UNDERSTANDING

the

APPLICATION

of

KEYLINE GEOMETRY

FOREWORD

Mr. P.A. Yeomans' (1905-1984) Keyline whole system design has proved to be a significant and lasting influence to the fields of agriculture, geography and landscape architecture in particular. Mr. Yeomans "esteem is evidenced by a nationwide poll conducted by Country Life magazine that placed PA Yeomans among the top 3 Australians who had contributed most to Australian agriculture".

For as long as I can remember I have been fascinated by water and its pattern of movement on landscapes. Our family farm in central Victoria, Australia had a rudimentary Keyline irrigation system that as child I would operate, placing and removing sods of soil in the channels that traversed our farm, these sods backing up the water in the channel and flood irrigating our paddocks throughout the year. My conscious involvement with these aspects of the Keyline system is now close to 45 years ago!

Since 1993 we have built our work around that of the Keyline design system and over that time I have come to be more and more astounded by the depth of Yeomans' geometric insights — some of which are now explored as never before,

FOREWORD

perhaps even more than Yeomans' navigated himself.

Georgi Pavlov and his brother Smilyan (of HUMA) have been working with us for over a year now and it became immediately clear that they both had a firm grasp of the geography, geometry and, above all else, the practical elegance of the Keyline system. This doesn't come easily to most people and part of this is because of the general lack of map or geographic literacy that most people have.

Georgi has done an excellent job in helping many see the genius of Keyline geometry that up to now have been only obvious to very few. Like unlocking a genie from a bottle, Georgi's work will help many overcome their misunderstandings up to now and herald a new generation of understanding around this quite epic design system.

Many people have unfortunately, and with varying degrees of error, misrepresented Keyline, particularly with regards to its geographic and geometric elements and principles. This is completely unfortunate and many of these people should know a lot better.

FOREWORD

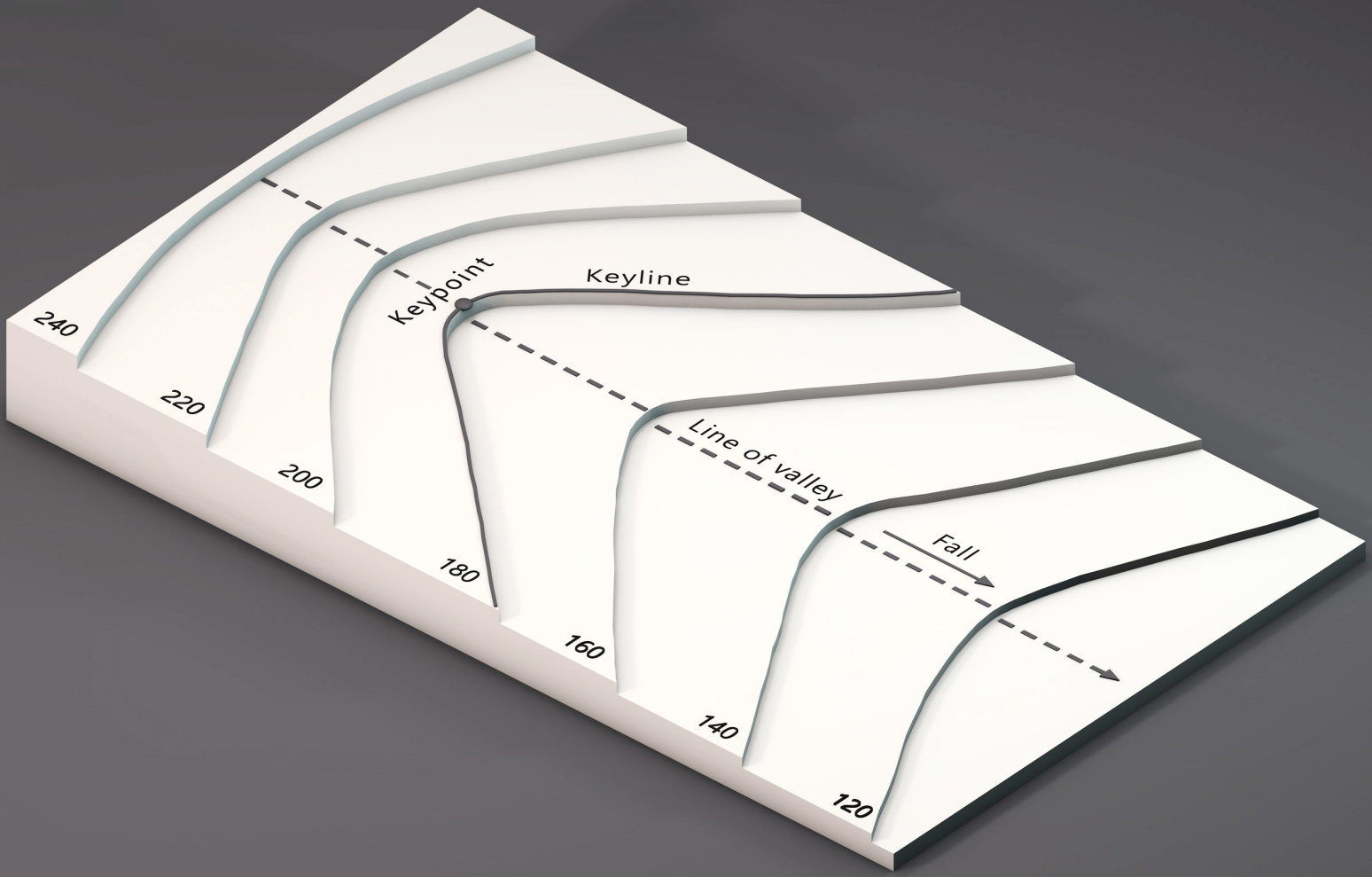
With this I commend all who are interested in Keyline and the patterns of landscape geography and in particular geometry to this booklet by Georgi, such that the incorrect can now stand corrected and the new can be shown the right way to proceed.

Darren J. Doherty,

Regrarians Ltd.,

Bendigo, Victoria, Australia,

August 2015.



Remake of an original Yeomans illustration: Keypoint and Keyline of the valley.

CONTENTS

ACKNOWLEDGMENTS

Thanks to my brother Smilyan Pavlov, together with whom we run our company HUMA.

Thanks to Regrarians for their support and to Darren J. Doherty for providing valuable feedback and information.

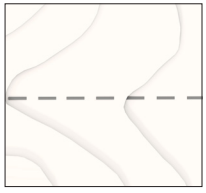
Thanks to the Yeomans family for promoting the Keyline system.

Thanks to Geoffrey Booth for maintaining the Keyline archive.

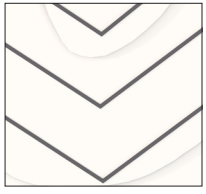
Thanks to everyone that have supported us. Without your support we would not have been able to move forward.

LEGEND

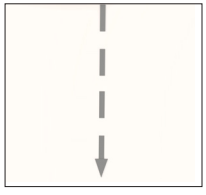
Boundary



Headlands

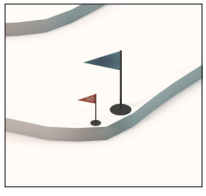


Offsets and guidelines



Offset trajectory, drainage, land shape direction

Contour lines



Surveying flags: orange for contours; blue for guides

GLOSSARY

Contour line: a line joining points of equal elevation on a surface.

Guideline: in the Keyline system a guideline is a line used for offsetting from.

