Final Report

Hillslope Flow Routing, Contaminant Transport, and Water Uptake in Zero-Order Watersheds Subject to Intensive Forest Plantation Management. Phase 1A: Watershed and Soil Characterization. Phase 1B: Instrumentation of First Hillslope and Trench

A cooperative study between the U.S. Forest Service-Savannah River, the University of Georgia and Oregon State University

Prepared By:

C. Rhett Jackson, Professor of Hydrology
Warnell School of Forestry and Natural Resources
University of Georgia
Athens, GA 30602-2152
rjackson@warnell.uga.edu ; 706-542-1772

Prepared For:

John Blake, Assistant Manager Research
USDA Forest Service Savannah River Institute
One Mile Inside Aiken Barricade (delivery) PO Box 700 (mail)
New Ellenton, SC 29809

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Summary of Accomplishments

Accomplishments Covered in Previous Progress Reports:

1. Used trenches, auger investigations, and field inspection to characterize soil profiles on the hillslope. Topsoils are light colored loamy sands, and they overlay an orange argillic layer variously composed of sandy clay loam, sandy clay, and clay. Depths to the argillic are highly variable, ranging from 16 to over 150cm. The entire hillslope was farmed prior to establishment of the current timber stand, and there is field evidence of previous terracing, gully erosion, and downslope soil movement (Greco 2008).
2. Measured in-situ hydraulic conductivities in the topsoil and the argillic using a compact constant head permeameter (Amoozemeter). Conductivities in the surface soils ranged from 4 to 30 cm/hour, with median values around 9 cm/hour, while conductivities in the argillic were generally one to two orders of magnitude lower with much greater variation from .001 to 4 cm/hour with a median around 0.07 cm/hour (Greco 2008).

3. Collected intact soil cores from the A and B horizon for laboratory determinations of moisture characteristic curves using hanging water tables (Greco 2008).
4. Mapped depth to clay on a 2m by 4m grid in the first 50 meters upslope of the trench.
5. Laid out the trench alignment.
6. Worked with USFS research, engineering, and safety personnel to design trench and drains. Provided conceptual design drawings and soils information.
7. Installed five nests of recording piezometers with one piezometer above the clay, one within the clay, and one below the clay in each nest. Also installed a rain gage in a forest opening near the site, and a 2.5 foot H-flume on the intermittent stream draining the watershed.
8. Installed a preliminary network of 14 maximum rise piezometers finished at the top of the clay horizon to record instances and maximum depths of perching.
9. Set up and ran a Hydrus 2D model of the hillslope. Found that Hydrus 2D wasn't capable of representing the entire hillslope from the ridgetop to the stream while also providing a detailed mesh in the shallow soil environment and representing wetting front behavior during storms.
10. Presented and published preliminary results at the 2007 Georgia Water Resources Conference (Greco et al. 2007, Appendix A, provided in a separate file).
11. Installed 48 maximum rise piezometers in a regular grid.
12. Master's student James Greco wrote his MS thesis on the soils investigations, the preliminary hydrologic response data, and the Hydrus 2D modeling effort (Greco 2008, previously transmitted).
13. Lead a tour of the site for potential DOE, ORNL, USFS, and Oregon State University collaborators. Began meeting with USFS, ORNL, and Oregon State University to discuss potential for additional Dept. of Energy funding to expand research into hillslope-riparian-stream interactions pertinent to water quality issues stemming from intensive short-rotation biomass production. Traveled to ORNL to meet with collaborators and plan a proposal to DOE.

Accomplishments since last progress report:

14. Continued to gather continuous water level data from the piezometer nests, flow data from the flume, and precipitation data from the site rain gage.
15. Designed and installed interflow interceptor plates and a gutter system to measure flows of water entering the trench above the argillic surface (Figure 1). Appendix B provides details of the interceptor plate installation methods. Of the 11 trench sections (each approx. 11 meters long), sections 4 and 10 featured no soils suitable for the installation of collection plates. Sections 5 and 8 each were instrumented with two flumes because the argillic layer in both sections featured two low points. In total, about half of the total trench length featured soil conditions that allowed installation of collection plates and gutters (precise measurements of instrumented trench lengths to follow later).
16. Designed and installed v-notch flumes to measure flow collected on the interflow plates and to measure flow collected in the French drains within each of the 11 trench sections (Figure 1).
17. Monitored trench response during several large storms.

