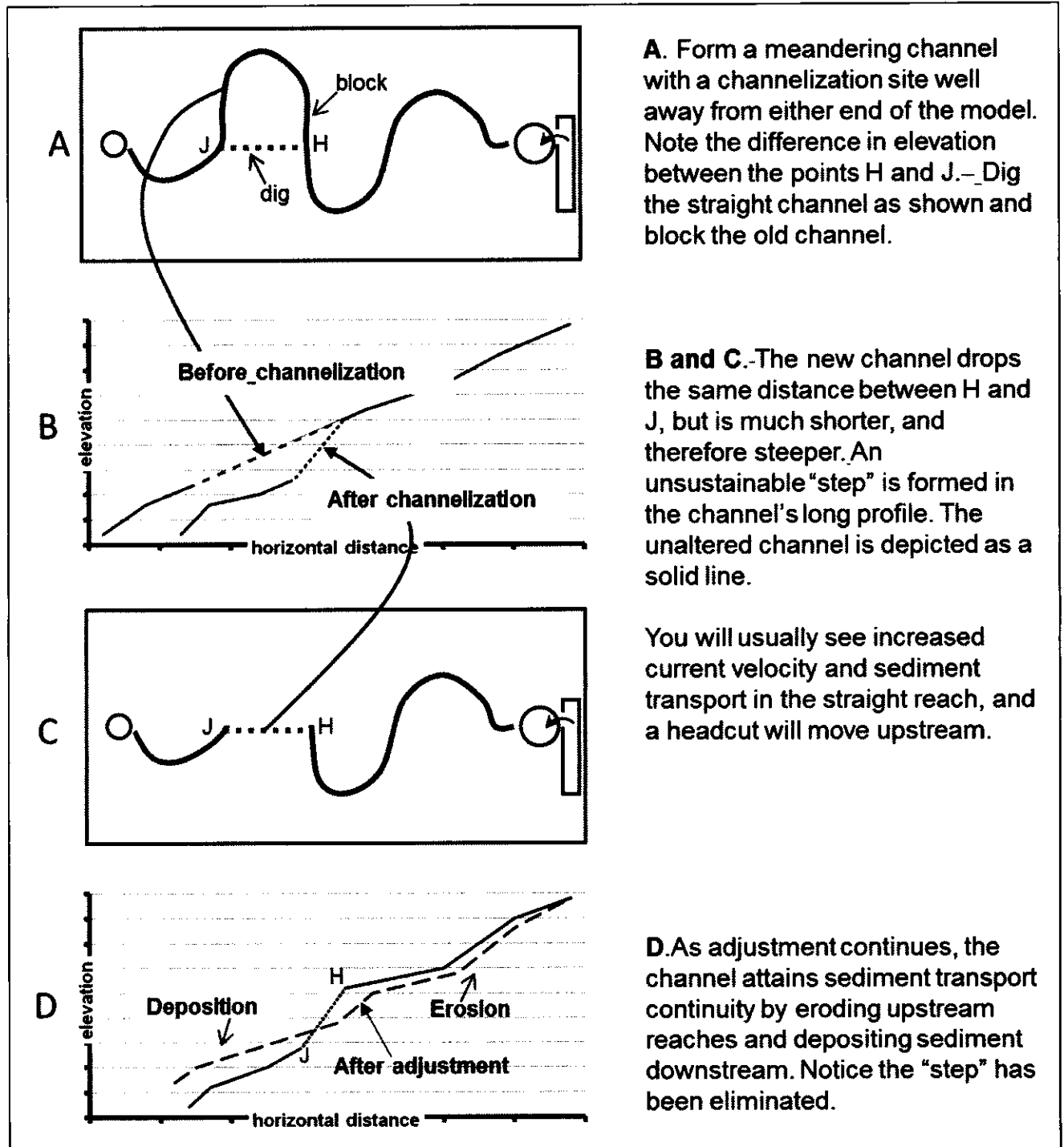
Figure 5.1 - Channelization by replacement of a meander bend with a straight section, and expected effects and adjustments in an Emriver channel.

