KEYLINE DESIGN TRANSFORMS FARM WATER MANAGEMENT

BY MARK SHEPARD

What you will read in this article is an excerpt from my book, *Water for Any Farm*. It is an introduction to my more than 25 years of on-the-ground experience working with and deviating from the Yeomans' keyline plan. From the backyard of my parents' house in the suburbs of Massachusetts to 10,000-acre ranches, from permafrost mountainsides just shy of the Arctic Circle to equatorial boulder fields of East Africa, from areas with three hundred inches of rain per year to those with less than three, in all of these places I have personally installed systems based on the keyline design methodology and its modified forms.

What you will read in this is tried and true. It is intended to give a sufficient background to any landowner so that they can optimize their water resource for higher site productivity and greater drought resistance, and, just as importantly, so they can know deep in their heart that they have helped to make one little piece of earth a little more life-filled, livable, and green.

The Basic Keyline Design

This is not intended to be a replacement for all of the available information on the keyline design system. It is merely intended to be a description of the various farm and ranch-scale water management systems at our disposal in the United States, including the basics of keyline design. For those interested in learning more about any of the systems we discuss, that information can be sought out in-depth elsewhere.

Arguably P. A. Yeomans' most significant discovery with the development of the keyline design system was the magic of landscape geometry. By knowing the locations of the keypoints and keylines on a piece of land, you can employ some ridiculously simple techniques to synchronize with the basic geometric shape of the land and radically change how that land interacts with water. It all starts with what Yeomans referred to as Keyline Pattern Cultivation. In his own words:

The objective of the pattern in Keyline pattern cultivation is to direct the shallow overland flow, which results from rainfall run off, to remain evenly spread and not follow its natural flow path to concentrate in the valley shapes. The same technique also provides the means for evenly spreading the water in the system of "hillside" irrigation named "Keyline Pattern irrigation." It is the Keyline pattern cultivation that can convert what is commonly called "wild flooding" into fully controlled irrigation.

Yeomans, Water for Every Farm

The Primary Valley Cultivation Pattern

“Keyline pattern cultivation of a primary valley is done parallel to and on the lower side of the Keyline or any other approximately contour guide line in the valley area below the Keyline”(WFEF, 47).