Figure 1. Collection plates, drip spoons, and gutter leading into the flume for trench section #2. Photo taken during flowing conditions on April 1, 2009.

18. Built a cover over the trench drain collection area (Figure 2).

Figure 2. Cover over the lower drains (April 2, 2009).

19. Acquired, calibrated, and installed 22 capacitance probes on the 22 flumes.
20. Continued to measure maximum rise piezometer data monthly in the 48 maximum rise piezometers.
21. Used the maximum rise piezometer data, along with observations of trench flow collections, to define high and low activity areas draining to the trench. Used this information to select contrasting locations for soil moisture measurements.
22. Acquired, tested, and installed 39 Decagon EC20 soil moisture probes connected to 8 Decagon dataloggers. The soil moisture sensors were arranged to monitor soil moisture near the trench and 40 meters upslope in areas contrasting in seepage to the trench. Within each set of soil moisture sensors, the soil moisture sensors are placed at both the soil surface and at the top of the argillic layer. When the argillic is too deep to reach with the soil moisture sensors, the deeper sensors were placed approximately 75 cm below the surface. The sensors were also arranged to capture differences in soil moisture between differing microtopographic positions. Thus, the soil moisture sensors were arranged to capture soil moisture variation across the slope, up and down the slope, between different depths, and between microtopographic positions.
23. Conducted routine maintenance of trench, trench cover, etc.
24. Acquired an Amoozimeter for continued investigations of in-situ hydraulic conductivities.
25. The project has helped support and train one MS student, five part-time technicians, and five temporary student workers.
26. Acquired funding from the Dept. of Energy Biofuels program to expand the project to two more first order watersheds to study the effects of short rotation high intensity biomass production on hydrologic behavior and water quality in the Upper Coastal Plain.

Key Observations from the Preliminary Study Period

The soils investigations clearly demonstrated large differences in texture and hydraulic properties between the topsoils and the argillic horizon and that these differences aligned with the visual differences in the soils (Figure 3). Topsoils featured high saturated hydraulic conductivities while conductivities in the B Horizon were highly variable but the majority of measurements were very low (median value around 0.07 cm/hour, see Figure 4). Moisture release curves of the topsoils and the argillic were also very different (Figure 5). The textural and hydraulic data indicate that the argillic layer should impede infiltration fronts, hold water in the root zone, and cause perching of saturated lenses during larger rainstorms.

Figure 3. Light colored loamy sand topsoils (10YR 4/4 and 10YR 5/4) overlying orange sandy clay loam and clay (2.5YR 5/6 and 7.5YR 5/6).

Figure 4. Saturated hydraulic conductivities in surface soils and in the argillic layer. Measurements made with a compact constant head permeameter (Amoozemeter). From Greco (2008).

Figure 5. Moisture release curves for argillic and topsoil samples.

As hypothesized, the 2m x 4m tile probe investigation of depth to clay revealed significant discrepancies between the surface topography and the clay topography. Depths to the argillic layer varied widely, ranging from 16cm to over 150cm. By subtracting the depth to clay from the surface elevations, we created a topographic map of the clay surface, and this map suggests a couple local low points in the clay topography as well as a couple areas of convergence above the slope (Figure 6).

Figure 6. Clay topography with locations of piezometer nests and preliminary set of maximum rise piezometers (from Greco 2008).

