Emriver Lab Manual

Safety and Lab Manual Contents

Chapter 1 (rev. 3.0) www.emriver.com

Introduction

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 being constantly developed. To keep this information manageable, we have modularized the lab manual to allow frequent updates and additions. For the latest information on module development please contact us at info@emriver.com or join the user newsgroup http://groups.google.com/group/emriver?pli=1.

See Chapter 2, Advanced setup, for detailed setup procedures.

In this chapter

1. **Safety**
2. **Lab Manual Contents**

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 and be very careful when using alternate supports.
- Use only approved support methods. Do not use standard sawhorses, folding tables, cinderblocks, or other such methods. Despite weight-bearing claims, no standard production sawhorse is strong enough to support the Emriver model. Sawhorses and folding tables can collapse under dynamic or side loading.
- Check all fittings on the aluminum horse 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 be warped or could collapse when loaded.
- Never set the box up on a surface with a slope exceeding 8% (7 in drop in 7 ft).
- Never use more than 27 gallons (102 liters) of water in the model. The combined weight of water and sediment in the box could cause the box or supports to collapse.
- Never use more than the provided 185 pounds (84 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 box. The power supply should be placed away from the model and any other source of moisture. Read the manual that comes with the power supply and be certain to connect it to a properly grounded outlet.
- When using 12-volt power from a battery or automobile, always use the fused connectors provided with the model. Never bypass the fuses.
- Be sure you understand the dangers associated with charging and using lead-acid batteries, and consider using the 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 do not understand these directions, do not use this model.

Emriver Lab Manual Contents

Chapters are free-standing and are numbered as shown below. Visit www.emriver.com/support.html for a list of modules currently available.

Emriver Lab Manual

Advanced Setup

Chapter 2 (rev. 3.0) **www.emriver.com**

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

For the latest information on module development please contact us at info@emriver.com or join the user newsgroup http://groups.google.com/group/emriver?pli=1.

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In this chapter

1. **Channel slope**

2. **Slope variables and equations**
   a. Box slope
   b. Calculating Smax
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3. **Controlling water discharge**
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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 6 mm/mm. You can set slopes throughout this range with only two or three box slopes 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 EDU and the standpipe. You'll only see this channel slope in a perfectly straight channel.

Later in the 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 over means can be used. The Lab Manual's Measurements Chapter gives details on direct measurement of box and channel slope in the Emriver model.

Slope variables and equations

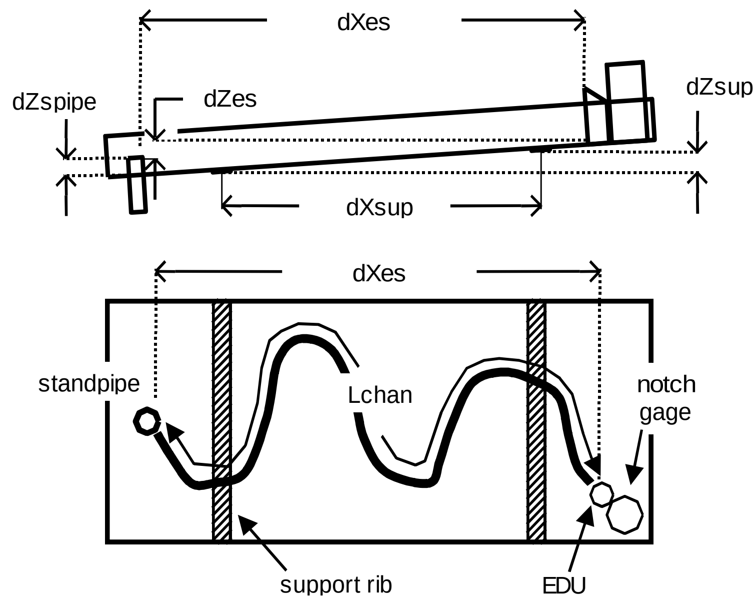

Figure 2.1. Variables used in setting and calculating slope in the Emriver model.

Variable	Definition
dXes	Horizontal distance between the energy dissipation unit (EDU) and standpipe
dZes	Vertical distance between the EDU outlet and top of standpipe
dZspipe	Vertical distance between top of standpipe and box floor; in other words, the length of standpipe extending from the box bottom
dXsup	Horizontal distance between the box support ribs, also the distance between aluminum horse centers
dZsup	Vertical distance between box support ribs
Lchan	Length of channel measured along the deepest part of the channel
Sbox	Slope of box
Smax	Maximum possible channel slope for a given box slope and standpipe height (DZspipe). Slope of a straight channel running from the EDu to the standpipe
S	Slope of a meandering channel

Box slope, Sbox

If the Emriver model is set up on a level surface, box slope is easily calculated by measuring the support height difference during setup. Simply place the two horses next to each other and directly measure their height difference as shown in Figure 2.2. Distance between the support ribs is 1320 mm or 52 inches. So

Sbox = dZsup /dXsup
= dZsup (mm) /1320 mm
= dZsup (inches) /52 inches

Calculating Smax

Smax is the maximum possible channel slope in the box, given a straight channel, box slope (Sbox) and standpipe elevation (dZspipe). If standpipe height is zero, then Smax = Sbox. As the standpipe is raised, Smax decreases. Smax can be directly measured using a leveling device and this equation:

Smax = dZes /dXes

For a given Sbox, Smax can be calculated by measuring standpipe height (dZspipe) and using this formula:

Smax = Sbox - (dZspipe (inches) /72 inches)
= Sbox - (dZspipe (mm) /1830 mm)

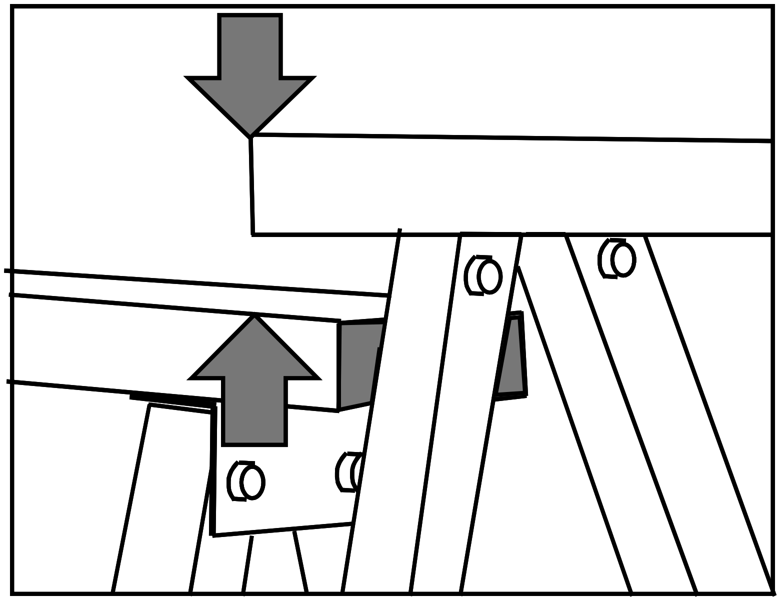

Figure 2.2. During setup, you can measure dZsup directly by placing the horses together as shown. The surface on which you assemble the model must be perfectly level for this method to work.

Calculating channel slope

The slope of a meandering channel can be directly measuring using a leveling device, a measuring tape, and this formula:

S = dZes /Lchan

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

sinuosity = Lchan /dXes

S = (dXes /Lchan)(Smax) (note the <u>reciprocal</u> of sinuosity is used)

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. During setup, place the two supports side-by-side (Fig. 2.2) and measure the height difference between them. This is dZsup.