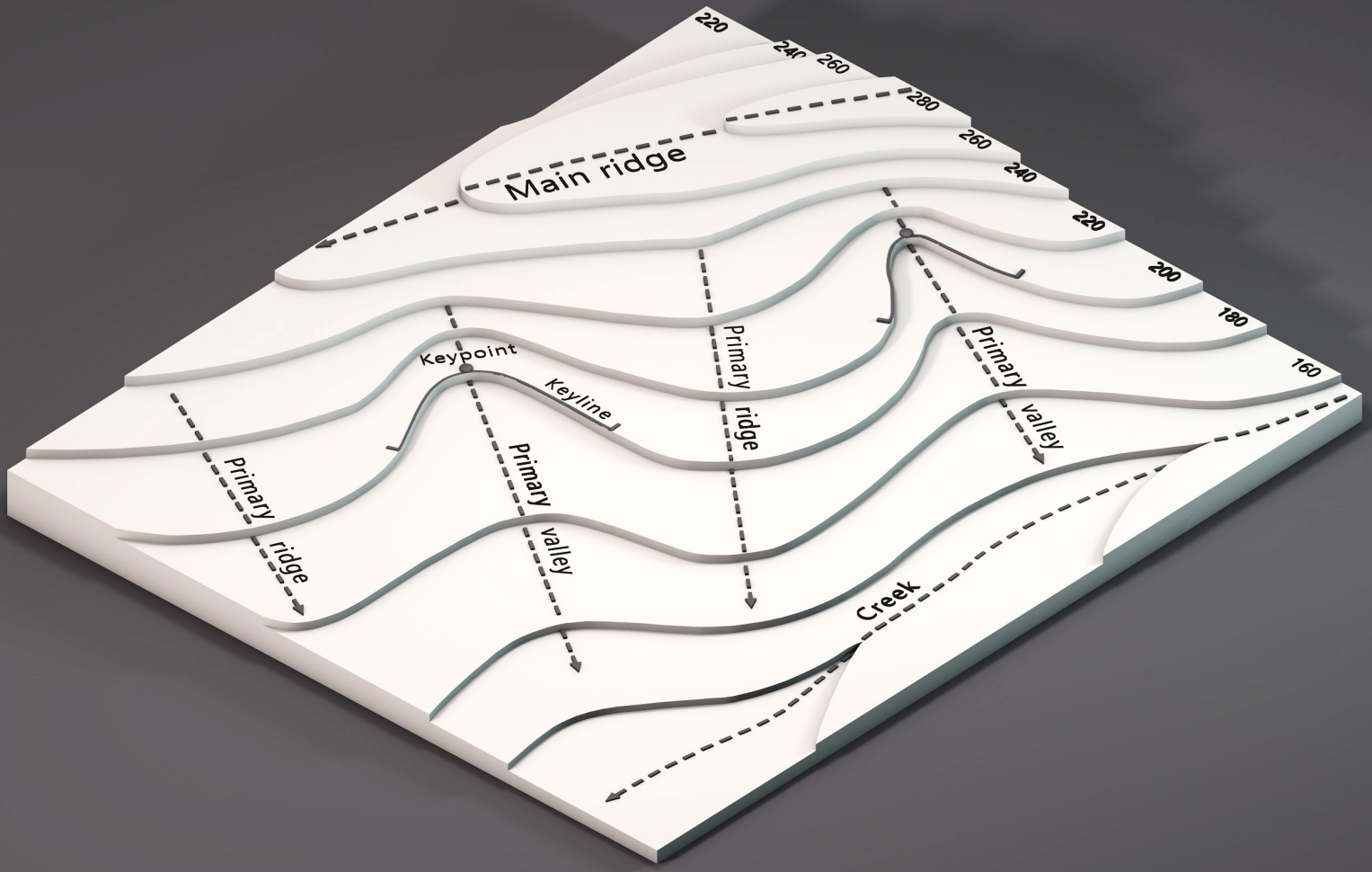
Headlands: a strip of unplowed land at the ends of furrows or near a fence or border; an area used for turning agricultural machines at the end of rows.

Keyline: can refer to the Keyline system as a whole, to a Keyline of the valley, or in general to the Keyline pattern of equidistance and water management.

Layout: the design or arrangement of something; the way something is laid out. In this book it refers to agricultural patterns, specifically Keyline.

Offset: in surveying an offset is a measurement of distance to a point at right angles to a survey line. Throughout the book it refers specifically to parallel lines.

Rays: the lines, or wings, that when joined together form an angle.



Remake of an original Yeomans illustration: Division of landscape within Keyline.

INTRODUCTION

The Keyline layout is an agricultural pattern the main benefits of which are equidistance, water management and erosion control. It was developed in the late 1940's by Australian mining engineer P.A. Yeomans (1905-84) and his sons.

Computers, the web, and the design software of today were not available in Yeomans' era. Surveying tools were not as sophisticated as those today and the advent of the GPS technology had not yet come about. How we can manipulate geometry through the use of software and the efficiency with which we can mark out and apply layouts on the ground by the use of GPS technology are things that were inconceivable at the time. Today we can apply the pattern with greater ease and efficiency.

This booklet is for readers that already have a basic grasp of the concepts behind the Keyline layout and have read the original books but have wondered about the layout's practical application on real landscapes. The main purpose behind the booklet is to demystify the planning and application of the Keyline pattern onto real landscape maps by highlighting a few key concepts. The purpose is not to show ideal examples, but rather what applies and happens on a regular basis.

