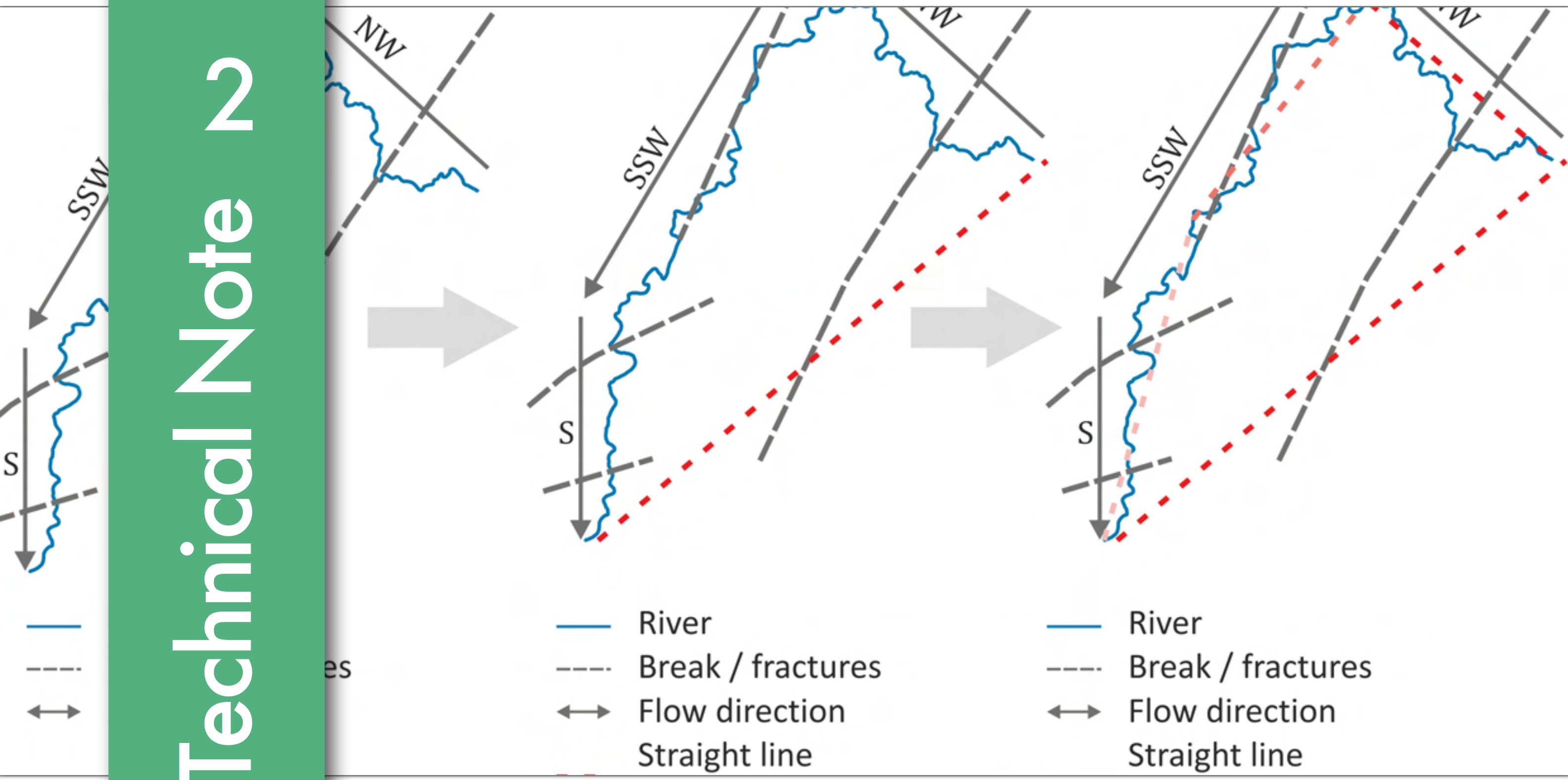
Technical Note 2



RIVER SINUOSITY INDEX:
Geomorphological characterisation

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RIVER SINUOSITY: Geomorphological characterisation

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1. Concept and usefulness

The concept of sinuosity is used to define the degree of meandering of a riverbed, which is then used to establish geomorphological river types. There are different sinuosity indices, each focused on a specific geo-topographical parameter (figure 1):

•Total sinuosity method: parameter based on the coefficient between the length of the riverbed and the shortest distance between its beginning and end.

•Brice method: the index is expressed as the ratio between the length of the riverbed and the length of the axis of meanders.

•Inflection sinuosity method: this is obtained by linking all the inflection points of a series of meanders with a broken line, with this line then used as the denominator of the formula.

•Leopold and Wolman method: this consists in dividing the length of the talweg by the length of the valley.

•Hydraulic sinuosity method: formulated as the quotient between the length of the riverbed and the average length of the valley.

•Topographical sinuosity method: defined as the relation between the average length of the valley with the shortest distance between the start and finish of the riverbed.