2. Use these formulas to calculate slope, given standpipe height dZspipe :

Smax = Sbox - (dZspipe (inches) /72 inches)
= Sbox - (dZspipe (mm) /1830 mm)

To determine S, you can measure it directly. If you do not have a level, you can measure Lchann and calculate sinuosity and then S:

S = (dXes /Lchan) (Smax)

for example: If Smax is 0.04, and Lchann = 2.12, then

S = (1 / 2.12) * 0.04 = 0.019

3. Alternately, you may make up spreadsheets and charts that show Smax for given values of dZsup and dZspipe. Figure 2.3 shows an example of such a chart. You will still need to measure Lchann in order to calculate the slope of meandering channels.

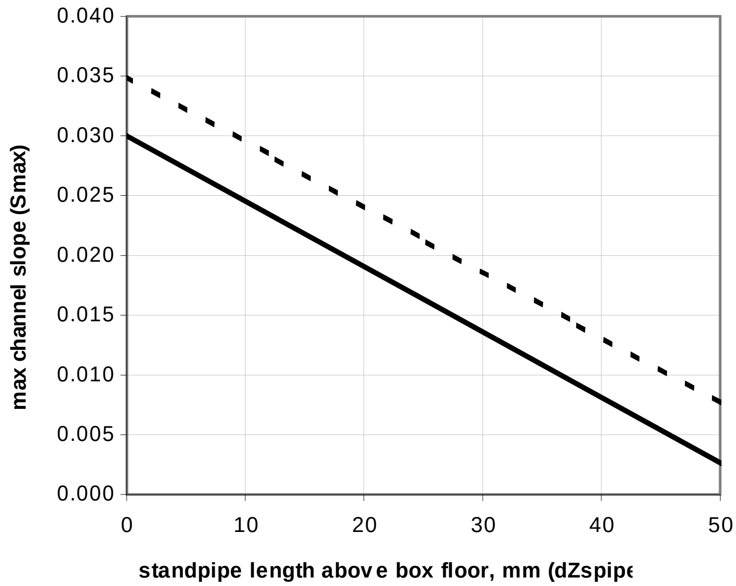

Figure 2.3. A graph showing maximum channel slope (Smax) for given box slope (Sbox) and standpipe height above the box floor (dZspipe). Note that the lines intersect at Sbox where dZspipe = 0; i.e. Smax = Sbox when the standpipe height is zero. Such charts can be constructed using the formulas above for various typical model setups.

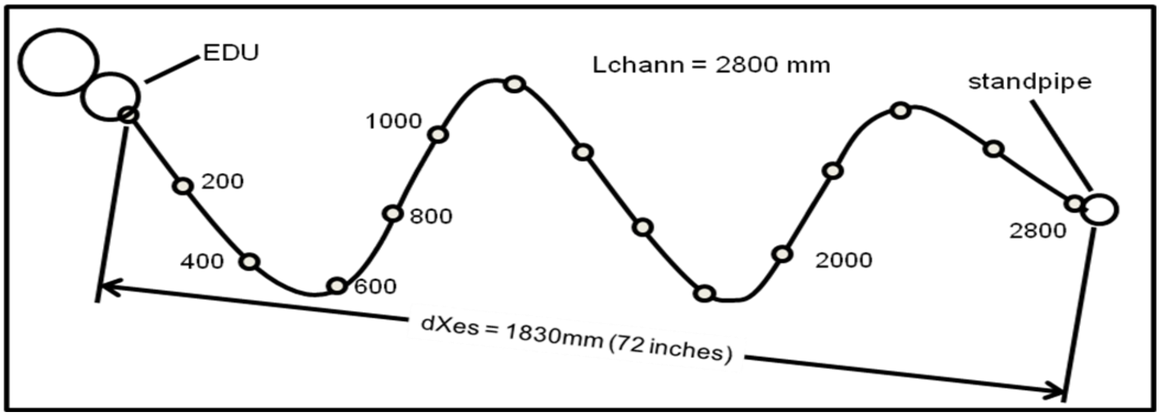

Figure 2.4. A meandering channel in an Emriver model showing typical meander size and variables controlling sinuosity and slope. Grey tickmarks are 200 mm apart.

Figure 2.4 shows a typical meandering channel in an Emriver model. In this example we have

Lchann = 2800 mm
dXes = 1830 mm So sinuosity = 2800 mm /1830 mm = 1.53

Let's assume that we have set up our horse supports so that their height difference is 3 inches or 76 mm. Box slope is thus

Sbox = dZsup /dXsup
= dZsup (mm) /1320 mm
= 76 mm /1320 mm
= 0.06 or 6.0%

Maximum channel slope with the dZspipe set at zero is thus 0.06. Let's set the standpipe about 2 inches (51 mm) above the box floor and calculate Smax:

$$
\begin{aligned}
Smax &= Sbox - (dZspipe\ (mm)\ /1830\ mm) \\
&= 0.06 - (51\ mm\ /1830\ mm) \\
&= 0.06 - 0.028 \\
&= 0.032
\end{aligned}
$$

So the slope of a straight channel from the EDU to the standpipe would be 0.032. Raising the standpipe 51 mm reduces Smax from 0.06 to 0.032.

Our meandering channel has a sinuosity of 1.53. We can determine its overall slope using this equation:

$$
\begin{aligned}
S &= (dXes\ /Lchan)\ (Smax) \text{ or} \\
S &= (1\ /sinuosity)Smax \\
&= (1\ /1.53)\ 0.032 \\
&= 0.021
\end{aligned}
$$

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Controlling flow

The Emriver model is supplied with water by a pump and reservoir. The reservoir is necessary because changes in the input and output of water to the box can vary. If the standpipe is raised, for example, several liters of water may accumulate in the lower end of the box before flow from the standpipe begins to refill the reservoir. Interstitial spaces in the modeling media hold over 25 liters of water. 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.

Flow is controlled by a valve array at the lower end of the box. Assembly, care and maintenance of the valve array are covered in the Emriver Use and Care Manual.

Flow measurement

Discharge is measured using a notch gage and head scale at the upper end of the box. The water surface elevation (WSE) in the notch gage is related to discharge. Each notch gage and head scale must be individually calibrated. Calibration procedures are given later in this document.

Using the Valve Array

Figure 2.5 shows how water moves though the model's plumbing system. Most demonstrations and experiments use only a fraction of the pump's full output. The bypass valve allows precise control of flow rates and prevents excessive backpressure on the pump when the main valve is only slightly open.

To send the pump's full output to the box, fully open the main valve and completely close the bypass valve. This is the only setting in which the bypass valve should be fully closed. From this setting, incrementally opening the bypass valve and closing the main valve will reduce the flow rate. To completely shut off flow without turning off the pump, fully open the bypass valve and close the main valve.

The threaded hose fittings at the ends of the hoses are 7/8-inch "garden hose thread" (GHT) connectors allowing you to use standard garden hoses to fill and empty the reservoir in field settings.   For example, a garden hose attached to the bypass valve's hose can be used to either fill or empty the system.

Discharge ranges

The range of useable discharges in the model runs from about 15 ml/s to 400 ml/s. At very low discharges, much of the flow is moving through interstitial spaces in the model and not much will happen in the channel. At flows above about 75 ml/s, channel beds begin to fully mobilize. This depends, of course, on channel morphology and slopes existing when the flow is increased.

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/s, can be used. Unless such structures are present in the model, flows above about 150 ml/s will create large channels with high sediment transport rates and you will be very busy moving sediment from the trap back into the box.