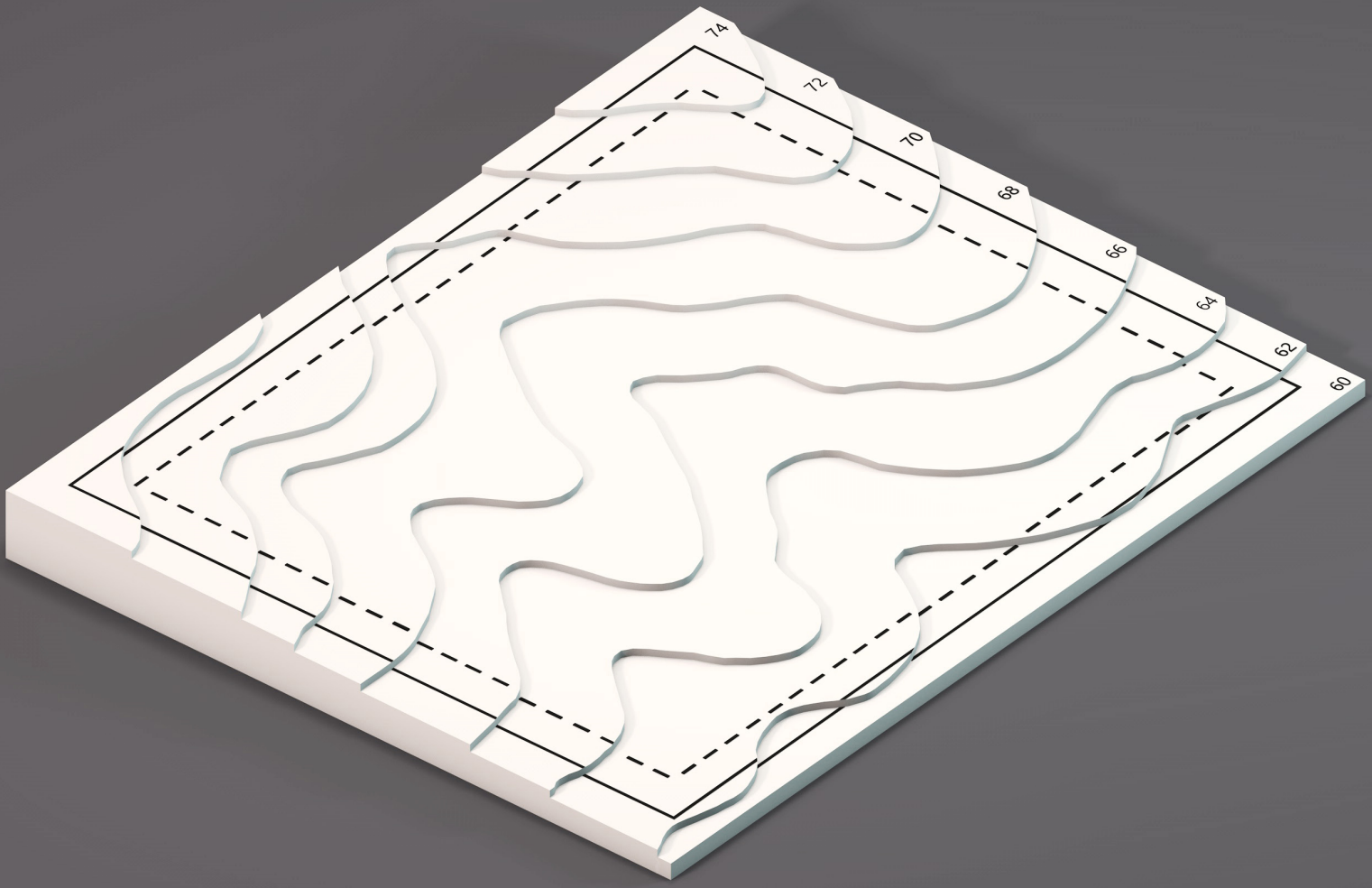
KEY CONCEPTS

LIMITING SCALE

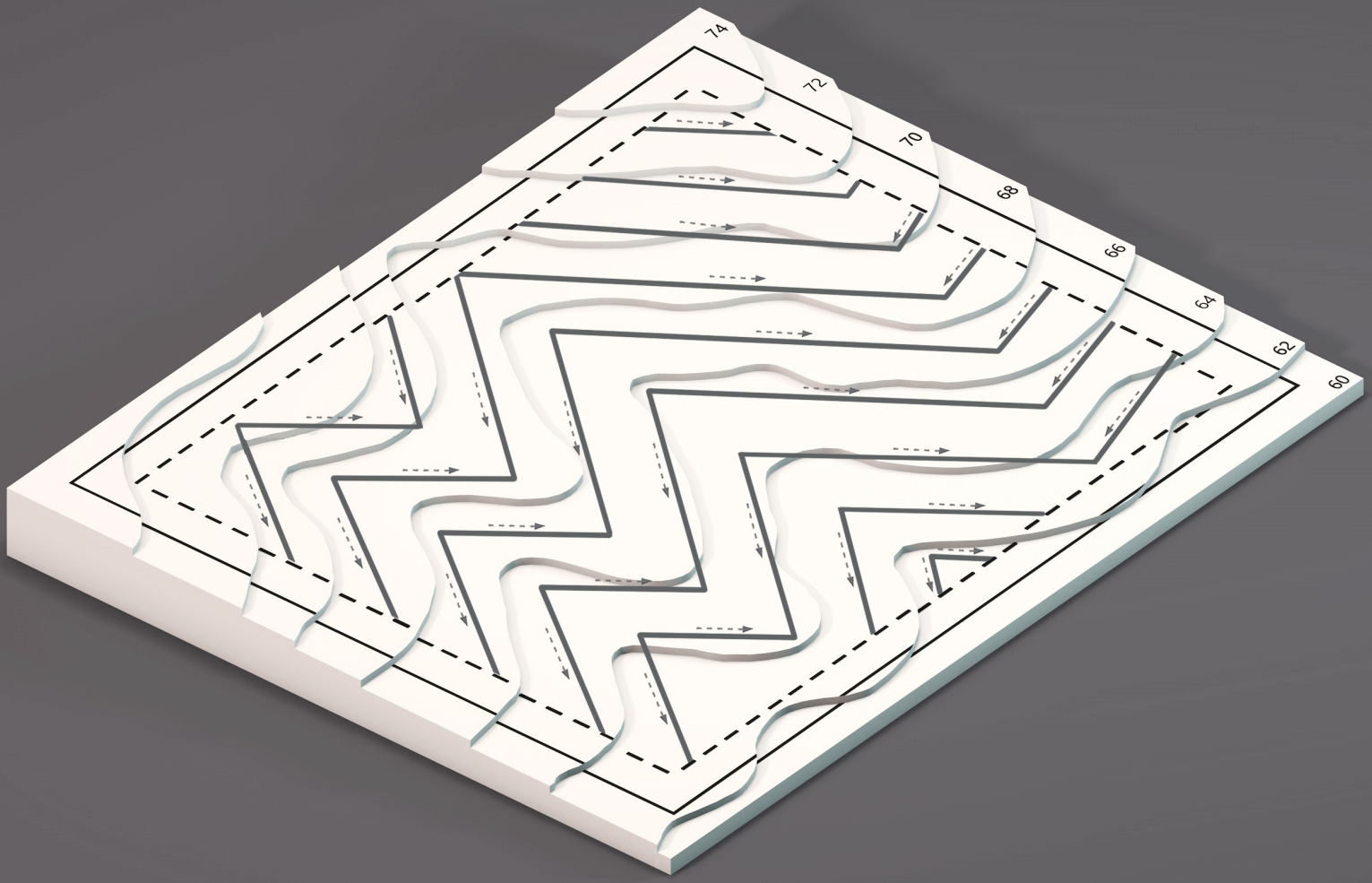
Limit as much as possible the extent of the area you have to deal with. This reduces the likelihood of having to spend time and effort to tackle complex land shapes which can compromise the overall convenience of the layout.

You may start first by marking out zones where land development is legally forbidden, then lay down water catchment earthworks and access routes, mark forestry strips, outline zones fenced out for natural reforestation, and so on to limit the extent of the working area. Whatever the case, one feature that helps limit the working area and is always an adequate addition to any layout are headlands. It is the free space that machinery operators use to turn their machines at the end of rows.

From the boundary of your working area, offset inwards a set distance that is enough to ensure any machinery, including attached implements, will have ample space to turn at the end of the rows. If the maximum width of the machinery is 5 meters, then an adequate headland width may range from 10 to 20 meters, - 2 to 4 times the width of the machine, depending on circumstance.



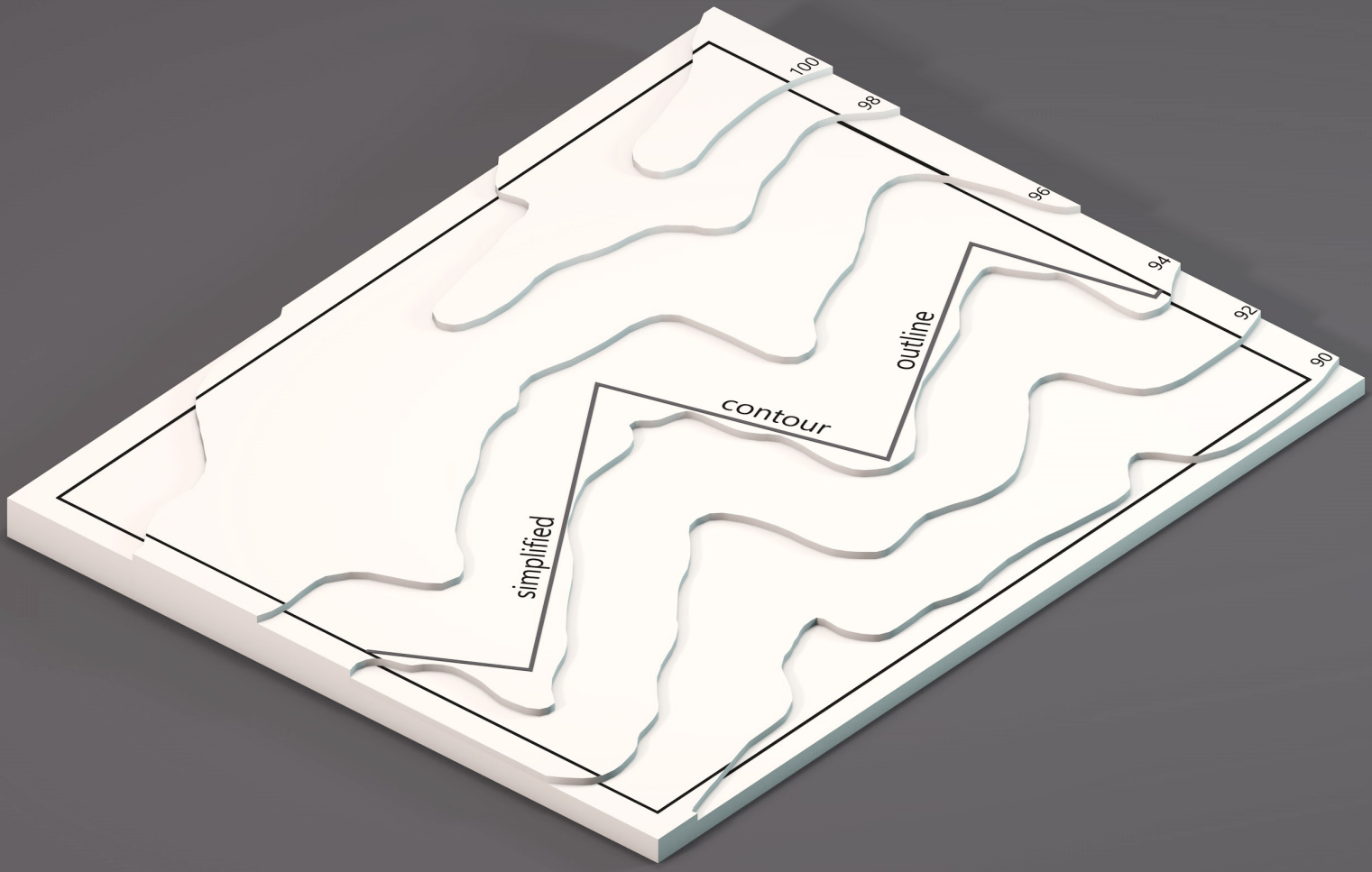
Headlands on a plain landscape.



Keyline pattern based on major land shapes.