The maximum rise piezometer data, coupled with the continuous water level data from the piezometer nests, indicate that perching of water within and above the argillic horizon is a common occurrence during storms. Data from the recently installed grid of 12 rows of maximum rise piezometers, each row with four piezometers going upslope from the trench, demonstrate great spatial and temporal variability in perching above the argillic (Table 1). Among the 12 approximately monthly

sampling events during the period from April 2008 through April 2009, the fewest non-zero responses at any piezometer was two (at two piezometers), while three piezometers featured perched water ten times. The average and median number of perching events were 5.88 and 6, respectively. Between December 19, 2008 and January 22, 2009, every piezometer indicated perching, and perching was observed in at least two piezometers during every sampling event, although every piezometer was dry at least twice (Table 2). No nearby piezometers featured the same time series of non-zero events. Data indicated weak seasonality, with high fractions of responding piezometers during winter months, but some summer storms also produced high fractions of responding piezometers (Table 3). Spatial and temporal behavior of perching was complicated, and the only simple generalities that can be drawn are 1) perching was common, 2) some piezometers responded very frequently, and 3) some piezometers responded very infrequently (Table 2).

Each recording piezometer nest featured three piezometers, one completed above the argillic, one within the argillic, and one below the argillic at the maximum depth achievable with hand augers (3 to 5 meters deep). The recording piezometers indicated that during larger storms, lenses of saturation formed within the argillic and extended upwards into the topsoil (See Figure 7 as an example). Only in rare events (and at one location), did the water table indicated by the deep piezometer approach the argillic layer. In general, saturation in the near surface environment was caused by perching that began within the clay layer.

Figure 7. Example time series of water levels in recording piezometer nest #3. Piezometer 3A is completed in the A horizon just above the argillic, Piezometer 3IC is finished within the argillic horizon ("In Clay"), and 3D is located in the sandy soils underlying the argillic horizon.

Table 1. Maximum Rise Piezometer Data April 2008 Through April 2009

Maximum Rise Piezometer Identification																								
Date	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4	F1	F2	F3	F4
4/18/2008	0	0	2.8	3.7	2.5	0	0	0	2.5	1.4	0	0	2.1	0.8	0	0.9	0.9	0	0	0	0	0	0	0
5/15/2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/26/2008	0	0	2	1.3	2	0	0	0	1.2	0	0	0	30	0	0	0	119	0	3	0	0	0	0	0
8/28/2008	5	3.5	3.5	23.5	0	0	3	3.2	4.3	6.5	15.4	6.4	34.3	6.5	0	0	0	0	0	0	10	0	2.6	3.3
9/26/2008	0	3.4	0	10	0	0	0	0	0	3.6	14.5	4.6	36	5.5	0	0	0	0	0	0	0	0	0	0
10/24/2008	0	0	0	0	0	0	0	4	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11/21/2008	6.9	0	0	14.3	0	0	0	5.3	0	8.2	0	0	42	0	0	1.6	0	0	0	0	0	10	0	0
12/19/2008	2	4.4	1.7	7	7.4	1.7	2.1	1.4	7.8	0.7	5.9	3.4	63	3.3	2.1	6	11.8	9.9	1.7	7.6	9.2	6.4	1.5	18
1/22/2009	43	11	18	112	73	11	23	13	35	114	56	32	64	27	11	19	19	39	50	13	95	55	24	100
2/19/2009	2.3	1.3	0	7.8	1.4	0	0	1.2	7.9	11.5	15.5	1.8	0	0	7.2	0	94.5	0	0	0	19.7	5.5	0.8	1.1
4/9/2009	8.3	0	0	10.5	5	4	0	0	6.1	22.2	25.3	2.8	51	0	0	6.1	85	0	1.7	2.5	30.3	0	6	19.6
4/23/2009	3.4	0	0	10.1	4	0	0	0	4.5	12.2	11.3	27.4	0	0	0	6.9	0	0	0	0	0	1.5	0	0
Number of Non-zero Responses																								
	7	5	4	10	7	3	3	6	8	10	7	7	8	5	3	6	6	2	5	3	5	4	5	5
				Wet		Dry	dry		Wet	wet			Wet		Dry			dry		dry				