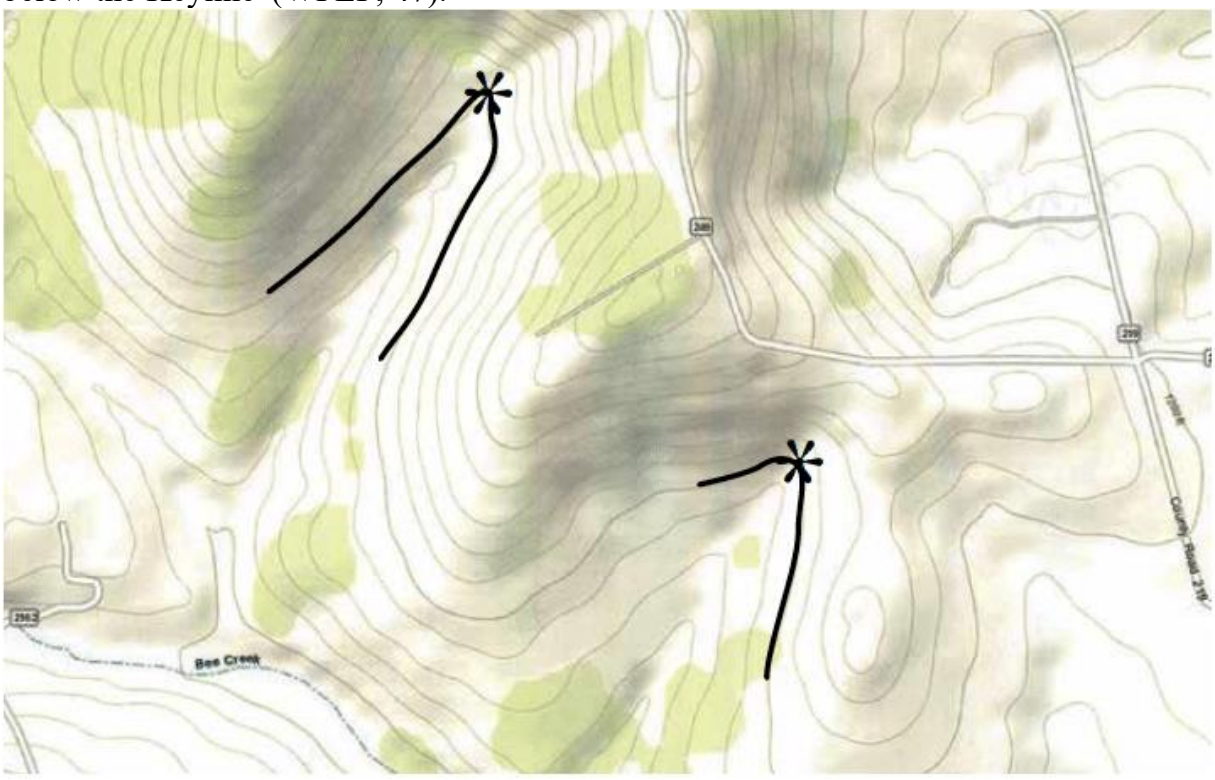

Figure 6.1

Figure 6.2a

Simple! Simple, but brilliant. In order to keep things as simple as possible, let's look at a relatively simple (for the United States) landform on a topographical map. Figure 6.1 is a topographical map with the keypoint in each of two primary valleys marked with an asterisk. Beginning at the keypoint, the keyline of each primary valley is marked in bold. The keyline is the reference line from which the valley cultivation pattern is derived. All fieldwork in the valley is done parallel to and downward from the keyline. The dotted lines in Figure 6.2a represent the path that one's equipment would take in that primary valley whether it be a plow, a mower, or hay baler. Notice, though, that this pattern only goes as far as where the side walls of the primary valleys become steeper and the mouth of the valley opens outward (the turning outward of your wrists in the breadbowl demonstration). This is the extent of the primary valley cultivation. Be sure to look closely at the contour lines in the valley in relation to the cultivation lines. As cultivation proceeds in parallel below the keyline, the tractor begins to make lines that start at a higher elevation in the valley center then gradually drop in elevation as they go toward the ridge. When cultivating a valley below and parallel to the keyline, the tool marks, furrows, and wheel-tracks all cause the valley water to drift toward the ridge instead of following their former path directly downslope to the valley floor. Later on in a grazing system, the pathway of animals moving through the paddocks follows and reinforces this pattern as well.

From now into the future, all activity on the land helps to cause water to drift from the valleys to the ridges. This is the way we divide up any overland water flow in the primary valley and get it to spread out toward the ridge. As it drifts toward the ridge, it is soaking into the ground and distributing water to areas whose shapes have already caused water to migrate to the valleys. Keyline pattern cultivation has just reversed the general trend of water in the landscape. Instead of water flowing downhill off the ridges and moving into the valleys, keyline patterning brings water from the valleys back out onto the ridges. Well, at least that's what Yeoman's says they're supposed to do.

As one can see in Figure 6.2a, the Keyline cultivation pattern doesn't really work for the primary valley on the right. The left (western) leg of the uppermost parallel below the keyline actually pitches toward the center of the primary valley and not toward the ridge like Yeoman's said it would. I know of hundreds of people attempting to set up the keyline cultivation pattern on their property who have encountered situations like this, and one of the first things people think to themselves is, "Have I done something wrong?"

Hmm . . . maybe we have! Maybe what we thought was the keypoint was actually the wrong spot. What if we "adjusted" things by choosing another location as the possible keypoint?