MAJOR LAND SHAPES

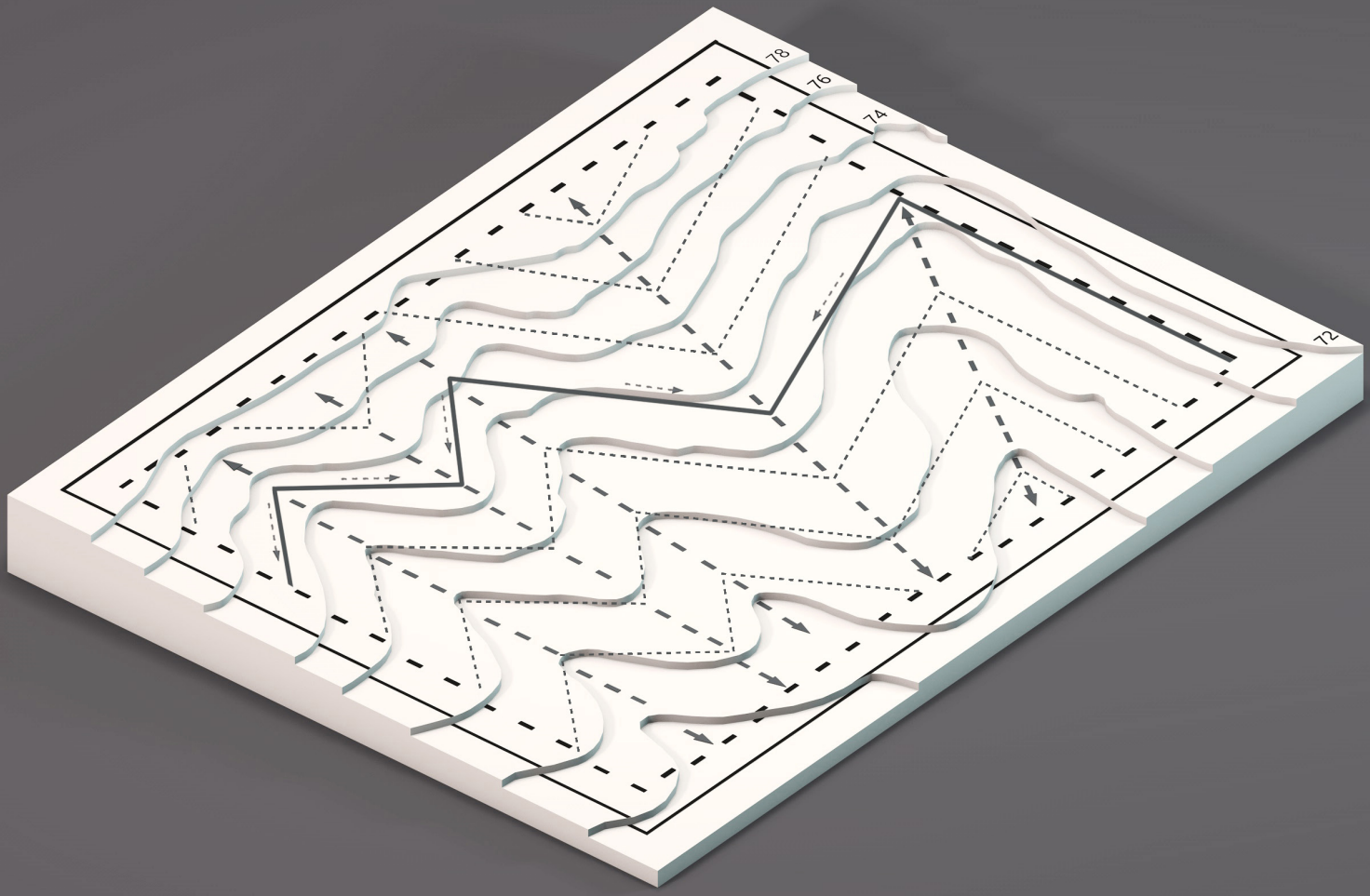
Do not offset directly from contours, but instead offset from a loose, simplified outline of a contour that considers only the major land shapes. This way you can have more control over the geometry of the layout while making sure that producing over-complicated shapes during offset is avoided.



Simplified contour outline used as a guideline for patterning.

FREEDOM TO PATTERN

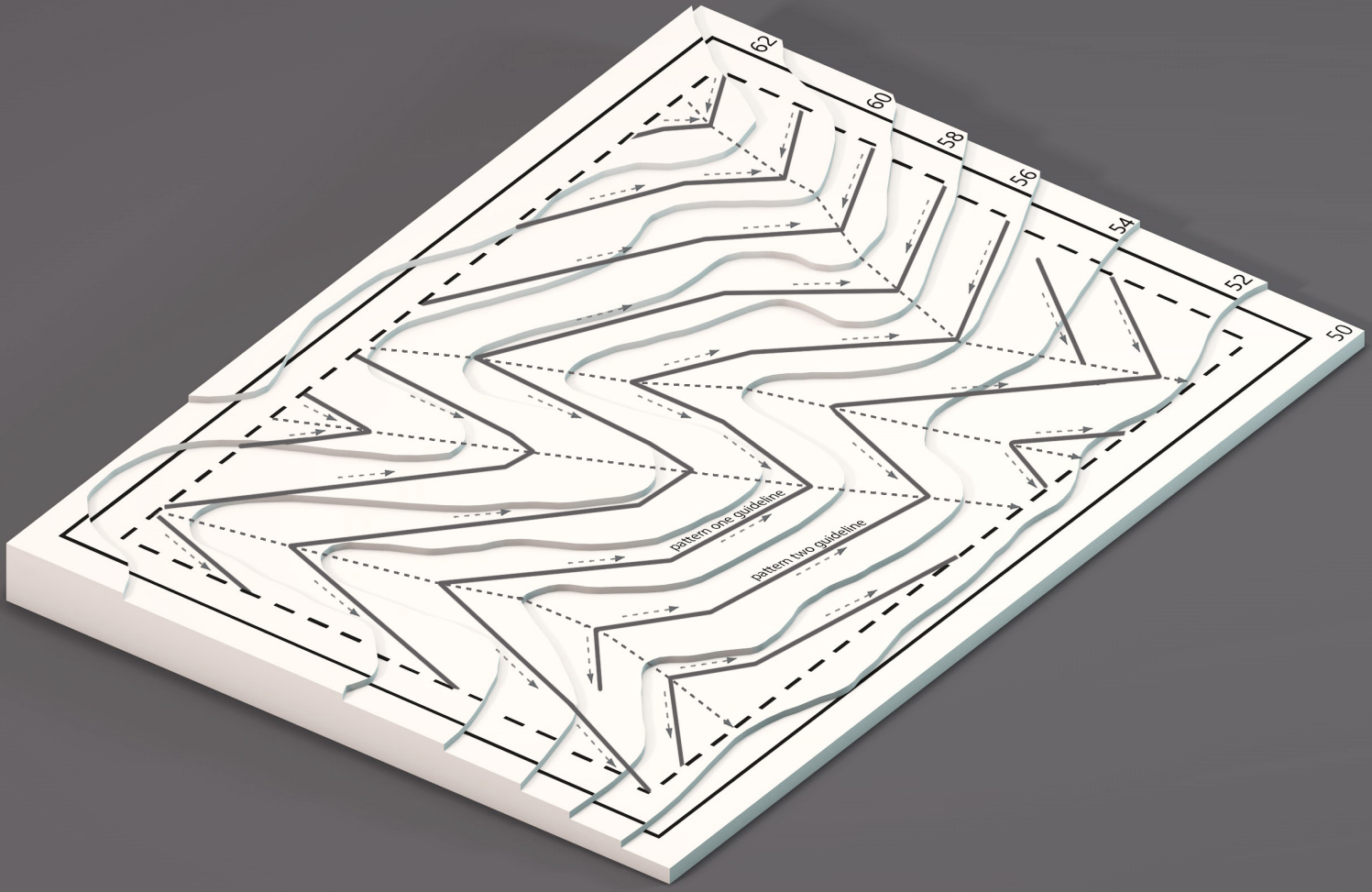
You do not need to be limited to offsetting from valleys downslope and from ridges upslope, as is the case in traditional Keyline pattern application. By keeping shapes simple, and by understanding angles and offset trajectory, you can set up your guideline geometry in advance in a way that enables you to offset both upslope and downslope from anywhere in the landscape. You can pattern extensive areas with a single guideline that tackles both valley and ridge shapes simultaneously, this way ensuring that on site application is kept simple. Ideally, start from the longest simplified contour outline within the area of interest.



Guideline offsetted both up and downslope.

MULTIPLE PATTERNS

When major land shapes shift in direction significantly, it is often necessary to start a new set of patterns. When you draw lines in the middle of major valleys and ridges, where the lines start to break to move in a new direction, starting a new pattern might be necessary. Knowing this, you can plan in advance how many sets of patterns you will need to cover the whole working area. Always strive to have as few sets as possible so that it is easier to implement later. Remember to leave headland space in between patterns that are in the same working area so that machines can freely turn at the end of rows and not have to intersect with adjacent patterns.