Maximum Rise Piezometer Identification																								
Date	G1	G2	G3	G4	H1	H2	H3	H4	I1	I2	I3	I4	J1	J2	J3	J4	K1	K2	K3	K4	L1	L2	L3	L4
4/18/2008	1.6	0	6.2	3.2	0	0	0	0	1.4	1.3	1	0.6	35.3	17.6	1.5	2	4.3	0.5	0	0	2	1	1	3
5/15/2008	0	0	0	0	0	0	0	0	0	0	0	0	9.5	10	0	0	0	0	0	0	0	0	0	0
6/26/2008	0	11	0	0	0	0	0	0	0	0	0	0	18	0	0	7.5	0	0	0	0	0	0	0	0
8/28/2008	10.8	10.2	14.3	6.5	0	0	0	0	0	5.4	0	0	5.6	0	5.5	0	35.3	0	31.3	0	0	0	0	12.5
9/26/2008	0	10.8	8.3	0	0	0	0	0	0	4.2	0	0	0	0	0	6.7	3.5	1.9	2.2	1.8	2.4	1.8	2.55	2.75
10/24/2008	3.1	21	0	2.5	0	0	0	0	3.4	0	0	0	0	0	0	0	0	0	0	0	0	4.1	0	0
11/21/2008	0	10.5	0	2.5	0	0	0	2.4	5.5	0	0	0	0	0	0	3.5	6.6	0	0	0	0	15	0	16.8
12/19/2008	26	60	31	74	4.4	5.5	1	3.3	13	43	1.5	0	75.75	65	0	8	1.5	0	2.5	2.5	6.5	19	37	32
1/22/2009	23	22	122	80	18	12	23	13	62	119	63	17	582	479	18	11	62	34	50	23	15	45	393	147
2/19/2009	1.8	2.5	4.8	36	1.6	4.3	0	0	0	2	0	3	6.8	1.1	0	8.7	42.4	24	13.5	13	0	2	0	22.8
4/9/2009	29.5	27.5	47.5	54.7	0	3.3	0	0	0	44	0	0	80	65.4	21.5	32	22	7.5	6	5.4	10.2	6.2	33	23.4
4/23/2009	0	4.8	6.5	34.6	0.9	0.5	0	0	0	26.8	0	0	55.5	24.6	0	14.3	26.7	17	17	21	0	0	25.5	21
Number of Non-zero Responses																								
	7	10	8	9	4	5	2	3	5	8	3	3	9	7	4	9	9	6	7	6	5	6	5	8
		wet	wet	Wet			dry	Dry		wet	dry	Dry	Wet			wet	Wet					wet		wet

No piezometer never holds water.

Some piezometers hold water for extended periods between storms.

A few were only wet for short periods of time in winter or spring.

There was no sampling event for which no piezometers showed water.

There was one event for which every piezometer showed water (1/22/2009).

“Wet” denotes 8 or more non zero events in the 12 monitoring periods while “Dry” denotes 3 or fewer non-zero events.

Table 2. Number of non-zero observations recorded at each maximum rise piezometer, April 2008 through April 2009.

Position Up/Down Slope	Number of Non-Zero Observations (out of 12 approx. monthly observations)											
4	10	6	7	6	3	5	9	3	3	9	6	8
3	4	3	7	3	5	5	8	2	3	4	7	5
2	5	3	10	5	2	4	10	5	8	7	6	6
1	7	7	5	8	6	5	7	4	5	9	9	5
	A	B	C	D	E	F	G	H	I	J	K	L
	Piezometer Line											

Table 3. Average and median response depth and fraction of maximum rise piezometers recording perching during each sampling period, April 2008 through April 2009.