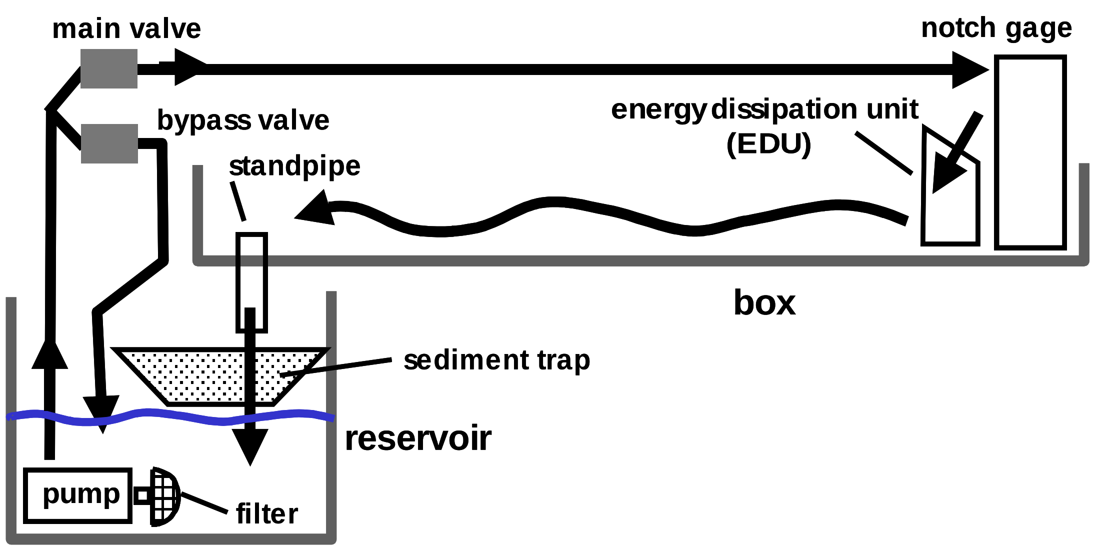
Creating hydrographs

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 valve array and the notch gage.

Using a number of one or two liter containers (large plastic cups would 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, though it should only be air dried (i.e. don't heat the modeling media). 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.

Figure 2.5. Flow control components and pathways in the Emriver model.

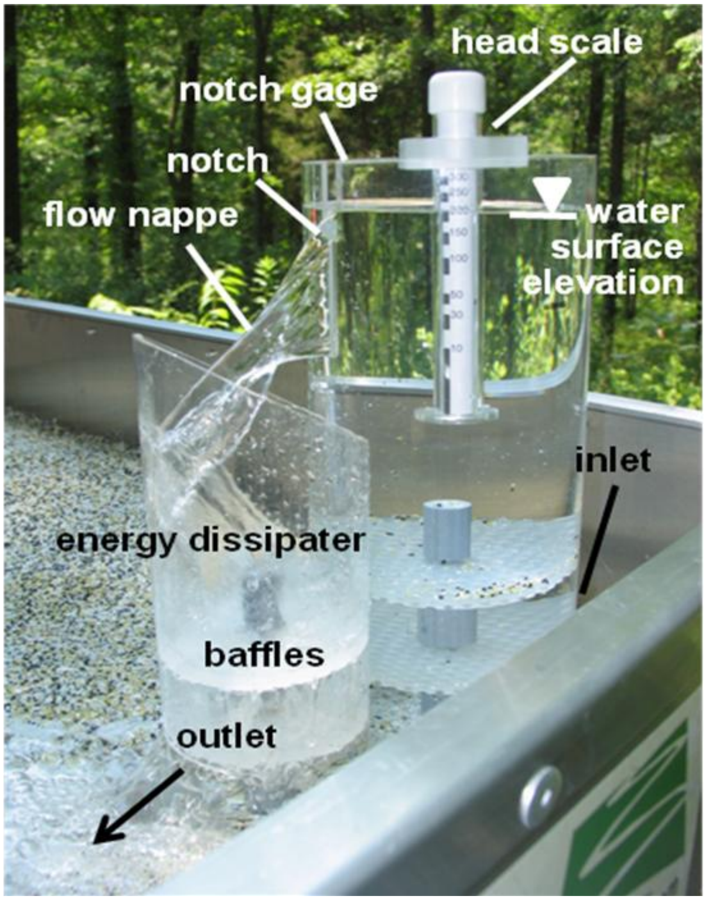


Use and calibration of the Emriver notch gage

The notch gage provided with your Emriver model allows you to precisely measure flow in the model during experiments and demonstrations. The volumetric flow rate of water, or *discharge*, is a fundamental independent variable in river geomorphology.

Parts of the notch gage are shown in Figure 2.6. Flow from the notch is proportional to the water surface elevation (WSE) in the gage. Discharge in your simulated rivers is determined by measuring the WSE. The baffles in the notch gage act in combination with the column of water in the gage to reduce currents in the gage that may affect accuracy.

Figure 2.6 shows parts of the head scale, which is used to measure WSE in the notch gage. The head scale is provided with a scale graduated in millimeters, though you may change this scale as described later in these instructions. The head scale can be placed on the rim of the notch gage at any point beyond 25 mm (one inch) from the notch opening. If the head scale is placed nearer than 25 mm, it may disturb the lines of flow exiting the notch gage.



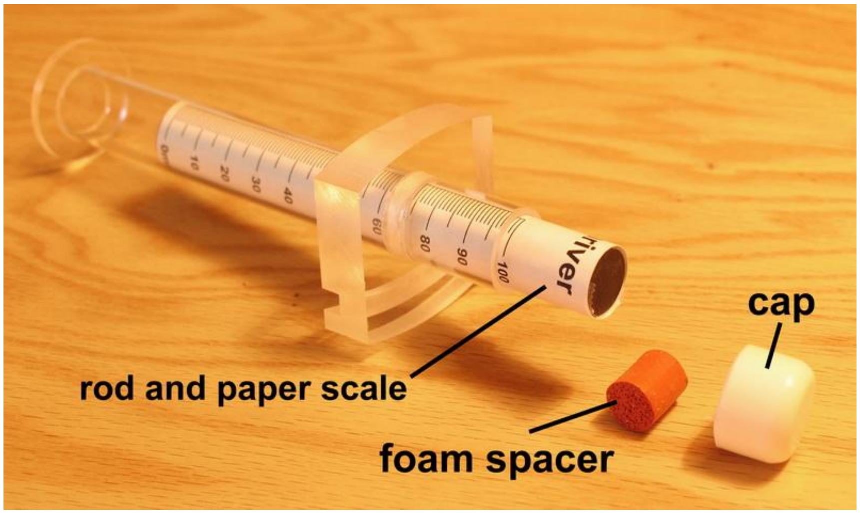


Figure 2.7. The head scale. A paper scale and plastic rod are held tightly inside the clear plastic tube by a compressible foam spacer and cap. The scale shown is graduated in mm.

Before use, the notch gage must be calibrated, i.e. you must establish the relationship between WSE and discharge. To begin calibration the gage should be placed in the box in the position in which it will be used. Next, place the head scale in the gage.

Fill the gage by using the pump and valve system to route a moderate flow through the gage so that the WSE reaches the approximate midpoint of the notch. Gradually decrease flow until it is zero or until the flow nappe is overcome by surface tension and flow runs down the exterior of the gage. To find the lowest WSE at which the nappe is free of the outside wall of the gage, increase flow slightly until the nappe just breaks free of the gage. This point is affected by the surface tension of the water in the gage, which can be affected by water chemistry, and can therefore vary. A WSE within 3 or 4 mm of this point is sufficient.