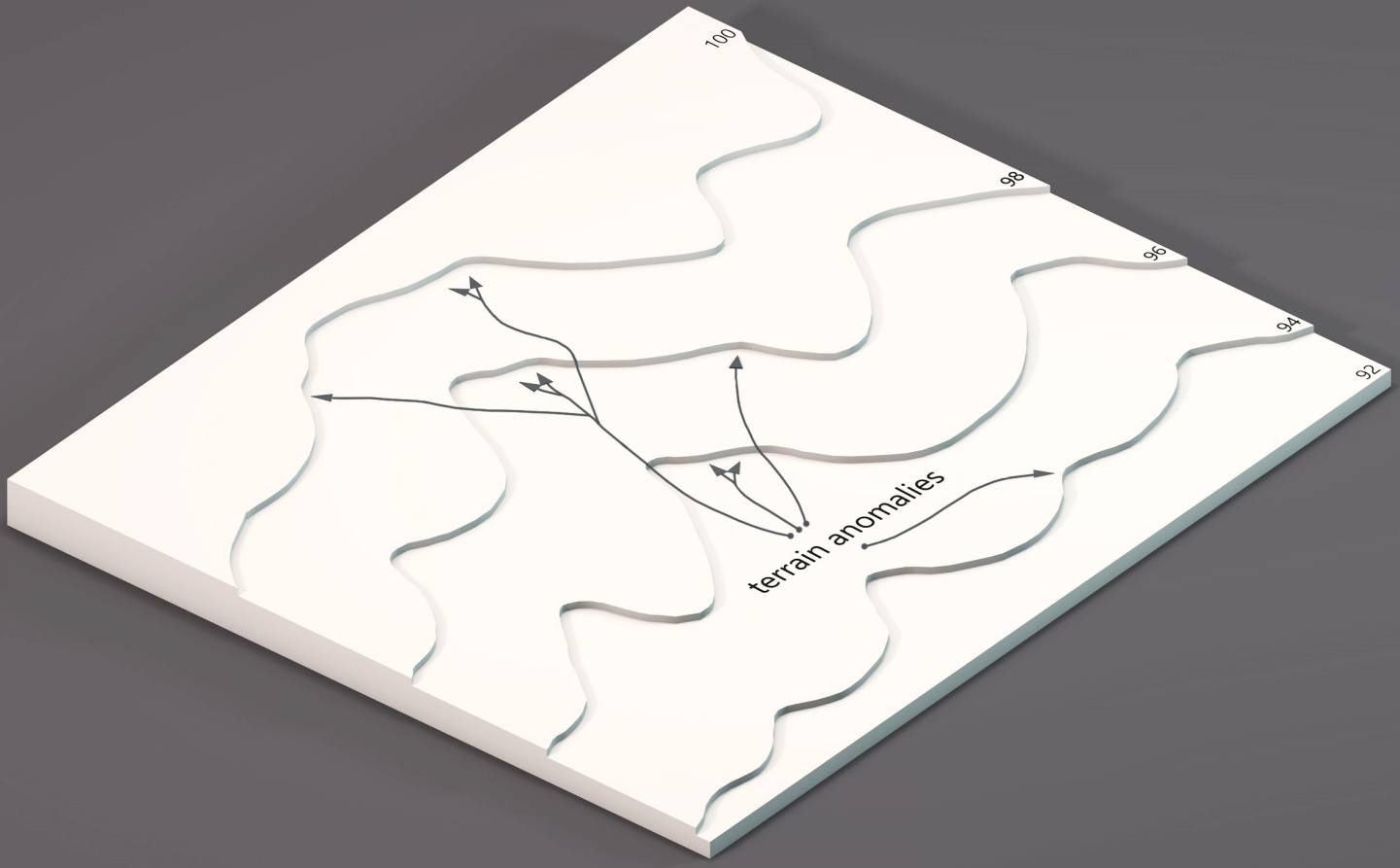


Demonstration of multiple patterns on a landscape.

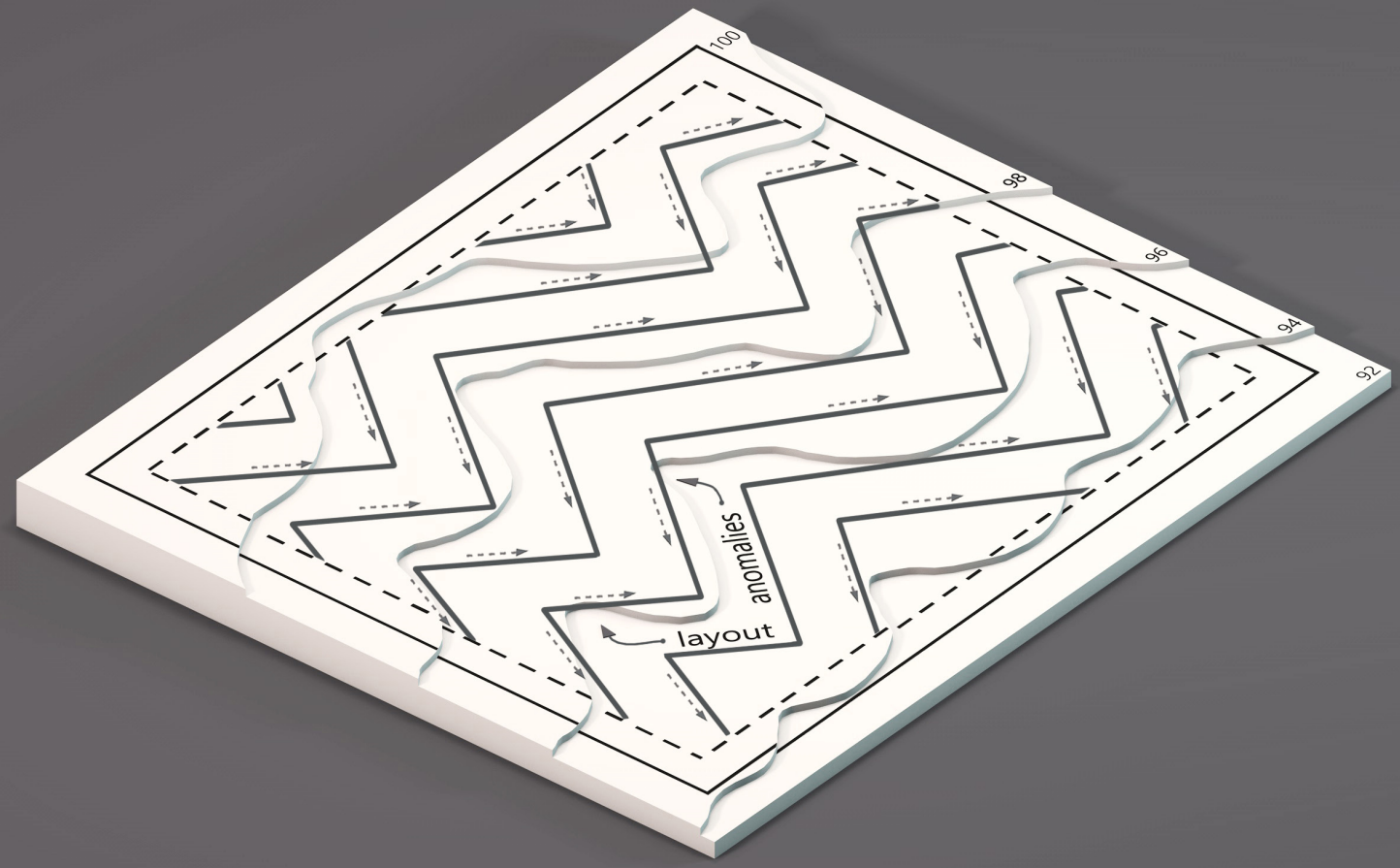
ANOMALIES

Not all valleys and ridges are true valleys and ridges. Land shape anomalies like runnels and indentations are largely insignificant, but they can significantly over complicate the layout if you offset directly from contours. Most of the time you can ignore them entirely by following and offsetting only from simplified outlines of contours.

You will certainly also get anomalies within the Keyline geometry. Relative to the land shape, the geometry at certain points may attempt to make water run uphill, causing it instead to sit. As long as you keep these occurrences rare and insignificant in scale, you can disregard them for the sake of the overall simplicity and convenience.



Irregularities within the the terrain.



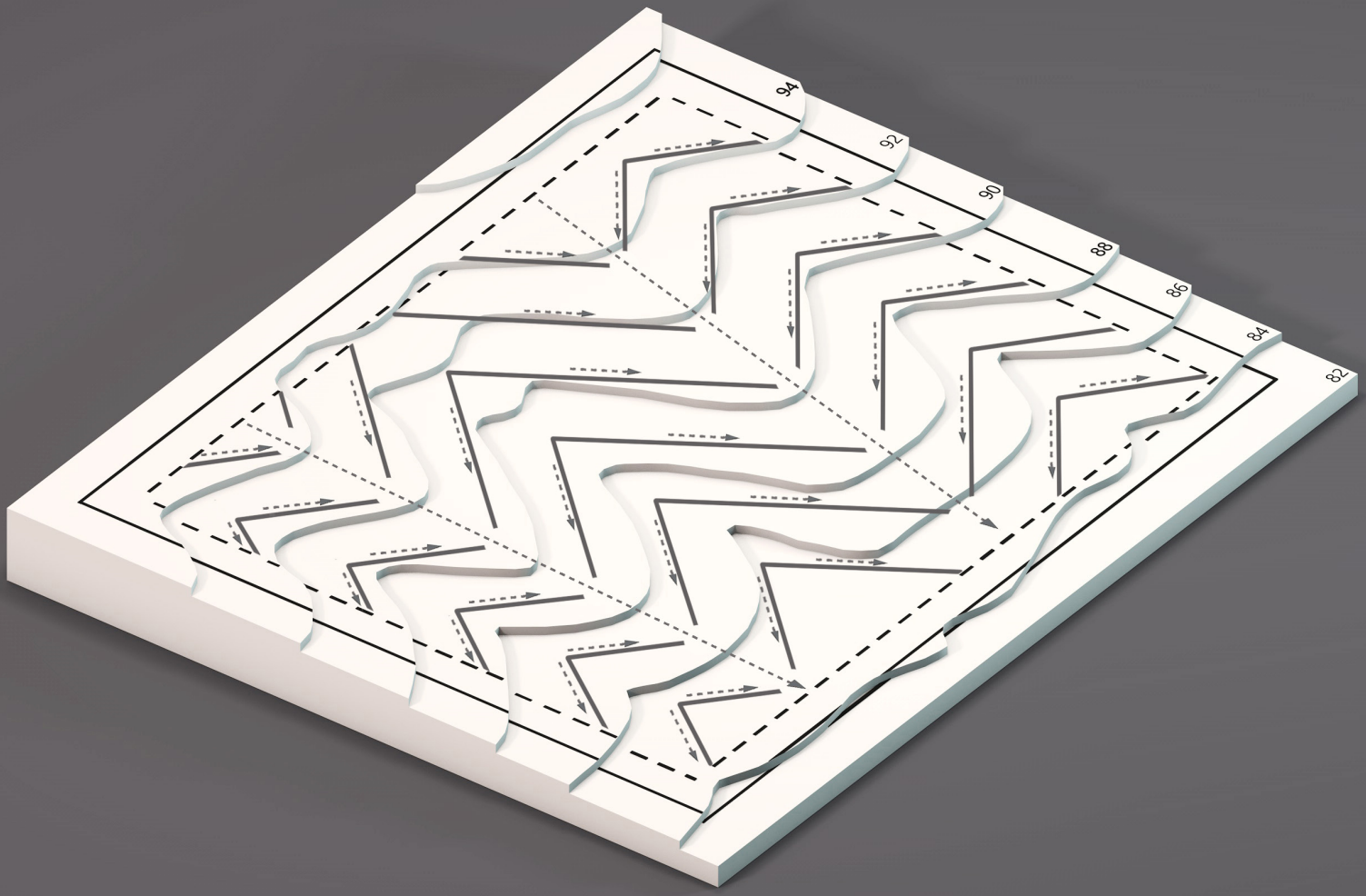
Anomalies within the the pattern in relation to land shape and drainage.