These six methods present both advantages and disadvantages regarding their applicability. The Brice index, also known as the 'length of the central axis of meanders method', is the most universally used due to its quick calculation and its capacity to adjust to medium and small scales. With the technique of using inflection points, the sinuosity of each meander can be established. However, despite being the most precise,

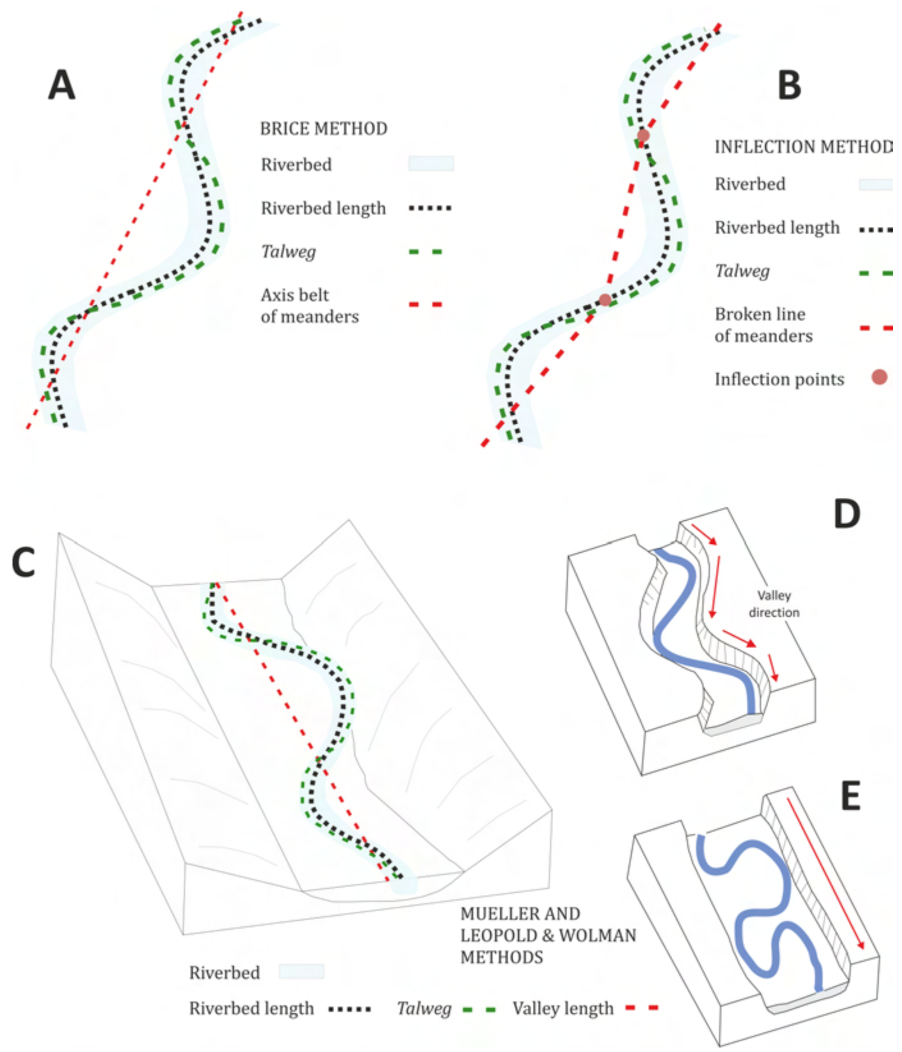

Figure 1. Graphical representation of river sinuosity calculation methods

the general sinuosity of a large stretch tends to produce a lower result than with the other method. The Leopold and Wolman procedure gives results that fall between those of the previous two indices. However, it poses the additional technical problem of having to determine the talweg of the riverbed.

The hydraulic sinuosity proposed by Mueller, is the most suitable criteria for morphometrical analysis, as it adjusts very well to the real value of sinuosity. With curved grids in the Brice or Leopold and Wolman indices, clear bias is created because changes of direction between valleys are not taken into account (figure 3d), thus giving the index a greater value than it has in reality. In more mountainous stretches, the length of the riverbed and the length of the valley usually coincide, as the river follows the line of the valley and it is usually a straighter path. Nevertheless, in sectors where the valley opens out, allowing the river to move laterally (meandering), the ratio parameters differ greatly (figure 3e). This is why hydraulic sinuosity is better suited for these cases as opposed to the Brice proposal, although it also poses problems when establishing the limits of a valley, especially in flat areas.

Working with the Mueller method, as well as providing meticulous work, can represent the existence of extremely narrow river stretches depending on the sinuosity, in the cases in which the sinuosity values are medium-high or even in vertical relief areas, with numerous short valleys. However, this index is ideal when producing a greater level of detail, for example, of a valley or section of river.

Topographical sinuosity, also proposed by Mueller, adapts well to enclosed valleys. Having said that, as free meanders extend, the value of the ratio loses reliability, as the average length of the valley almost matches that of the straight line between the start and finishing points of the riverbed, meaning that the digression of the riverbed is not taken into consideration.