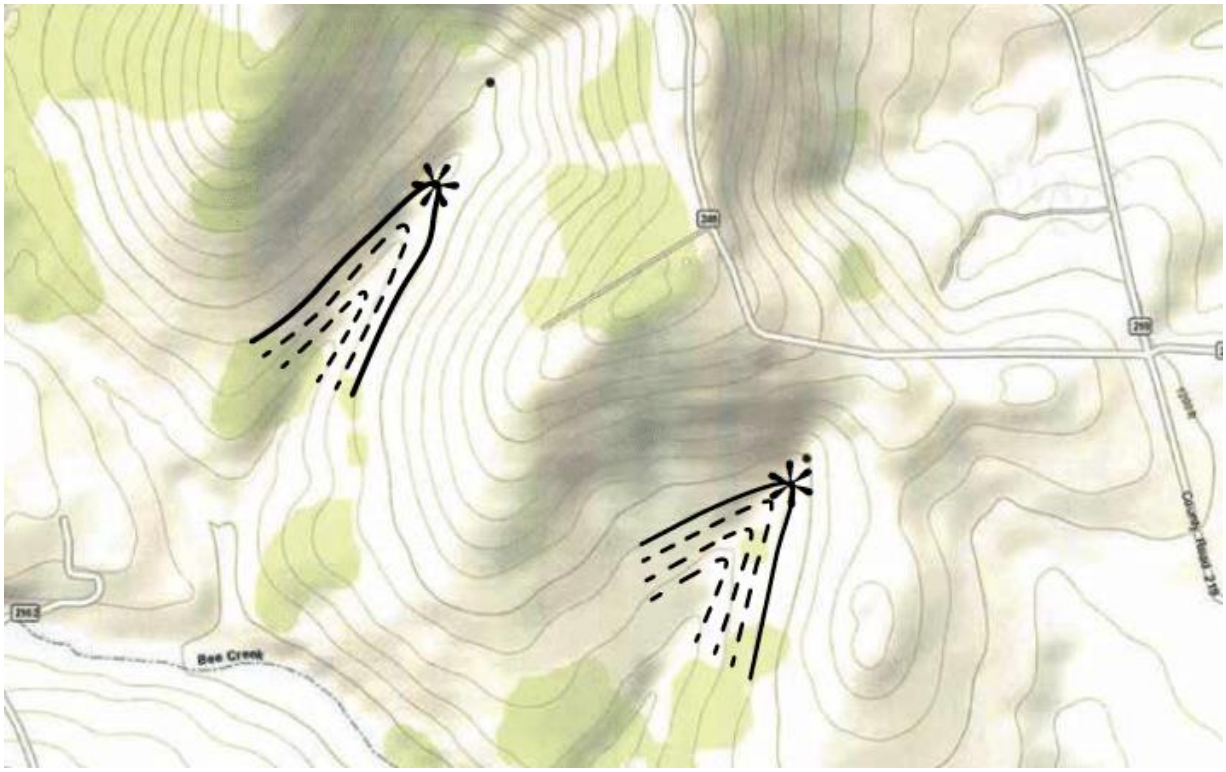

Figure 6.2b

In order to see what such a change might do, in Figure 6.2b we deliberately moved both originally marked keypoints, generated a new keyline and then drew some parallels below the keyline to see what this would do (remember . . . whether you're sketching on a paper map or a computer, changing the location of a line at this stage is quite affordable. Once you start to lay out new field cultivation patterns, install terraces or move fences, things get more expensive). When we began to make parallel passes with equipment below the new keyline in each primary valley, surface water will indeed follow the cultivation pattern and move from higher in the primary valley out toward the ridges just like Yeoman's said. Choosing a slightly different location for the "keypoint" (understanding that this location might be some place other than an actual geographic keypoint) is one of the simplest adjustments that one Figure 6.2b can do to help adjust a system where the landform does not actually behave according to "keyline geometry." Primary Valley cultivation isn't the be-all and end-all of keyline pattern cultivation, however. There are also primary ridges to consider.

The Primary Ridge Cultivation Pattern

"The general pattern of primary ridge cultivation is parallel upwards from a selected contour…" (WFEF, 49).

Once again, simple and brilliant. Let's turn now to Figure 6.3 and leave out the valley cultivation pattern for now.

Figure 6.3

When selecting a contour line as the reference line for ridge cultivation, according to Yeomans, one can pick any contour line as the reference line. In order to have the cultivation pattern cover as much of the landscape as possible, though, one can choose the lowest practical elevation contour line on any given property.