STEEP SLOPES

Some slopes can be too steep for machine cultivation on Keyline. Steepness is one of the main reasons why crops are laid out at 90° perpendicular to the contours of the terrain on steep slopes. That way machines can turn at the flatter areas both upslope and downslope at the end of rows. In general, if the slope steepness is higher than 20° you might have to resort to a different layout pattern that is more convenient for machine operators. If using Keyline geometry, where the landscape steepens, the patterns can be made flatter; and where the landscape flattens, the patterns can be made reasonably steeper.

DRAINAGE

The primary management need for some areas might be that of water or cold air drainage. Regarding the former, the Keyline geometry can deal with it by facilitating a better distribution of water across the landscape. In terms of the latter, Keyline also directs cold air towards the middle of ridges. You can either run a road track or leave headland space there in between patterns to ensure the cold air drains effectively downslope. You can see an example of this implemented by Darren Doherty, here.

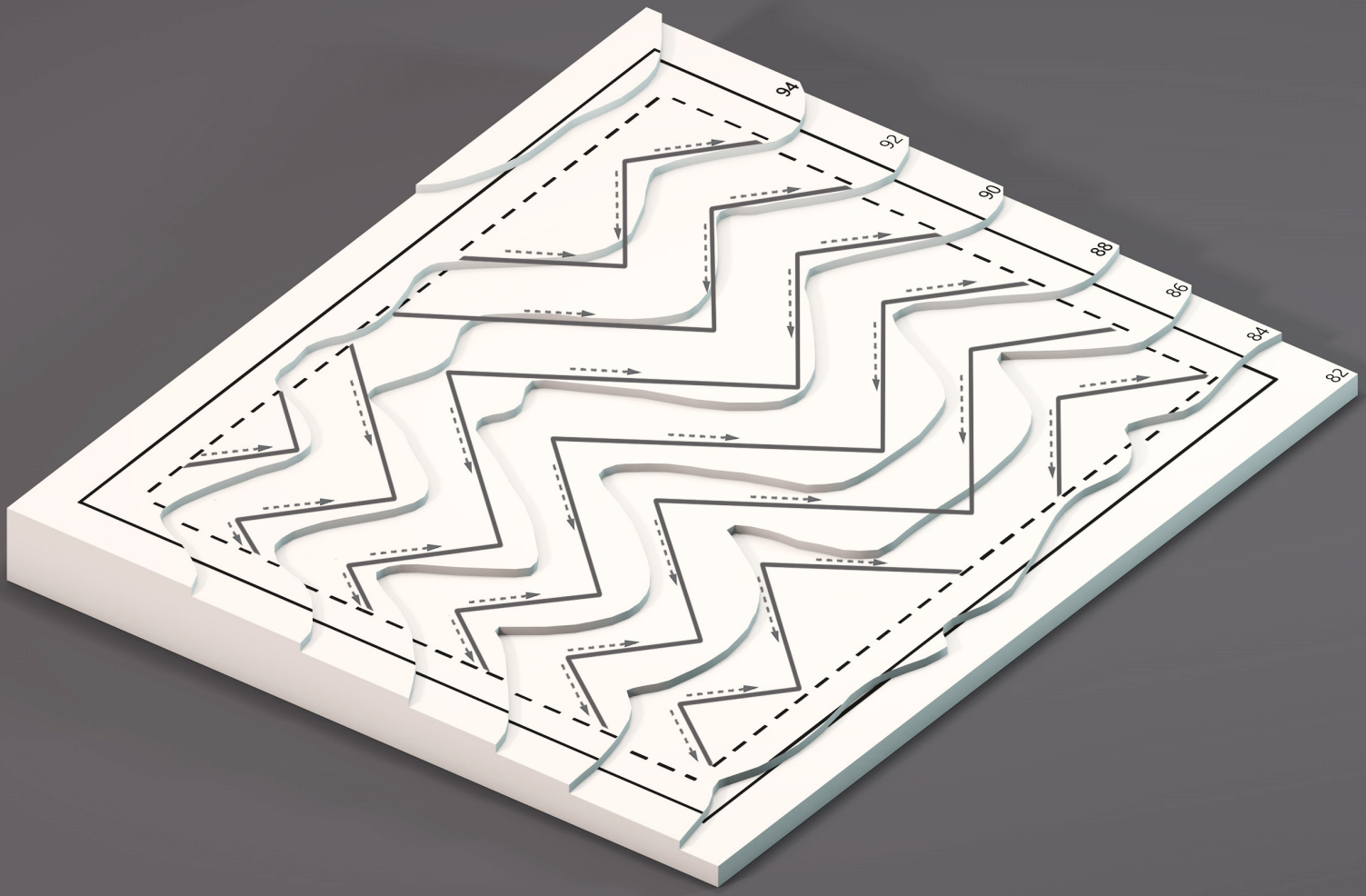


Drainage pattern.

SIMPLICITY

The design is complete when it cannot be simplified any further without undermining its functionality. The good layout is comfortable and convenient for the people that have to work with it; rows are equidistant and as long and straight as possible, without steep slopes and turns; patterns have an easy flow from one to another; guidelines for offset are few and simple in shape for easy marking on site. Creating convenience and inspiration for the people who will manage the landscape is a powerful way to help ensure the longevity and regeneration of an enterprise.

That being said, it is often necessary for compromises with the geometry to have to be made, and that's okay. It is much better to have a layout that is not entirely correct but that is easy and inspiring to work with, than a layout that is technically correct but that everyone hates working with.



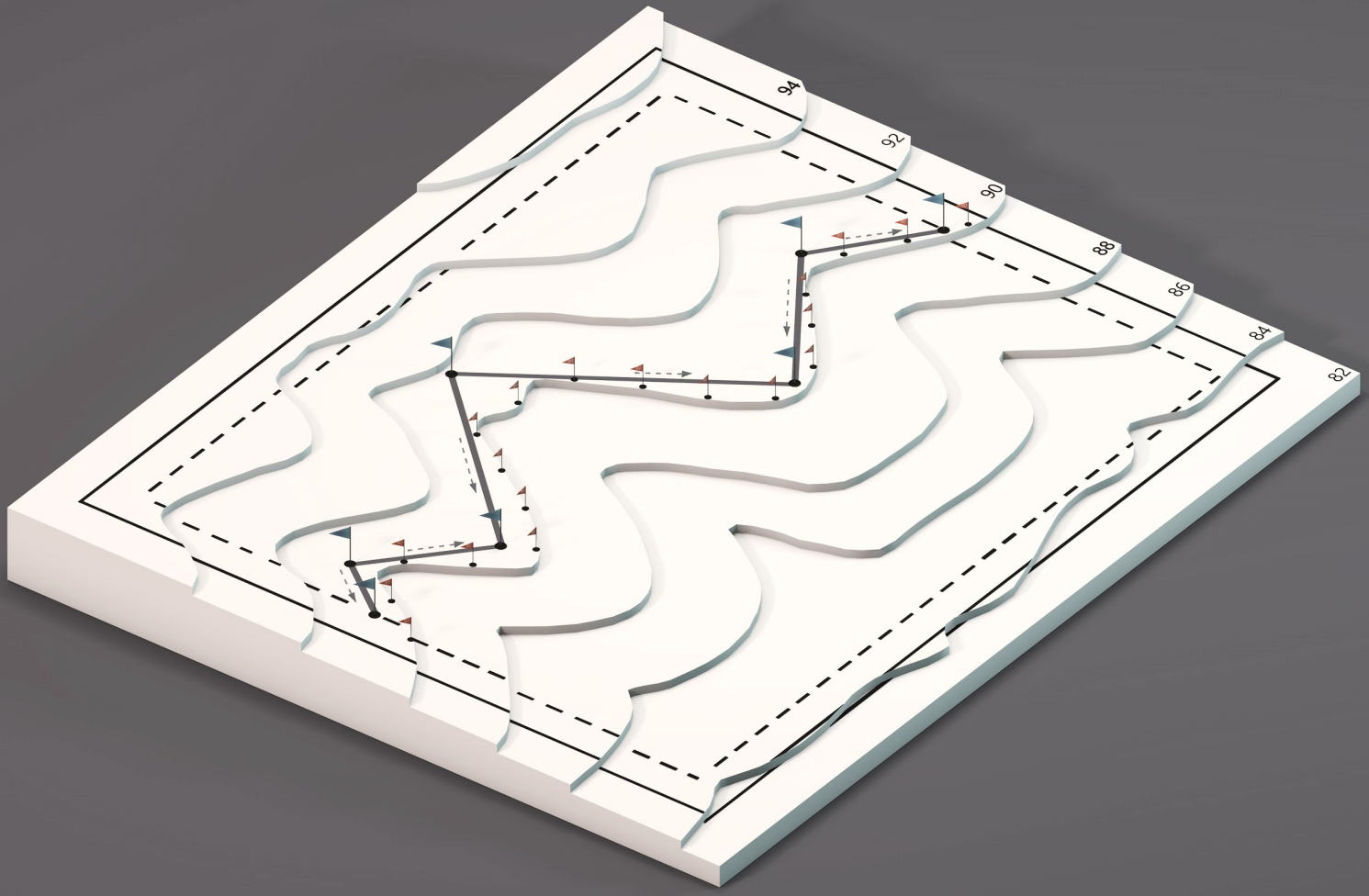
Complete layout.