We recommend the SI units of ml/second as the most practical for the range of flows used in the model. You will need a 2000 ml beaker (or other container with a volume of at least 1000), a 1000 ml graduated cylinder, a stopwatch, and notebook.

Use the beaker to capture flow from the gage. Higher volumes of captured flow per run will yield more accurate measurements. Before each capture, record the WSE on the head gage. Record the rate of flow by simultaneously diverting the nappe into the beaker and starting the stopwatch. After each capture, record the time in seconds and tenths and volume of flow captured in milliliters, as well as a second reading of the WSE on the head gage. If the two WSE readings are not the same, the WSE changed during the run and the data for that run should be discarded. Figure 2.8 shows a typical data sheet.

Take at least two flow measurements at the first WSE setting. Then adjust the flow so that the WSE increases by 3 to 5 mm. Allow the flow to stabilize for a few seconds and take another two or three flow measurements. Continue incrementally increasing flow and measuring discharge until you reach the full output of the pump or the capacity of the notch.

The notch gage uses a two-stage notch that allows measuring a wide range of flows (from about 20 ml/s to 400 ml/s) with a compact gage. The discharge - WSE curve shows a slight jump at the point of width increase in the notch, so measure this point carefully. You should also measure discharge when the WSE is just at the break in notch size, because this is an important reference point.

Typical Emriver notch gage calibration data					
		before	after		
volume, ml	time, s	head scale, mm	head scale, mm	Q, ml/sec	notes
840	38.2	22	21	22.0	lowest possible WSE with free nappe
680	31.6	22	22	21.5	
570	15.8	25	25	36.1	
610	17.1	26	26	35.7	
700	14.8	30	30	47.3	
670	15.8	29	29	42.4	
960	13.8	37	37	69.6	
885	12.9	37	37	68.6	
635	7.0	41	41	90.7	
760	8.6	41	41	88.4	
810	7.2	48	48	112.5	
890	7.9	48	48	112.7	
640	4.2	56	56	152.4	at lower point of notch break
710	4.6	56	56	154.3	
970	5.8	58	59	167.2	
880	5.3	58	58	166.0	
940	4.8	64	64	195.8	
890	4.6	64	64	193.5	
840	3.4	70	70	247.1	
770	3.1	70	70	248.4	
990	3.3	76	77	300.0	
855	2.7	76	76	316.7	
860	2.3	84	85	373.9	Full flow
880	2.4	85	85	366.7	

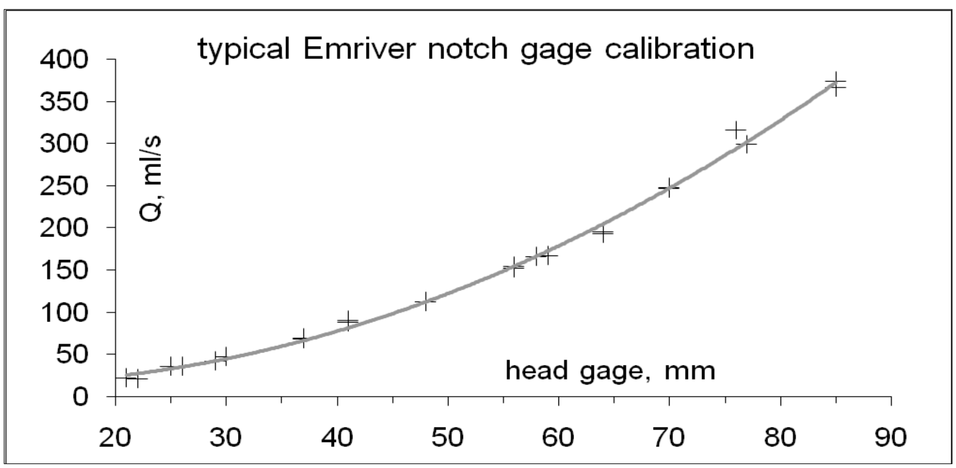


Figure 2.8. Typical notch gage calibration data.

Making a custom scale for the notch gage

The head scale is delivered with a paper scale calibrated in millimeters. After calibrating your gage, you can determine discharge by reading the WSE in mm and referring to the calibration curve.

Alternately, the outside of the head scale may be marked at a few key flow points with a suitable marker. The points to be marked will depend upon what the model is being used for. For basic demonstrations to laypeople, for example, where you must work quickly and will only use two or three flow rates, you might simply mark these values on the head scale or notch gage wall with a grease pencil.

Alternately, discharge values may be marked on the paper scale alongside the millimeter values. Parts of the head scale are shown in Figure 2.7**.** To remove the paper scale, simply pull the plastic cap off the head scale. Custom scales may be constructed and held in place inside the tube with a very small piece of tape or a 2 mm dot of glue. Hot melt glue works well, and can easily be removed by gently heating the tube in warm water. Don't use solvent glues, which may dissolve the acrylic tube.

For further information and support, e-mail us at info@emriver.com**.**

Care of the notch gage

The gage and head scale should be handled and stored carefully to prevent damage. The notch is precisely machined, and calibration and accuracy will be affected if it is damaged. The gage should be stored and transported in the plastic mesh in which it was shipped. This mesh will both protect the gage and allow it to air-dry after use. To clean the gage, carefully pull out the baffle assembly and use non-abrasive rags and mild detergent. Solvents of any kind may dissolve or mar the plastic.

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 towards 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.

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.

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 2.4 shows an example.

3. Route moderate flows of 25 to 55 ml/s and allow for groundwater table development and sediment transport continuity.

4. Increase flows to about 100 - 150 ml/s 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 discharge to 55 ml/s 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.

Valley shape

For demonstrations of basic channel processes like 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 2.9, 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.

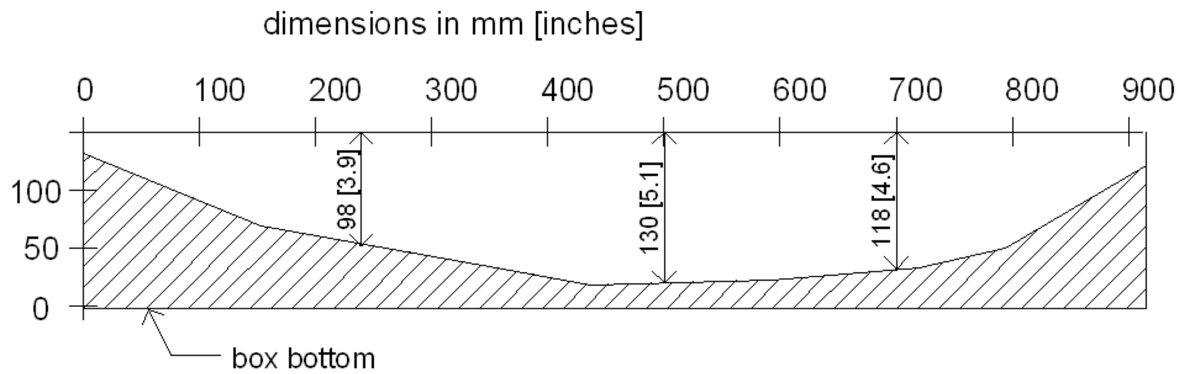


Figure 2.9. Typical “valley” morphology formed at the beginning of a demonstration. As meanders in the channel migrate, they will tend to erode away the valley sides, producing steep bluffs. This is only an example. You should experiment with other shapes.

Sediment properties

The modeling material used in the Emriver is cryogenically-ground thermoplastic. Most of the material is the same dense, hard melamine plastic from which countertops are made. Such thermoset plastic is difficult to recycle because it cannot be re-melted and re-molded. The material we use is mostly recycled from industrial materials (i.e. 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.