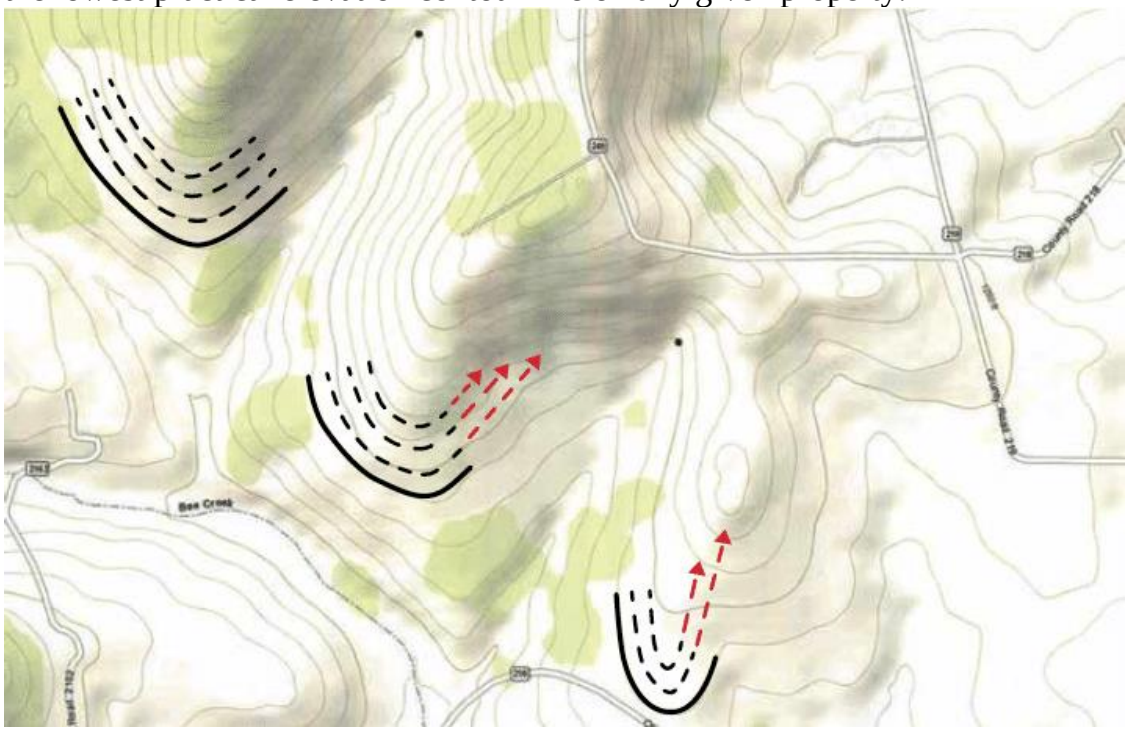

Figure 6.3a

In Figure 6.3a, this reference contour is marked in bold. The dotted lines in Figure 6.3a represent the tractor path for keyline pattern cultivation of a ridge. Upon examination of the relationship between the contour lines and the cultivation path, one

can now see that by cultivating parallel and upward from the reference contour, any water striking the ridge will encounter rip lines, furrows, wheel tracks, etc., and that will cause the water to drift toward the ridge.
However, anyone who can read a contour map can clearly see that there's a problem. Although the pattern on the westernmost primary ridge of fig 6.3a looks as if it will work just fine, the same is not true for the other two primary ridges. On the primary ridge in the middle and most noticeably on the primary ridge on the right (east), the parallel lines clearly show that any water following the Keyline ridge cultivation pattern would travel at such a steep slope that it would likely cause erosion on those ridges.
One of the reasons for following the Figure 6.3a keyline cultivation pattern is to prevent valley erosion. "Wild flooding," Yeoman's called it. Replacing wild flooding in a valley in order to create it on the ridge is pointless. Figure 6.3a plainly shows us that not any old contour line on a ridge can be used as the reference line. We will have to "adjust."