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5.1.1.2 Advanced Channel Straightening Exercise

Using the crossbeam level rod available for purchase in the Academic Kit from Little River Research & Design and a laser level, you can do three surveys (before, during, and after channelization) to show how the long profile changes when rivers are straightened. The essential steps are:

1. Establish a stable, meandering channel as discussed previously.
2. Turn off flow and survey the long profile. This is your "before" condition.
3. Straighten the channel.
4. Resurvey the long profile, taking care to note the new and old channel profiles as shown in Figure 5.1. This is the "during" or as-built condition.
5. Reestablish flow and allow the channel to adjust.
6. Turn off flow and resurvey. This is your "after" survey. Your results should look roughly like the schematic in Figure 5.1, though many variations are possible. You may see upstream incision without downstream deposition, for example.

5.1.2 Widening

Channelization through cross-sectional enlargement, usually widening, is commonly done to increase hydraulic conveyance. It may also be used in attempts (which are almost always unsuccessful) to stabilize channels. In urban areas or around bridges, widened channels may be lined with concrete or riprap.

Widening causes abrupt changes in process continuity. Flow entering the enlarged cross section invariably slows, and sediment is deposited. The widened reach becomes a sediment sink and usually begins to regain its former dimensions. This, of course, will negate any project benefits. If widening disrupts a stable, tree-lined reach, the resulting reach, after filling with sediment, may be much less stable than before.

We can also see a less stable channel after the deposition process because well-consolidated bank sediments, which may have contained cohesive materials like clay and silt, are often replaced with sands and gravels that are much less resistant to fluvial erosion and not as easily colonized by woody plants.

The disruption in sediment continuity and "hungry water" effect may cause net erosion of bed and banks in downstream reaches after channel widening.

Channel widening involves many of the same processes and responses as inchannel mining, and the demonstration is thus very similar. Given similar initial conditions, you may see less dramatic effects with widening. As with the gravel mining demonstration, negative impacts on the channel come largely from disruption in sediment transport continuity.

As with inchannel mining, the channel cross-sectional area is greatly increased. The response can be complex, but in the simplest terms, the widened reach will show decreased sediment transport capacity because flow velocity for a given discharge will decrease. Since current velocity in a channel is directly related to this area (by $V = Q/A$, where V is current velocity, Q is discharge, and A is cross-sectional area), average velocity in the widened reach will almost always decrease relative to the unmodified reach upstream. Usually, sediment is deposited until the reach is in equilibrium (with respect to sediment transport) with adjacent reaches. In heavily managed rivers, this process is kept in check by periodic removal of the deposited sediment – it is not a naturally sustainable condition.

To begin this demonstration, start with a metastable channel and consistent sediment transport continuity. Pick a reach in the center of the model and widen it using a scoop, sieve or your hand.

You will usually observe several processes:

- Average current velocity is greatly reduced in the widened area. Sediment continuity is completely disrupted as the widened area becomes a sink for bedload.

- A steeper hydraulic grade line, caused by the increase in cross-sectional area, may encourage increased sediment transport above the widened area, causing a headcut to form and migrate upstream.

- The banks and bed of the channel upstream of the widened area will sometimes erode. This part of the channel will show a net export of sediment. As with the inchannel mining demonstration, you may see relatively high bedload transport rates in this reach compared to the reaches further upstream. You can thus visually observe the downstream changes in sediment transport rates that show the discontinuity.

- One or more dunes may form in the widened area, with downstream slipfaces. More likely, though, you will see one or more bars form as the channel regains its former cross-sectional area.

- The downstream end of the widened area will erode as sediment is removed by the channel to regain sediment transport continuity.

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5.2 Bank Armoring

Bank armoring is likely as old as civilization. Where people settle or build structures near rivers, they encounter channel movement across the floodplain that threatens those structures. Channel migration is, of course, part of the process that built fertile, flat floodplains, but people are in constant conflict with it.

Armoring schemes are limited only by the imagination, economics, and materials at hand, ranging from old automobiles, junk, and tires dumped on banks by a landowner to multibillion-dollar engineered projects along big rivers like the Mississippi. Environmental values can suffer from both types.