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

Modeling media sizes and colors

Because the plastic sediment used in the Emriver model is recycled material, it would be very difficult (and costly) to produce material in which sediment particle sizes are related to color. You may notice some relationships between size and color in the model, but these are strictly coincidental.

Sediment sizes in the model range from 0.016 in to 0.080 in (0.41 to 2.0 mm). Particle size distribution is weighted toward the larger particle sizes in the model.

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, if you will) 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 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.

Emriver Lab Manual

Measurements

Chapter 3 (rev. 3.0) **www.emriver.com**

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

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In this chapter

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, thalweg or channel distance is measured along the deepest part of a channel, though other paths can be used. These include the centerline of bankfull or other characteristic discharge. Here we will use the deepest part of the channel.

Your Emriver model comes with a narrow fiberglass-reinforced tape. The tape is graduated in 5 cm increments, with yellow bands at each full meter. You may visually estimate distances between the 5 cm marks or use a small ruler to measure these distances. To measure channel length, lay the tape in the center of your channel, following its curves as closely as possible. 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. The tape is marked every 50 mm.

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.

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

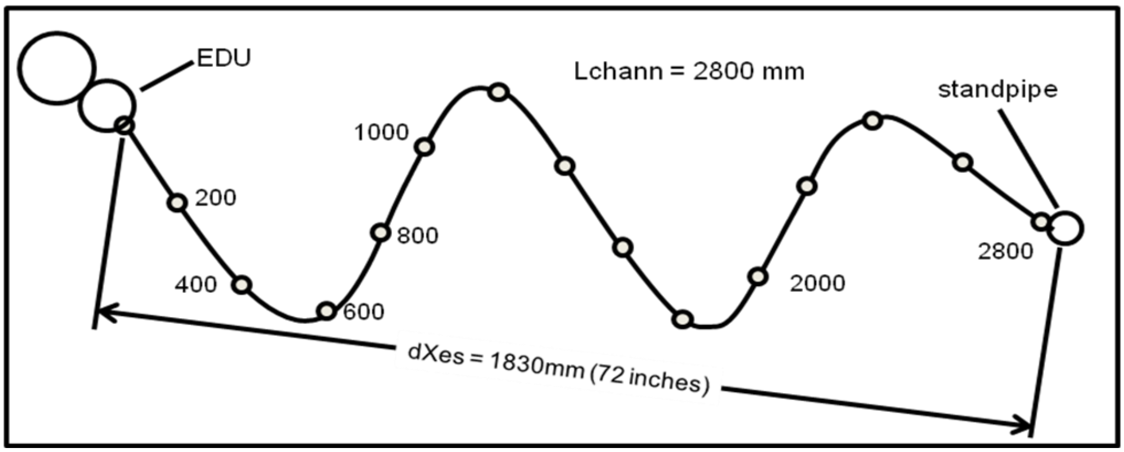


Figure 3.2. A meandering channel formed in the Emriver model. Here the channel is marked in 200 mm increments. Lchann and dXes, two variables used in calculating slope and sinuosity, are shown. See Chapter 2 for a detailed discussion of slope calculations.

Vertical measurements and laser levels

Elevations in the Emriver model are measured using either an optical or laser level and the included leveling rod. A small rotating laser with a visible beam works very well. Many surveying levels use a non-visible beam and a receiver. These are poorly-suited for use with this model because the receiver is to large to use with the Emriver's small leveling rod.

The Emriver model includes a cross-beam and bracket that hold a leveling rod, shown in Figure 3.3. The sole purpose of the bracket is to hold the rod vertical at a given point. 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 straightedges.

The acrylic level rod supplied with your Emriver model is used to measure vertical distance from a reference laser beam to points in the model. Except for its size, the rod is used exactly as a surveyor's level rod. The rod's red color makes the red-orange beam of a laser level visible even in sunlight.

The crossbeam and rod bracket serve to hold the rod stationary while measurements are being made. This is their only function. The crossbeam should be near-level, but is not reliable as reference line. The crossbeam slides longitudinally on the box gunwales while the rod bracket moved side-to-side on the crossbeam, allowing measurement of most of the surface area inside the Emriver's 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 shows how to remove and reassemble 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.

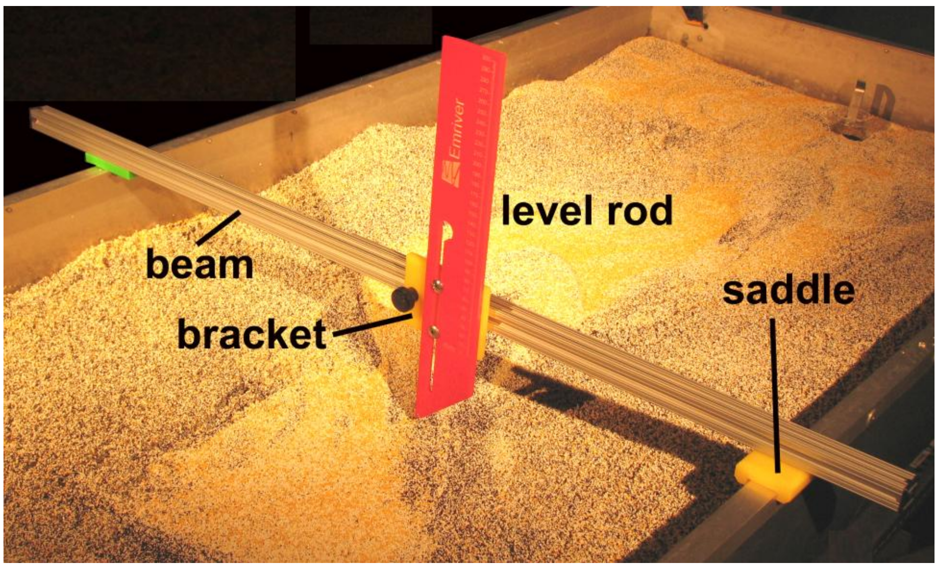
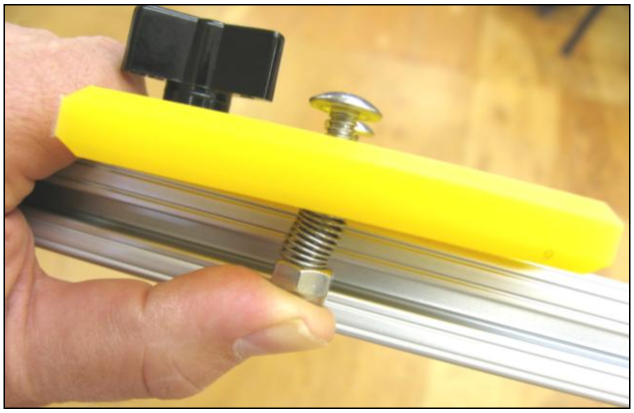
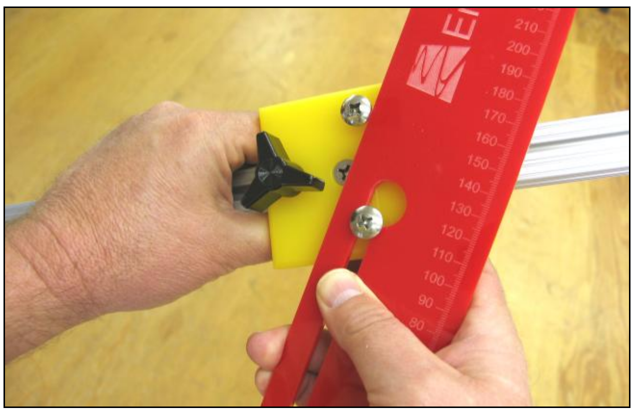