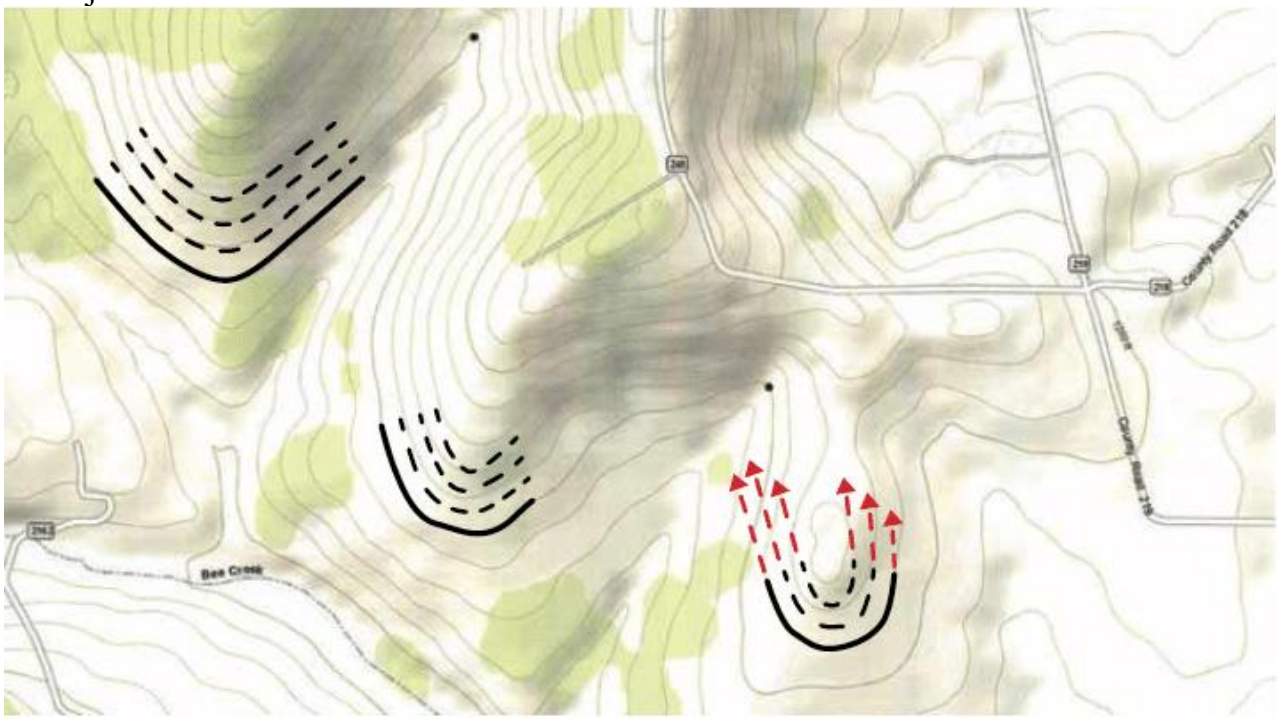

Figure 6.3b
Figure 6.3b is just one such adjustment. On the middle primary ridge, the "ridge reference contour" (solid, bold) was moved up one contour line. On the right hand ridge we moved up two contour lines. As once can see, this appears to have corrected the problem on the middle ridge, but it has not solved the problem on the right hand ridge at all.
As a matter of fact, none of the contour lines on the right hand ridge will serve as a "ridge reference contour" for the keyline cultivation pattern. That ridge simply does not obey keyline geometry. Yeoman's repeatedly reminds us that keeling geometry is universally applicable. Other authors note that when a landform doesn't obey keyline geometry these "landscape anomalies" can be ignored and the system "adjusted."
Without being judgmental or self-righteous, I would like to point out that most of the problems that landowners have had with Keyline Design has everything to do with the

fact that in the majority of situations, the “simple” Keyline cultivation pattern does not work on a complex landscape. It needs adjustment. The adjustments are what this book is all about.
When we do have a simple enough land-form that it does obey Keyline geometry, we can then combine primary valley cultivation with primary ridge cultivation.
The combination of the primary valley cultivation pattern with the primary ridge cultivation pattern shows a complete system in which the use of the land itself causes water to spread to the ridges rather than drift to the valleys. This is shown in Figure 6.4.