5.2.1 Soft Armor

Soft armoring involves the use of living plants, either alone or in combination with natural material structures, to protect a riverbank against erosion. Planted vegetation protects a riverbank in numerous ways including holding soil together through root structures, absorbing rainwater, dissipating the impact of rainfall through leaves, and helping to slow water flows and encourage sediment deposits that can help build up the shoreline rather than wear it away. Bioengineering is generally less expensive than hard armoring, and supports natural habitat for both terrestrial and aquatic wildlife, but it has practical limitations. The riverbank must be stable enough to support vegetation, and even strong trees are sometimes no match for freezing, thawing, and ice scouring, or large-scale seasonal floods.

5.2.2 Hard Armor

Hard armoring is a riverbank stabilization technique in which the bank is graded to a low angle, then covered with materials such as stones, called rip-rap, or stacked with rock-filled wire baskets called gabions. Hard armoring may be appropriate in severe situations where more environmentally friendly solutions like seeding or planting are unlikely to hold. Hard armoring can be expensive and may not be aesthetically pleasing but it does provide excellent stream bank protection. An alternative to installing gabions parallel to the shore is to build groynes, or a series of walls running perpendicular to the shore, anchored in the riverbank and extending into the river to slow and redirect the water flow.

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5.2.3 Setup for Bank Armoring Demonstrations

For most bank armoring demonstrations, you may either begin with a meandering channel or form a straight channel and allow small meanders to develop. Most observers find a meandering channel to be within their river experience (and more visually interesting). With bank armoring demonstrations, you may want to experiment with higher discharges, which usually accelerate fluvial adjustment and structure failure processes. If you form three or more meander bends and use relatively low flows, you may be able to contrast the response of armored and unarmored bends.

(Maximum slope) **Smax**	variable, about 0.020 (2%)
(Slope of meandering channel) **S**	approx. 0.015
Planform	gentle meanders, at least a full meander wavelength (preferably more), sinuosity about 1.3; alternatively, a straight channel
(flow) **Q**	35 - 110 ml/sec
Initial conditions	well-established sediment transport continuity, meanders with point bars and well-formed channel features

5.3 Modeling Riprap

The Emriver model is supplied with small quartz stones that can be used to simulate riprap. The density of quartz is approximately 2.65 g/cm^3. Note that the quartz stones will have a tendency to scour into the streambed – a process that does occur in real-world rivers, but usually not as readily as in the Emriver model. You can also use acrylic objects to simulate riprap made from different materials. The lighter-density acrylic material can show that at higher storm discharge rates, riprap will eventually fail and bank incision will occur. Acrylic and stone objects give very useful and interesting demonstrations of effects and processes related to bank armoring.

After constructing a stable, meandering channel, try armoring an outside bend with riprap. Observe the response at low flows, and try higher flows as well.

Figure 5.2 depicts a process the Emriver model shows particularly well: the interaction of hard, stationary bank armor with migrating meanders. The effects of a particular bank armoring project on fluvial process are complex, and you will no doubt see varied results. In general, you may observe these processes:

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- Increased shear stress at the toe of the riprap, and resulting scour of bed material that may cause stones to roll into the bed and downstream. Note that riprap tends to focus rather than dissipate hydraulic energy.

- Sometimes you will see scour in upstream and downstream riffles as well. This results from the alteration of energy and sediment transfer in the armored reach.

- The downstream bend may erode for the same reason.

  Meander migration may cause deposition to occur at the upstream end of the riprap. You may see channel alignment change dramatically as the meander bend moves through the site as shown in Figure 5.2. This demonstration shows one of the problems with hard structures in alluvial channels: unless the channel's planform never changes, the structure is certainly doomed to obsolescence due to movement of the channel across the floodplain, however slow this process may be. In the case shown in Figure 5.2, accelerated downstream erosion and channel migration would more than offset any benefits from the area protected by riprap (unless the riprap is protecting a high value structure such as a house). This can be visualized easily with the houses from the Emriver Structures Kit.

A

← flow

Meander bend is armored. Engineers will rightfully argue that more of the bend should be armored in this example.0

B

As the bend naturally migrates, its lower end is locked in place by the riprap. A bar begins to form along the upstream edge of the riprap.

C

The bar enlarges. At this point energy focus on the downstream end of the riprap becomes intense, a deep scour hole forms, and riprap may begin to fail. This process may cause the channel to move to the right (facing downstream).