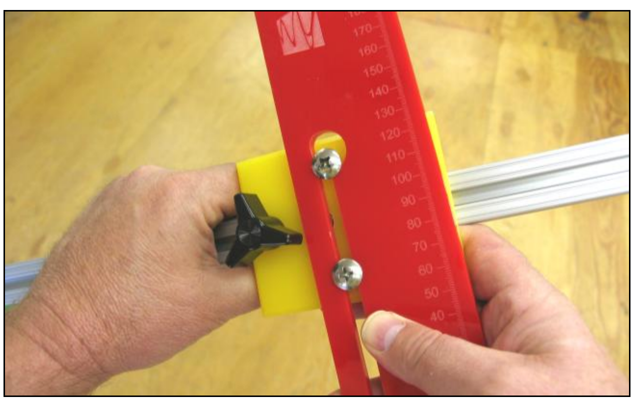
Figure 3.3. The Emriver leveling rod, bracket, and crossbeam. Older models may use a slightly different design.



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.

Figure 3.5 shows basic leveling setup. The Emriver model makes an excellent teaching tool for field methods, especially when used with a rotating laser, because the surveying methods are essentially the same as those used in the field.

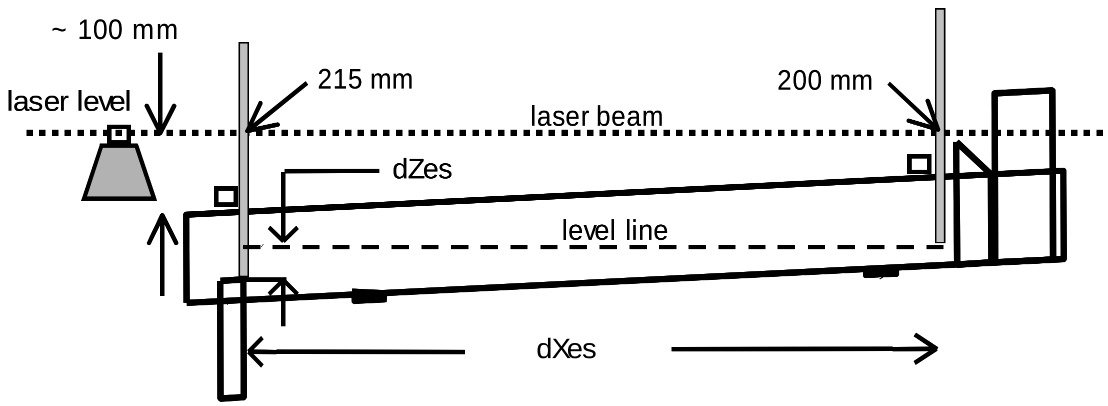


Figure 3.5. Schematic showing basic leveling. Here a rotating level is set up and leveled so its beam is about 100 mm above the Emriver's box. The level rod is depicted as a grey line at two different positions. Readings on the level rod show that dZes is 15 mm. If dXes is 1320 mm, then slope for a straight channel between the two points would be 15/1320 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 deepest channel point (or thalweg) 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.

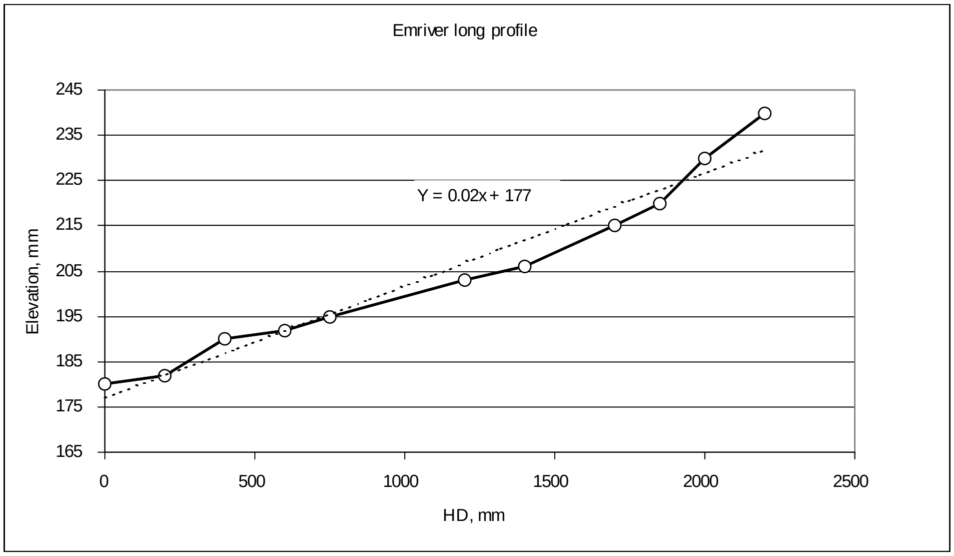


Figure 3.6. Example of a long profile in a meandering channel in an Emriver model.

Water discharge

Input to the model is measured using the notch gage, which can measure flows ranging from about 20 ml/s to over 350 ml/s, which is essentially the usable range for the Emriver model, given the media properties and box size.

The notch gage must be calibrated. If you use the gage for demanding experiments, you should periodically check this calibration. Calibration procedures are given in Chapter 2 (Advanced Setup). Note also that changes in water chemistry (and thus surface tension) may affect notch gage readings at very low flows. For most work, these changes are negligible.

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

You may use screens to filter the sediment from captured flow before measuring its volume. Ordinary window screening has about the right mesh size. Small kitchen strainers will also work well.

Sediment discharge

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, though it should only be air dried (and never in an oven of any kind). The sediment absorbs very little water.

We have not yet tested the method, but it should be possible to pour the sediment water mixture into a large graduated cylinder and measure both simultaneously by noting the volume of each. You would have to determine the pore volume in a typical sample of sediment and apply a correction factor for the water contained in the sediment interstices. This method should work for simple exercises and classroom experiments, and the required calculations (and examination of assumptions) would provide a good learning experience.

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

For the latest information on module development please contact us at info@emriver.com or join the user newsgroup http://groups.google.com/group/emriver?pli=1.

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

1. **Intro to demonstrations**
2. **Inchannel gravel mining**
3. **Channelization**
   - Straightening
   - Widening
4. **Bank armoring** (in progress, not included this version)
   - Soft methods
   - Hard armor
5. **Energy management** (in progress, not included this version)

Intro to demonstrations

The first Emriver-like models that we know of were built in the late 1980's 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. In this case, static drawings and talks proved 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 model and its ancestors are very powerful tools for teaching and understanding river process and morphology. On seeing the model, experienced river observers almost invariable 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 (i.e. things happen faster in the model) and expanded physical scale, i.e. in the 2-meter Emriver one can see the equivalent of at least a few hundred meters of real stream. Thus we very 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 or civil engineering who may have little or no formal training in applied fluvial geomorphology. And, of course, the model is very useful to academic geomorphologists for more advanced demonstrations, research, and teaching.

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, of 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 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 a minimum of 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. Only about a dozen people can observe the model at a given time. You may have to split a large audience into smaller groups.

Inchannel 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 non-geomorphologists. These include channel downcutting (also called incision) both upstream and downstream of the site, and increased lateral migration (and bank erosion) upstream of the mined area.