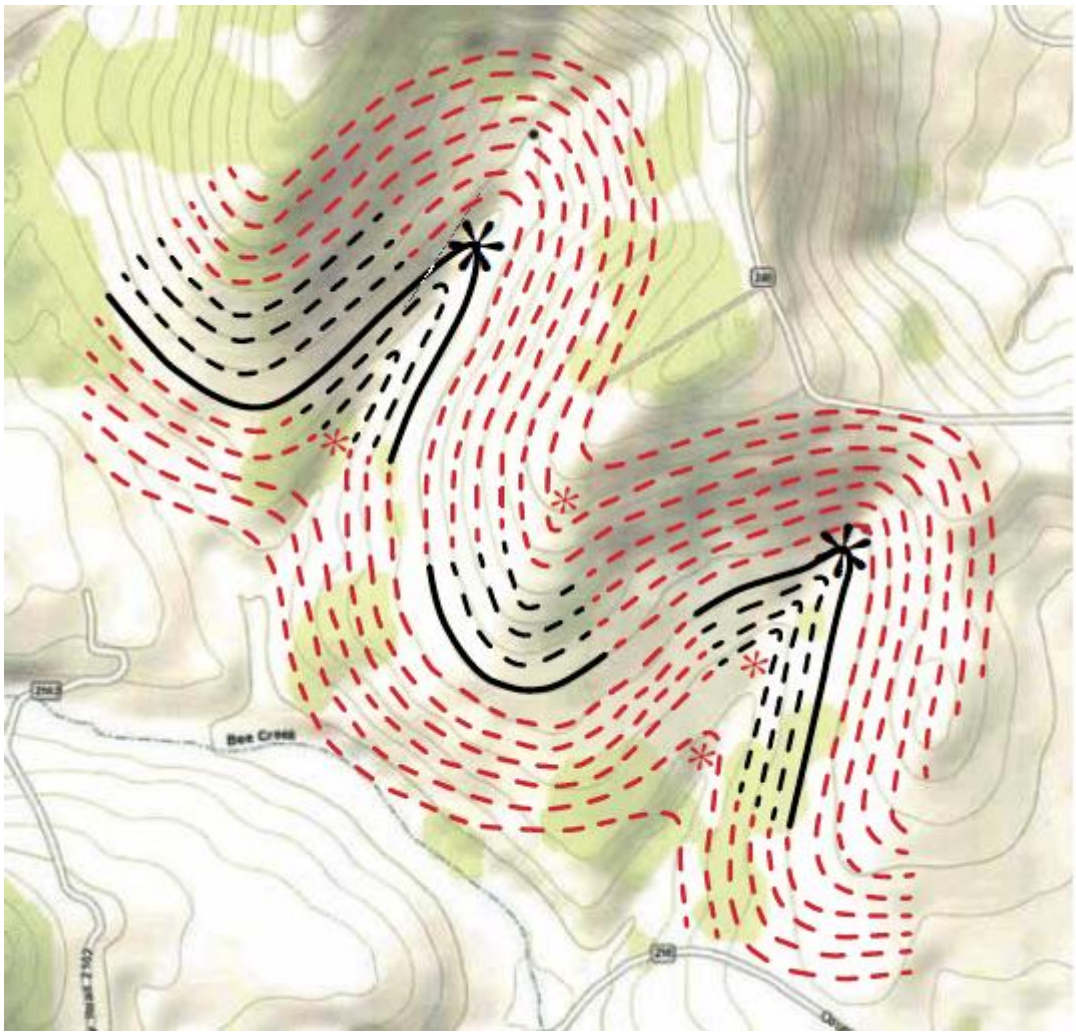

Figure 6.4

We can see a couple of things in the combined diagram. For one, as one proceeds upward and parallel to the ridge guide contour, eventually equipment turns on the ridge become too tight. (red asterisk in upper middle ridge) At this point, either the equipment operator needs to move uphill back to a wider turning radius, or a new ridge reference contour line is chosen from which to cultivate parallel lines farther up.
We can see a couple of things in the combined diagram. For one, as one proceeds upward and parallel to the ridge guide contour, eventually equipment turns on the ridge become too tight. At this point, either the equipment operator moves uphill back to a wider turn radius, or a new uphill contour guideline is chosen from which to cultivate parallel lines farther up.

The same is true in the valleys. As the equipment works parallel to the keyline and lower in elevation, the turns become tighter and tighter. This can proceed until the operator makes a smoother curve in the valley bottom, or until a new reference contour is chosen from which to parallel downward (see red asterisks in both primary valleys).

What can be seen in both ridge and valley cultivation is that crescent-shaped spots of uncultivated land "appear." In *Water for Every Farm,* Yeomans shows this pattern in diagrams but fails to suggest what to do with these "odd spots." (Are these perhaps more landscape anomalies?) Bill Mollison's *Permaculture Designers' Manual* uses the same graphics as *Water for Every Farm* and also fails to address how to approach these areas. These irregular shapes on crests of primary ridges and in the bottoms of primary valleys were significant influences in the development of the Master Line System.