APPLYING ON THE GROUND

There are different ways to apply the keyline pattern on the ground, ranging from basic to highly sophisticated. Here I briefly outline a way of applying the pattern that does not require expensive equipment.

Using any basic surveying equipment, mark a contour line on the ground around where you think the guideline that was on your plan should begin. Then simplify the general land shape of the contour by offsetting from it just a few points until you get the triangular outline of the guideline as it was on your plan. Once you've marked the guideline, leave adequate free space for the headlands.

Where multiple patterns are concerned, follow the same procedure by marking contours first and then the simple guidelines based on them. Make sure that there is also adequate headland space in between the individual sets of patterns.

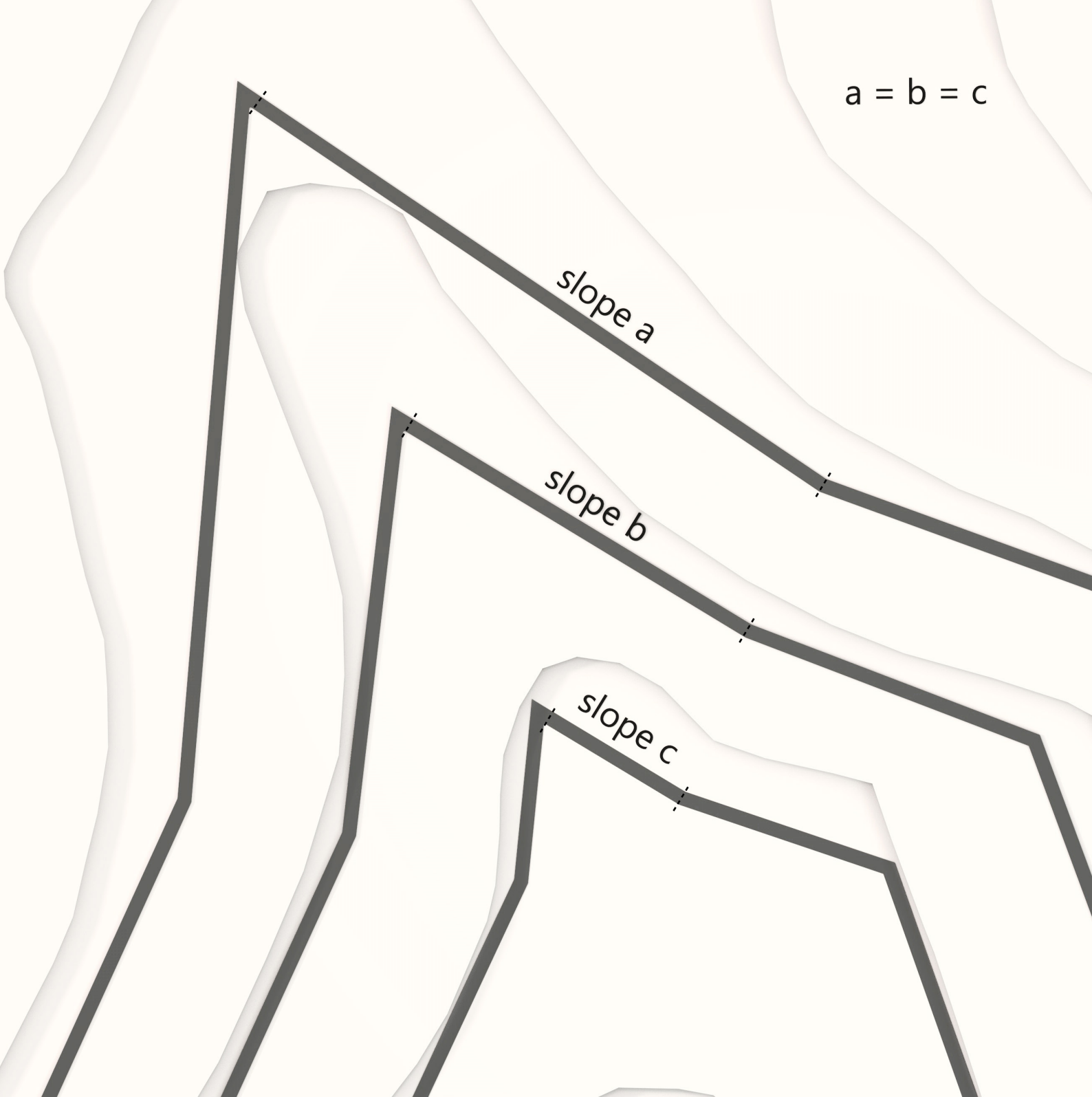


How the previous layout example was made. A contour (orange flag) is first marked and then the simplified guideline (blue) that's used for patterning.

GEOMETRY HINTS

PARALLEL LINES

Parallel lines are lines of equal slope. Because of this the distance in between them remains constant throughout their length during offset. They will never intersect and that is why they are equidistant. And because the lines are parallel, where they join to form angles, the angles remain constant during offset to the point the geometry starts to flatten and inverse. This phenomenon is what makes the offsets predictable and controllable, and what makes the keyline layout simple to understand and to apply.


a = b = c
slope a
slope b
slope c

OFFSET TRAJECTORY

Angles are at the heart of how offsets work. If you draw a line that splits the angle formed by rays in exact halves, then that line shows the trajectory the offset is going to follow both upslope and downslope. Knowing the trajectory the angle will follow allows us to know beforehand how our geometry will look relative to the landscape below or above it. This helps in adjusting the angle of the geometry in advance in order to make sure that when we offset, the geometry, relative to the landscape, will abide by the principle of directing water from valley to ridge.

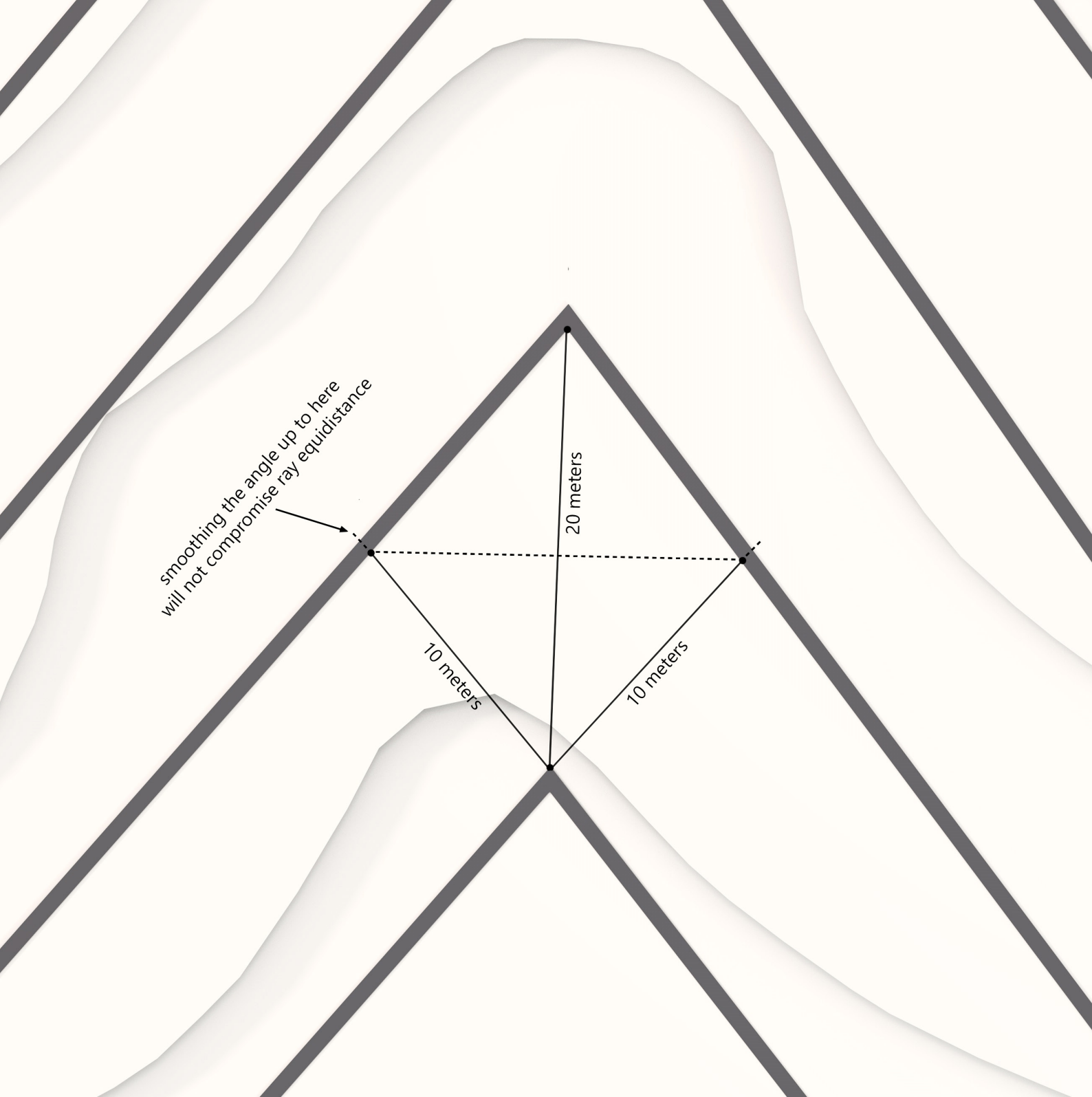
To change the direction of the offset trajectory you only need to change the angle of the geometry by adjusting the rays. Changing offset direction is necessary when the land shape changes direction or form significantly. In such cases you may need more than one set of offset patterns. Understanding offset trajectory will help you know how many patterns you will need.