D

Here the riprap project is mostly buried in deposited sediment. The floodplain immediately behind the project has been protected, but the channel has been grossly destabilized downstream, and a large area of the floodplain has been reworked much more rapidly than it otherwise would have been.
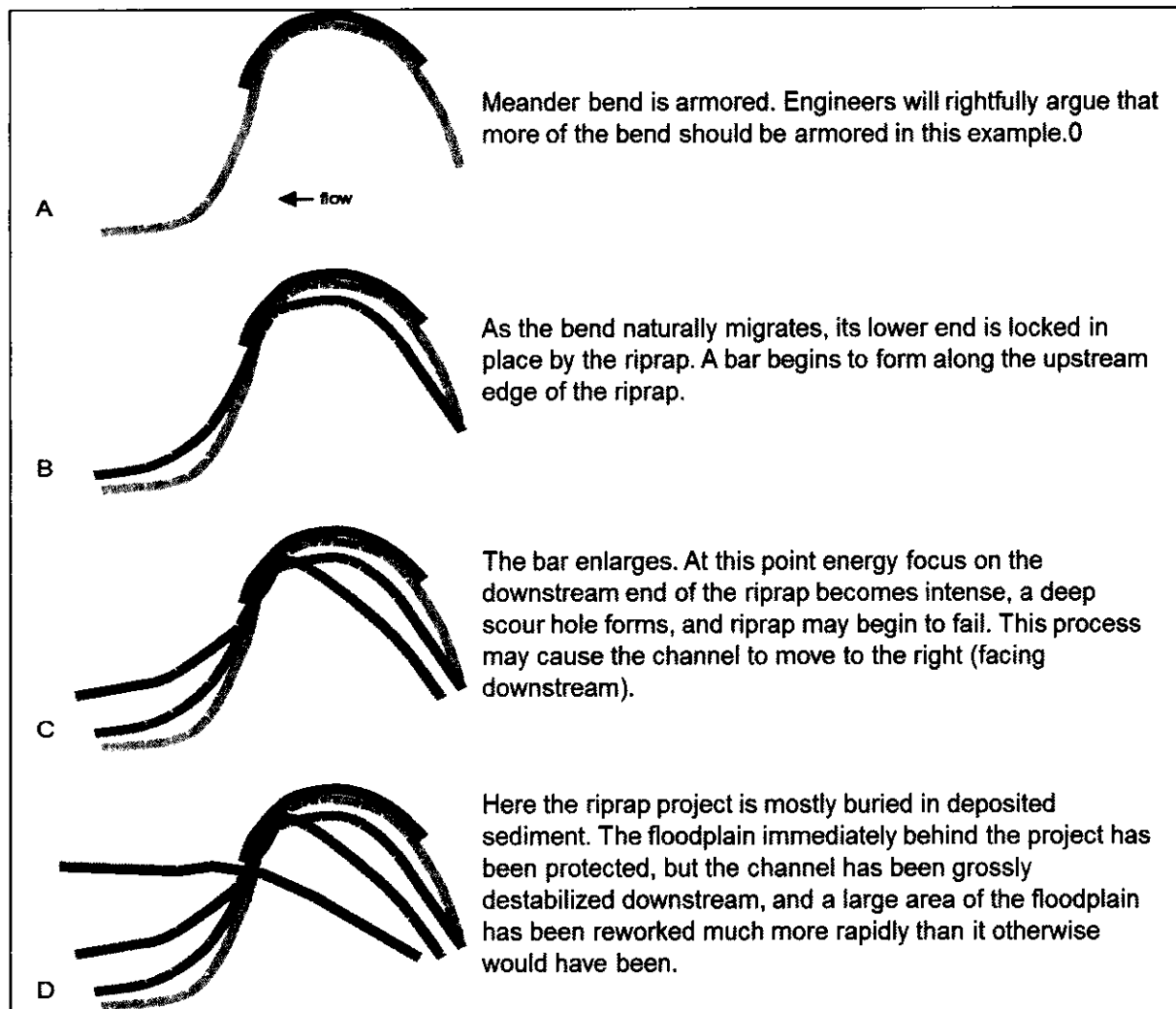
Figure 5.2 - Hypothetical planform channel response to armoring with stone riprap. Depending on channel characteristics, sediment, and water flow regime, many different responses are possible.