Setup for gravel mining demonstration

Smax	variable, about 0.020
S	approx. 0.015
plan form	gentle meanders, at least a full meander wavelength, sinuosity about 1.3; or a straight channel
Q	35 - 55 ml/s
initial conditions	good 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 flows of about 150 ml/s for at least 15 seconds to form channel features. In the straight channel, you should allow alternate point bars to form. Adjust Q to 35 - 55 ml/s. After decreasing the flow, make sure that the channel is metastable and sediment transport continuity is good 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. Use the leveling rod to do this. By setting the rod tip just at the water surface elevation, you can both observe and measure upstream incision. Absent 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.

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

- 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 further 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.

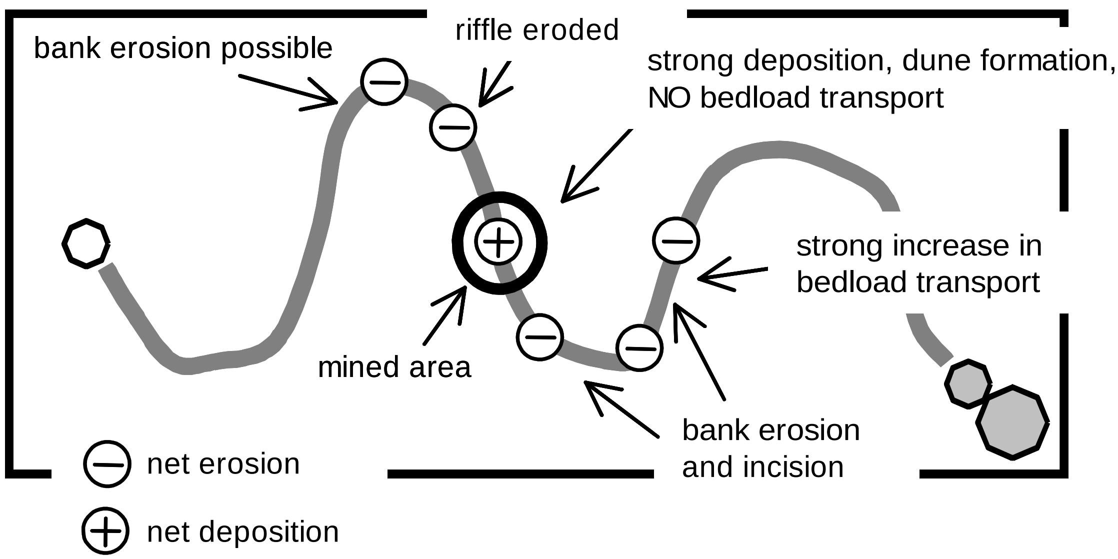


Figure 4.1. Expected response to removal of bed material to simulate inchannel mining. Usually, you can see a very strong increase in bedload transport rates upstream of the mined area. This net increase in transport is balanced by erosion of the channel's bank and beds.

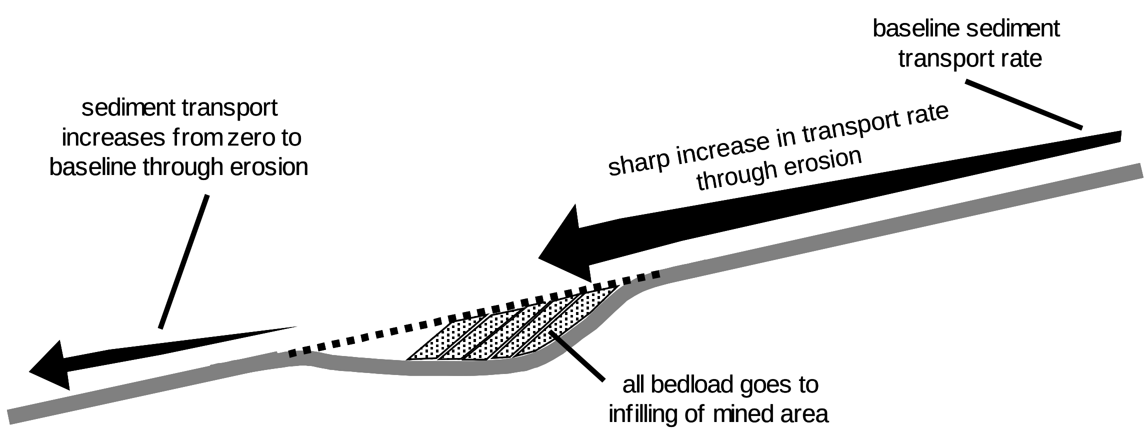


Figure 4.2. Schematic showing an Emriver long profile after bed material has been mined. Width of the arrows corresponds to sediment transport rates, which (usually) are clearly observable in the model. Note how the original grade, and thus sediment transport rate, tends to be restored by deposition as the channel seeks continuity in sediment transport.

You may again remove sediment from the mining site 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.

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.

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.

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

Smax	variable, about 0.020
S	approx. 0.015
planform	gentle meanders, at least a full meander wavelength, sinuosity about 1.3
Q	35 - 55 ml/s
initial conditions	well-established sediment transport continuity, meanders with point bars and well-formed channel features

As usual, begin with a meandering metastable channel. Figure 4.3 shows a typical planform. Visually check sediment transport continuity. Discharge should be set at about 45 - 60 ml/s.

Pick a meander bend in the middle of the model. You'll want to observe channelization impacts both upstream and downstream of your straightening. Figure 4.3 shows a typical setup. Use the level rod and bracket to mark the water surface elevation upstream of the channelization site. Place the rod tip just at the water surface and leave it there through your demonstration.

Note the difference in streambed elevation above and below your proposed channelization site (points P and Q, Figure 4.3). 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 the figure.

As shown in Figure 4.3, 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. 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.

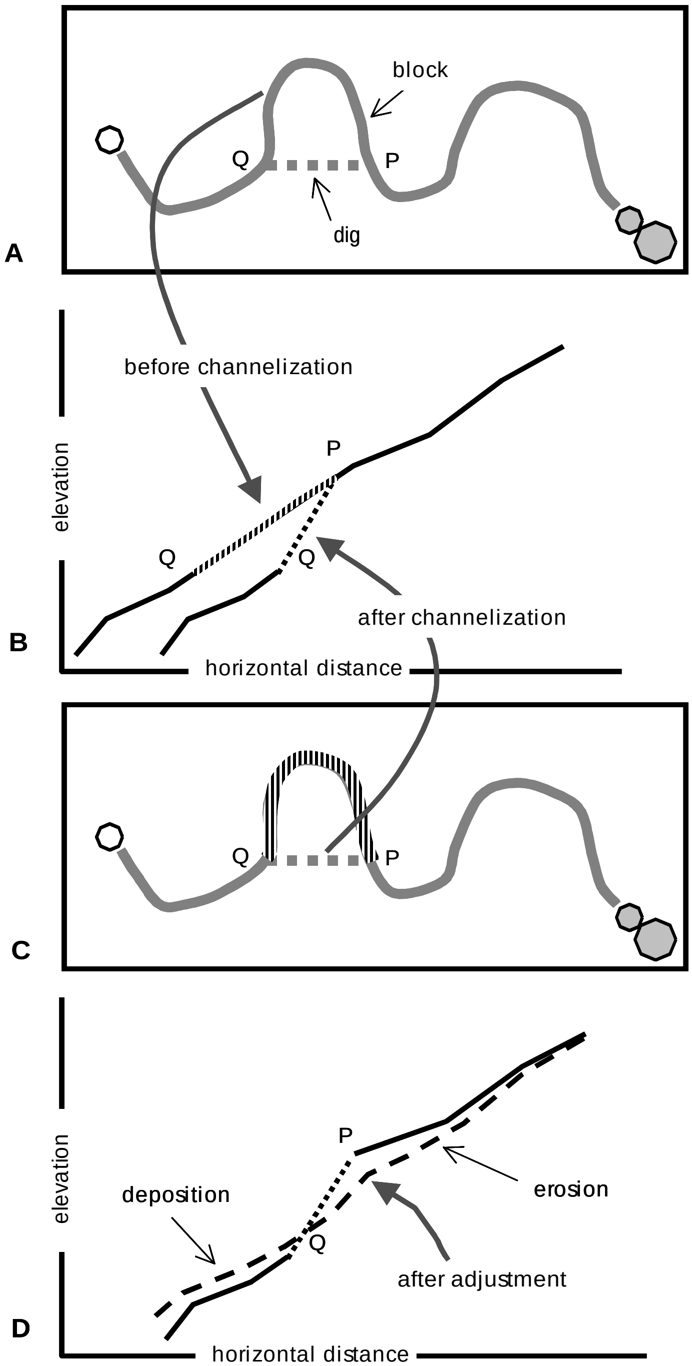
In summary, you will usually see:

- Velocity within your channelized reach will be higher than in adjacent reaches, both 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 4.3D. In general, downstream reaches agrade 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 P and Q. Dig the straight channel as shown and block the old channel.

B-C. The new channel drops the same distance between P and Q, 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 4.3. Channelization by replacement of a meander bends with a straight section, and expected effects and adjustments in an Emriver channel.

Advanced channel straightening exercise

Using the leveling gear and a laser level, you can do before-during-and-after surveys to show how the long profile changes when rivers are straightened. The essential steps are:

1. Establish a stable, meandering channel as discussed above.
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 are shown in Figure 4.3. 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 4.3, though many variations are possible. You may see upstream incision without downstream deposition, for example.

Widening

Channelization through cross-sectional enlargement, usually widening, is commonly done to increase hydraulic conveyance. It may also be used in attempts (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 the before.

We can also see a less stable channel after the deposition process because well-consolidated bank sediments, may have contained cohesive materials (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 involved 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 $V = QA$, where V is current velocity, A is cross-sectional area, and Q is discharge), 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 good 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.

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 riparian landowner to multi-billion dollar engineered projects along big rivers like the Mississippi. Although environmental values can suffer from both types, it’s the former that we most often try to discourage by using the Emriver model.

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 more within their river experience (and more visually interesting). With bank armoring demonstrations, you may want to experiment with higher discharges, which will accelerate fluvial adjustment and, usually, 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.

Smax	variable, about 0.020
S	approx. 0.015
planform	gentle meanders, at least a full meander wavelength (preferably more), sinuosity about 1.3
Q	35 - 110 ml/s
initial conditions	well-established sediment transport continuity, meanders with point bars and well-formed channel features

Riprap

The Emriver model is supplied with acrylic particles that can be used to simulate riprap. The acrylic particles have a density of roughly 1.3 g/cm^3. The density of stone can be twice this value. The acrylic material will thus tend to be more readily displaced by flow in the model. You may use stone particles as well, but these 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. Both acrylic and stone particles 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.

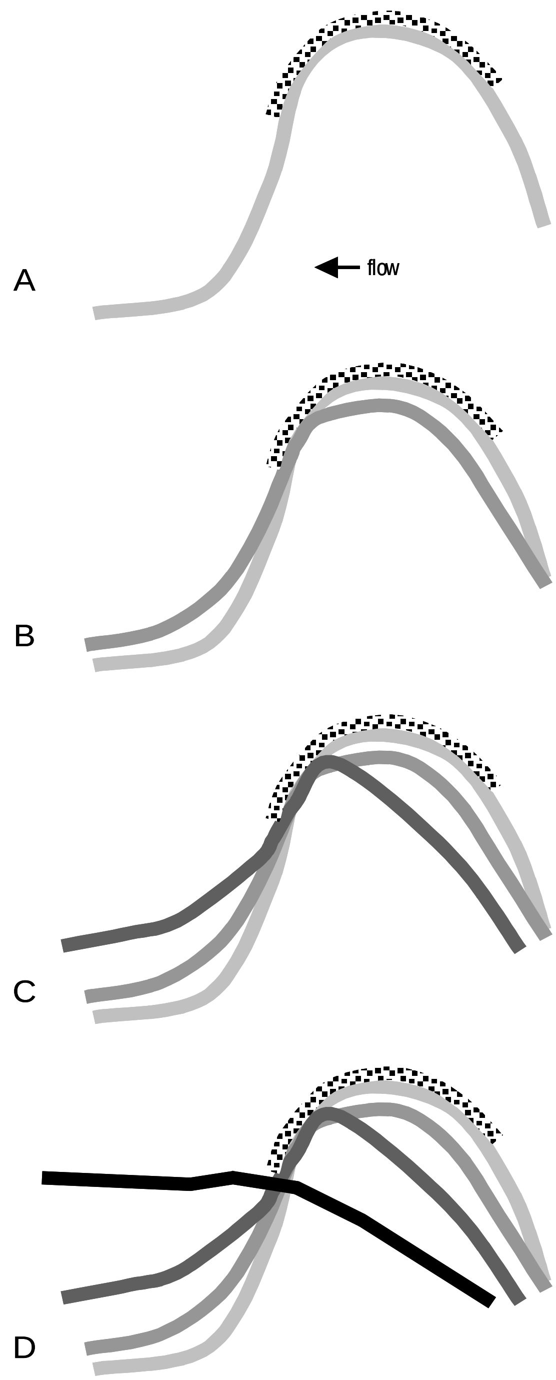
Figure 4.4 depicts a process the Emriver model shows particularly well: the interaction of hard, stationary bank armor with migrating meanders. The effects of a particular bank armoring project on fluvial process are complex, and you will no doubt see varied results. In general, you may observe these processes:

- 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 4.4. This demonstration shows one of the problems with hard structures in alluvial channels: Unless they 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 4.4, 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).



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

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 there. 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 4.4. Hypothetical planform channel response to armoring with stone riprap. Depending on channel characteristics and sediment and water flow regime, many different responses are possible.

- **Bank armoring** (in progress, not included this version)
  - Soft methods
  - Hard armor
- **Energy management** (in progress, not included this version)

[END OF DRAFT CHAPTER]

Emriver Lab Manual

Exercises and Experiments

DRAFT Chapter 5 (rev 3.0) **www.emriver.com**

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

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In this chapter

1. Sediment transport measurement, continuity, and channel stability.
2. *In production*
3. *In production, etc.*

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.

This experiment builds on those outlined in Chapter 4 of this manual, and requires an understanding of those chapters, especially those covering advanced setup and measurements.

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 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, 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 that 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 given in Chapter 4.

Steps

1. Set up the model using the initial conditions and instructions given for the gravel mining demonstration in Chapter 4. Form a meandering channel and use a flood pulse to form small floodplain surfaces (bar tops). Then reduce flow to about 55 ml/s to establish an equilibrium channel.

2. Once you have established an equilibrium channel (i.e. 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.

Next, turn off the water flow.

3. 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 (deepest point in the channel) 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 in Chapter 5. 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 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 below and in Chapter 5. You will have to quickly observe these processes as flow is restored. See www.emriver.com/emvid.html for a video showing most of these responses.

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 in Chapter 4.

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

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, noting also 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.

List of expected responses. See Figures 4.1 and 4.2 for a schematic explanation.

- 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.

- A headcut forms and migrates 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 further 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 an equilibrium long profile 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.

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 experimental, 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 (Figure 5.1 may help) 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!

[END OF DRAFT CHAPTER]