α
α
α
α
α
α

ANGLE SMOOTHING

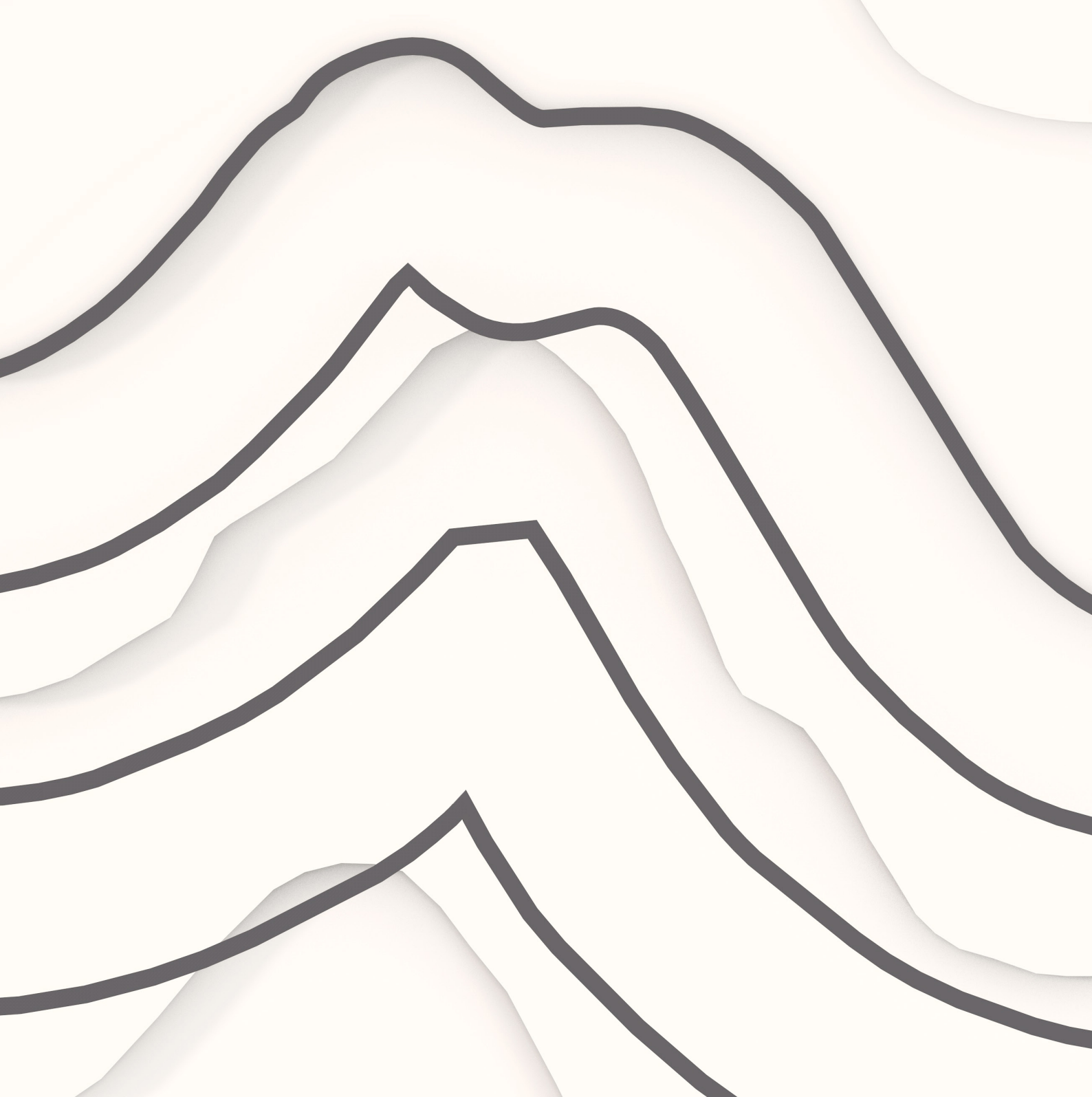
Parallel lines are not equidistant where rays join together to form angles. The distance in between angles of parallel lines is always greater than that in between their rays. This phenomenon becomes an opportunity for adjusting and smoothing angles without necessarily breaking the overall equidistance of the layout. Knowing this becomes useful when you consider that the maximum angle of turn for most tractors is between 50 °- 55 °. As it is always better to have much less steeper angles in order to ensure a smooth driving experience for machine operators, if you note any steep angles then you can smooth them without worrying too much about compromising the overall equidistance of the layout. Also note that even though the layout appears to have sharp angles on paper, machinery with dragging implements will naturally take smooth turns and therefore smooth out the pattern during implementation.

Remember also that angle and ray steepness are relative to each other. Here is a hint: for every 10 ° of increase or decrease in the angles of your geometry, the slope of the rays themselves increases or decreases by 5 °.


smoothing the angle up to here
will not compromise ray equidistance
20 meters
10 meters
10 meters

CURVES

A curve is made up of multitude of straight lines joined together. It is a much more complicated geometry made up of many angles throughout its length, with each angle having its own trajectory to follow. For this reason curves are harder to control and to predict. With contours being curves that also contain land shape anomalies, offsetting from them can quickly result in an over complicated shapes. It is much more efficient to follow a simplified outline of the major land shapes and start with simple triangular lines that you can have better control of. If necessary, the lines can be made smooth after the design is finished. The illustration on the next page shows an example of curve geometry and how it behaves during offset from a contour.



QUESTIONS & ANSWERS

KEYPOINTS & KEYLINES

Question: Why is there no mention of keypoints throughout the book?

Answer: While keypoints and Keylines of the valleys are highly relevant for the placement of features like dams, they have become irrelevant for setting up the geometry of Keyline largely due to the advent of modern software and technology. The point of the book is to highlight the bare essentials when it comes to setting up this agricultural layout and not bog the readers down with what is not used in practice anymore.

TRIANGULAR LINES

Question: Why is every layout example throughout the book made with triangular lines and not curves? Aren't curves easier to drive on and more aesthetically pleasing?

Answer: We must differentiate between what's on paper and what will be on the ground. Triangular lines are much easier to manipulate and to predict while planning. It is better to setup your layout plan as efficiently and simply as possible so that it can be read and understood by all. While the lines do have sharp turns on paper, machines with dragging implements will naturally take smooth turns and will smooth out the layout during implementation.

IMPLEMENTATION

Question: Why is there only one example of an approach to implementation?

Answer: It is the most basic way that I know of to approach the on-site application of this layout. Few people are likely to possess or be able to afford the expensive software and GPS equipment that are necessary for more advanced approaches to implementation. The approach that is outlined in the book works well and can be successfully followed by most people with minimum expense and effort. The book aims to empower the individual, not attempt to make them be unnecessarily dependent on other people or things.

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ABOUT AUTHOR

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My name is Georgi Pavlov and I live in Bulgaria. I work at HUMA, together with my brother Smilyan Pavlov where we are involved in the sphere of landscape, graphic and web design, and education.

Regarding landscape design, I am interested in simple, no nonsense, solid concepts and practices that provide the greatest leverage towards large scale landscape re-generation.

Keyline was a love of first sight for me. Equidistance, water management and erosion control through the same pattern..brilliant. Unfortunately there isn't that much information about the Keyline system and its application. A few people have already been working on making more information readily available. I wish to contribute towards this goal with this brief booklet. I hope you found it to be useful. Best of luck!

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