Date	Average Response Depth (cm)	Median Response Depth (cm)	% Responding
4/18/2008	2.11	0.7	54.2%
5/15/2008	0.41	0	4.2%
6/26/2008	4.06	0	18.8%
8/28/2008	5.59	2.8	52.1%
9/26/2008	2.64	0	39.6%
10/24/2008	0.86	0	8.3%
11/21/2008	3.15	0	31.3%
12/19/2008	14.55	5.95	93.8%
1/22/2009	72.71	34.5	100.0%
2/19/2009	7.70	1.8	66.7%
4/9/2009	16.78	6.1	70.8%
4/23/2009	7.88	0.25	52.1%

Although the capacitance probes for recording water levels in the flumes for measuring trench flow did not arrive until May 2009, regular observations of trench flow were made in winter 2008 and spring 2009 (Table 4). By using dust in the stilling basin to mark high water marks, we could ascertain whether and how much flow had entered each flume in the intervening period. We were also present to make observations during large thunderstorms or frontal storms on April 2, April 9, May 5, and May 11, 2009. The data indicate high variability in the amount of flow reaching each of the eleven 11m long trench sections. Trench sections 1, 2, 4, 5, 7, and 8 received the most flow, while sections 3, 9, 10, and 11 received little or no flow at any time. No section received high flow rates during this observation period, with the highest measured flow rates around 0.06 liters/second (Table 4). The event that caused perching in all 48 maximum rise piezometers did not deliver appreciable flow to the trench (Tables 1, 2, 3, and 4).

Table 4. Summary of Trench and Drain observations from December 2008 through June 6, 2009.

Date		Segment										
		1	2	3	4	5	6	7	8	9	10	11
Dec 08	Drain	Algae	Algae		Algae	Algae		Algae	Algae			
12/19/08	Trench	-	-	-		-	-	-	-	-	-	
	Drain	-	-	-	drip	-	-	-	drip	-	-	-
2/19/09	Trench	-	y	-		y	y	m	-	y	-	t
	Drain	-	-	-	-	-	-	-	-	-	-	-
3/4/09	Trench	t	y	-		t	t	t	-	-	-	-
	Drain	y	y	-	drip	y	-	-	-	-	-	-
4/2/09	Trench	drip	flow	-		y	y	-	-	-	-	
	Drain	flow <8am .058 l/s	flow <8am .015 l/s	After 5pm .01 l/s	flow <8am .04 l/s	flow 9am <.01 l/s	flow 11:30a .051 l/s	flow 9am .022 l/s	After 5pm .015 l/s	-	-	flow 10am .064 l/s X
4/9/09	Trench	-	-	-		-	-	-	-	-	-	
	Drain	-	-	drip	flow	-	-	-	drip	-	-	-
5/5/09	Trench	drip	drip	-		x	x	x	drip	-	-	
	Drain	drip	-	-	-	-	-	-	-	-	-	X
5/11/09	Trench	-	drip	-		-	-	-	-	-	-	
	Drain	flow <.01 l/s	-	-	flow <.01 l/s	-	-	flow <.01 l/s	-			
6/4/2009	Trench	-	-	-		-	-	-	-	-	-	
	Drain	-	-	-	-	-	-	-	-	-	-	-

Notes: Prior to beginning periodic observations, it was noted that drain pipes 1, 2, 4, 5, 7, and 8 all had algae growing in the ends of the pipe, indicating nutrient-laden flow occurring frequently enough to initiate algal growth.

- indicates no evidence of flow since last visit

y indicates evidence of prior flow, but not currently.

t indicates evidence of small amounts of prior flow (trace)

m indicates possibility of prior flow (maybe)

drip indicates dripping observed at time of inspection

flow indicates continuous flow observed at time of inspection

X – roof leaking into trench section due to blocked or broken gutters, flow due to roof runoff

When flow was observed during storms, inspection of the trench face revealed that most of the flow was seeping out of the clay, rather than out of the sandy topsoil overlying the clay (Figure 8).

Figure 8. Concentrated seepage from the argillic layer below the line of collection plates (April 2, 2009). Note sloughing of soil surface occurring in areas of concentrated seepage.