One of the main objectives of keyline pattern cultivation is to influence the shallow overland flow of runoff water so that it remains evenly spread across the landscape instead of following its natural path straight down the slope to the valley floor. Remember, of course, that before any human patterning, water will flow from the high spots to the low spots. Water striking the ridges will flow downhill to concentrate in the valleys. Ridges functionally receive less than the actual rainfall amount because the water flows away to the valleys, and valleys receive more than the actual rainfall amount since they receive some of the water that originally fell on the ridges but flowed down the slopes to lower elevations. This flow is not all in the form of channeled flow. In areas with light rains and on more gentle slopes, the majority of the water movement in the landscape may be by sheet flow.

Water falls evenly on the land and soaks into the top layers of soil. Gravity, constantly at work, suggests that this water move to lower elevations. The incessant pull of gravity is part of what brings water deeper into the soil. If the pore space between soil particles is large (sand and gravel), most of the rain will be pulled straight down toward the center of the earth, especially on flatter landscapes. No sheet flow occurs. Rills and runoff streams won't happen. With smaller pore spaces in the soil, water is not pulled toward the center of the earth fast enough to counter the effects of slope and the entire sheet of water, oftentimes just barely below the surface of the ground, is pulled downhill toward the center of the valley. Slowly, this body of water migrates away from the ridges toward the valleys.

This principal can be illustrated with a simple experiment. Take a kitchen sponge and saturate it with water. Wring it out a little so that it doesn't drip. Next, place it on a tilted surface such as a cutting board or cookie-baking sheet with one side propped up. At first no water will trickle out of the sponge, but, eventually, gravity will begin to pull the water from the sponge. The water will begin to flow out from the lower side of the sponge and travel down the board.

The flow of water moving within the sponge itself is sheet flow. It is this shallow surface and subsurface flow that the keyline cultivation pattern is masterful at directing. When all farming activities follow the basic keyline patterning, all wheel tracks, cultivating furrows, and subsoiler lines follow the keyline cultivation pattern, all sheet flow is nudged toward the ridges. In flatter landscapes with sandier soil, in regions where the rainfall comes in smaller, gentler rains, the keyline pattern

cultivation may be all that is needed to effectively keep all rainwater on the ridges long enough to allow it to soak in deeply and remain as a resource for increased crop yields.

In places where larger rain events are the norm, such as areas that receive their rain via thunderstorms of various sizes, simple keyline cultivation may not be enough to significantly influence sheet flow. In areas with heavier, clay soils, even in flat country, keyline patterning alone may also not be enough. The patterning will still have an effect, but rainwater will pile up on the soil surface faster than it can soak into the soil. The surplus water not soaked into the soil will eventually overwhelm the cultivation ridges and resume its surface flow overland directly to the valley floor. Some water still drifts toward the ridges, induced by the keyline cultivation patterning, but much will be lost as it overwhelms the system that is undersized for that particular rainfall type, soil type, and slope.

Some other circumstances that were not addressed by Yeomans at all, which are extremely important in the United States and Canada, are rainfall on frozen ground, rapid snowmelt, and rain on snow events. When these occur, subsoiler rip lines and tiny surface furrows are totally inadequate to capture all of the available water, if they're even able to capture any. In many places (this has happened at New Forest Farm in Wisconsin several times, on multiple occasions some years!) this water may be the only water a site gets for the entire season. The loss of this precious resource is entirely preventable with the introduction of a simple yet powerful tool.

Mark Shepard is a Wisconsin-based permaculture designer, agroforester and ecological farming consultant. He and his family have transformed a typical 140-acre row-crop dairy farm into a permaculture-based perennial-agricultural ecosystem using oak savannah, successional brushland and Eastern woodlands as ecological models. The result is one of the first and finest farm-scale models of permaculture in the United States. He is the author of Restoration Agriculture *and his new book for Acres U.S.A. on water management,* Water for Any Farm*, is now available. A technical manual to accompany* Water for Any Farm *is scheduled for release later this year.*

Mark Shepard's intensive course "Practical Permaculture and Agroforestry for Farmers" is now available on Eco-Ag U Online. Join Mark Shepard as he shares real permaculture knowledge he's gained over a lifetime of study and through the implementation of these systems on his own family's farm. Not just a theory class, you'll hear real-world advice and tips on these innovative farming systems. Whether you "go all the way," as Mark is doing, or simply introduce some new crops and diversity into your traditional farm or small acreage, this online workshop is certain to provide the roadmap you'll need. View course details and free preview here.