Observations to date indicate that most of the interflow occurring the winter/spring of 2008-2009 has moved through the argillic layer itself rather than over the top of the argillic layer. During the wet period culminating in heavy rainfall on April 2, 2009, water was observed seeping out of the argillic layer on the trench face below the line of interceptor plates (Figure 8). Where this seepage was concentrated, it tended to cause sloughing of the surface layer of clayey soil (also Figure 8). While seepage through the argillic appeared to be concentrated in certain areas, there was no evidence of lateral macropore flow. These observations are consistent with the piezometer data that indicate that perching is initiated within the clay layer and not on top of the clay layer.

Flow data from the 2.5 foot H-flume installed on the intermittent stream draining the small watershed into which the hillslope contributes indicates only weak connections between perching events and watershed flow response. For most storms, the data indicated that shallow hydrologic processes within and above the argillic horizon are not contributing to watershed scale storm flows. The streamflow data need to be assessed relative to local water table dynamics.

Implications for future research

A major accomplishment of this phase of the research was the acquisition of additional funding to research the effects of short rotation high intensity biomass production on hillslope hydrologic processes and water quality at the small watershed scale. This will require instrumenting hillslopes and streams on two additional watersheds. Lessons learned from this phase of the project will be used to make data collection more efficient and more focused in the next phase of the project. One major change will be in the design and construction of the interflow interception trenches.

In this phase of the project, the interceptor trench was designed to 1) collect flow moving above the clay horizon, 2) act as a French drain to collect flow moving within the clay horizon, and 3) allow for visual observation and possible measurement of lateral macropore flow. However, observations of trench seepage indicate that the large majority of the interflow passes through the clay itself, and macropore flow has not been observed. Thus, trenches installed for the next phase of the project can be much simpler, designed simply to use French drains to collect flow moving both within and above the clay horizon. Thus, the trenches do not need to be kept open and can be filled with gravel and covered with topsoil (Figure 9). Segmenting the trench has been shown to be very useful in characterizing and quantifying the variability in hillslope flow paths. Therefore, the new trenches should be segmented similarly to the current trench.

Figure 9. Simplified trench design for the next phase of the project.

During the construction of the trench, it was observed that tap roots of the pine trees growing on site pass through the argillic horizon (Figure 10), revealing the possibility that decayed tap roots from long dead trees have left holes in the argillic. It is assumed that whatever materials eventually fill the spaces left by the decayed roots have significantly higher hydraulic conductivities than the clayey soils of the argillic. Thus, if the argillic were perforated with many such holes, the mesoscale conductivity of the argillic horizon is likely to be much greater than that determined by the in-situ measurements made

with the Amoozometer. This would explain why significant interflow is rare on this site despite very low measured conductivities of the argillic horizon. In the next phase of the project, exploration of the effects of current and past tap roots on the mesoscale physical and hydraulic properties of the argillic horizon is recommended. Such exploration could take the form of ground penetrating radar surveys, removal of areas of the topsoil to expose horizontal cross sections of the argillic layer, and physical testing of the properties of the remnant holes. Investigators at the short rotation project, located on a broad, flat hilltop, have found deeper soils and longer lasting perching events than have been observed at this site. It is possible that topsoil depth and tap root penetration of the argillic are functions of hillslope position. It is recommended that the tap root investigations be conducted on hilltop, backslope, and toeslope positions,

Figure 10. Tap root of pine tree, partially exposed at trench face.

Conclusions

1. The argillic layer within the soil profiles at the study site has very low hydraulic conductivities with respect to rainfall rates and A horizon conductivities at the study site.
2. Because of the low hydraulic conductivities in the argillic, perching of percolating water during storms within and above the argillic horizon is common.

3. The topography of the argillic horizon is complex and differs significantly from the surface topography.
4. Spatial and temporal trends in perching are also complex and are not well explained by the regular grid of 48 maximum rise piezometers.
5. Occurrence of significant amounts of saturated interflow over or within the argillic horizon is uncommon.
6. Saturated interflow entering the interflow interception trench is highly variable, with some trench segments responding frequently to storms and others responding not at all during the study period.
7. Streamflow behavior in the intermittent stream indicates that shallow hydrologic processes within and above the argillic horizon are not contributing to watershed scale storm flows during the majority of storm flows.

References

Greco, James L. 2008. Controls and Occurrence of Interflow over a Restrictive Argillic Horizon in a Low Gradient Hillslope. MS Thesis. University of Georgia, Athens, GA.

Greco, James L. and C. Rhett Jackson. 2007. Occurrence of perched saturation and interflow over an argillic horizon in a low relief hillslope. Proceedings of the 2007 Georgia Water Resources Conference, March 27-29, University of Georgia, Athens, GA.

Appendix A – GWRC paper

Sent in a separate file

Appendix B

Installation Techniques for Interceptor Plates and Gutters System on the Trench Face to Collect Interflow Moving Over the Argillic Horizon

The interceptor plates are designed to direct saturated water at the top of the argillic layer at the trench face into a gutter system which drains into v-notch flumes. The plates are beveled on one side and driven approximately horizontally into the trench face near the top of the argillic layer. The plates are 61 cm long and 17.5 cm wide and made of 18 gage galvanized steel. They are driven into the soil until 5 to 8 cm are left from which to hang the gutters. We experimented with the minimum thickness sturdy enough to withstand pounding into the soil and compromised on 18 gage steel. The desired outcome is illustrated below.

In the fall of 2008, we developed a method for inserting the plates to achieve the desired configuration with minimal soil disturbance. In this Appendix, we describe problems we encountered with installation and the final installation methodology we developed.

Initially, we placed the plates against the soil using a level to make sure they started horizontally, and then we struck the outside edge of the plate with sledge hammers. However, because the beveled edge would cause the plate to turn upwards or downwards, and because soil structure tended to reinforce the upward or downward trajectory of the plates, most of the plates ended deviated unacceptably from horizontal.

To achieve near-horizontal plate installation, we inserted two horizontal guide rods prior to installing each plate. We had the guide rods constructed from smooth aluminum rods to minimize soil disturbance and to facilitate extraction of the rods so they could be used again. After inserting the guide rods, we would hold the tops of the plates against the bottom of the rods with the bevel oriented so the plates would tend to turn towards the rods, but the rods would inhibit any change of direction of the plates. In some cases, the friction between a guide rod and the inserted plate would be too great to allow extraction of the guide rod, and we would leave it in place. The guide rod system allowed near-horizontal installation of the interceptor plates. Guide rod photo?

Plate installation revealed that the transition from the loamy sand topsoil to the subsoil (variously consisting of sandy clay loam, sandy clay, and clay) was gradual. Soil cohesion within the topsoil and within the transition soils was insufficient to allow interceptor plate installation. Therefore, interceptor plates had to be installed 15 to 25 centimeters below the visually apparent shift from the A to the B horizon in order for clay content to be high enough for strong soil cohesion. Of the 11 trench sections (each approx. 11 meters long), sections 4 and 10 featured no soils suitable for the installation of collection plates. Sections 5 and 8 each were instrumented with two flumes because the argillic layer in both sections featured two low points. In total, about half of the total trench length featured soil conditions that allowed installation of collection plates and gutters.

Initially, we planned to overlap interceptor plates. However, pounding a new plate into the soil adjacent to a previously inserted plate caused stability problems with the trench face. It was necessary

to leave a 3 to 5 cm gap between plates. In order to catch the water dripping off the ends of the plates and to capture water exiting the trench face between the plates, we designed a thin open aluminum channel modeled after a laboratory Scoopula. We inserted these channels into the soil at the ends of the plates to capture the water from the ends of the plates and between the plates.

Gutters were hung from the inserted plates with c-clamps and supported below with rebar driven into the trench face. The gutters delivered water dripping from the plates to the 60 degree v-notch weirs.