As previously mentioned, sinuosity is used to mark out the types of riverbed, though the setting of thresholds has generated a degree of disagreement in the field and there are no unanimous standards as of yet, apart from that of calculating straight stretches, considered to be: Is<1.05. The only clear point is that a high level of sinuosity indicates a river with a meandering course, bringing the average curvature down in accordance with the index. The following classification has been suggested, based on 4 types of sinuosity:

<1.05 (straight); 1.05-1.3 (sinuous); 1.3-1.5 (moderate meandering) and >1.5 (meandering form).

When calculating sinuosity it is worth remembering that:

- Defining straightness from sinuosity may generate a degree of ambiguity in meander lobes with long wave lengths.
- The value of sinuosity, regardless of the method used, is dependent on the scale of the work and the author’s personal interpretation when outlining the denominator value of the ratios (length of the meander axis, inflection points on the broken line, etc.).
- In total sinuosity – understood to mean the quotient between the total length of the riverbed and the straight line marked from the source to the mouth – it is essential to take into account direction changes marked by the framework of the breaks and fractures. With directional changes over 15O, a new sinuosity stretch is recommended, as if not, the real index value is distorted (figure 2).

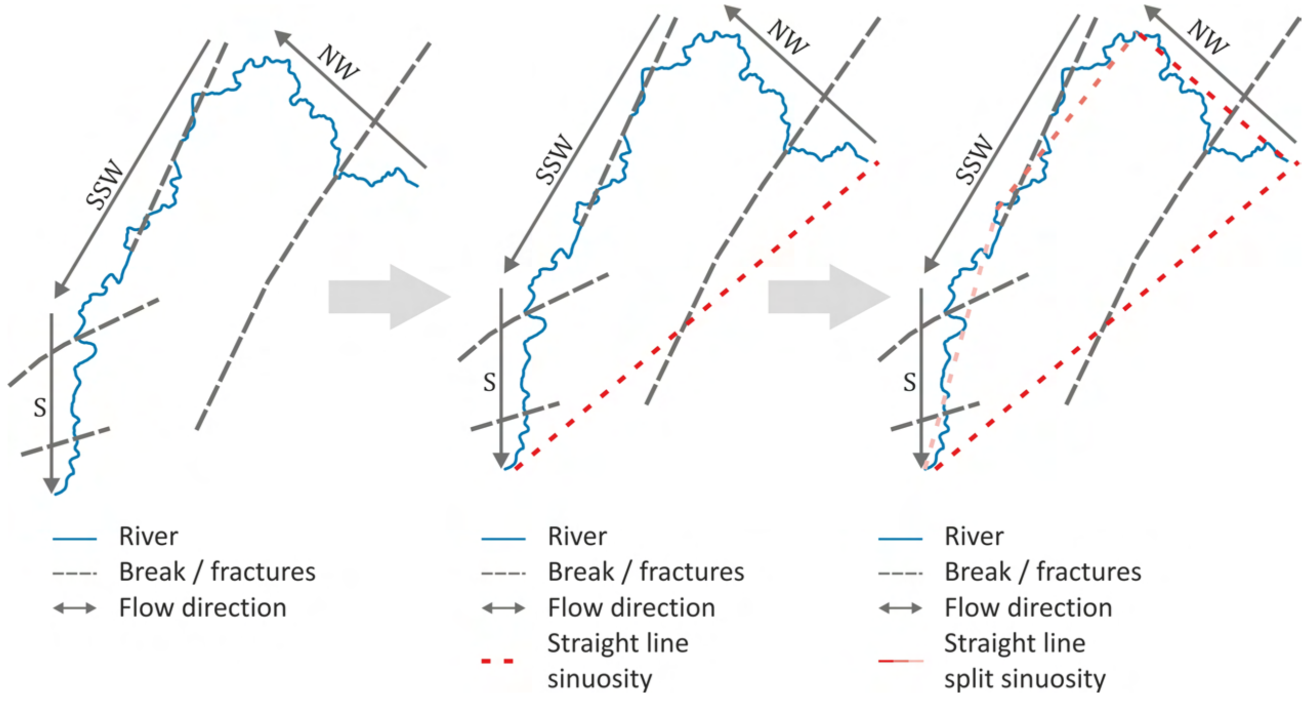

Figure 2. From left to right: river directed by breaks/fractures → erroneous calculation of total sinuosity → correct calculation of the total sinuosity

2. Calculation process via GIS

There are various tools within the GIS field which offer the user a quick method of accessing any of the sinuosity types required. The model and recommendation of this technical data sheet, is based on the ArcGis 9.x ® software from ESRI (the tool used is displayed in square brackets). The process consists of generating a copy of the layer of the rivers we are going to name, for example, ‘Sinuosity’. This layer has to be split [Split tool] based on the length of the particular river whose sinuosity we are interested in discovering. If we base the formula denominator, length of the axis of the meander belt on the Brice method, it is immediately obtained with the Hawth’s tools1 extension [Hawth tools> Analysis tools> Line metrics: sinuosity]. This function generates a new field in the attributes table where the sinuosity indices are stored for each stretch of the split river (see process diagram in figure 3).

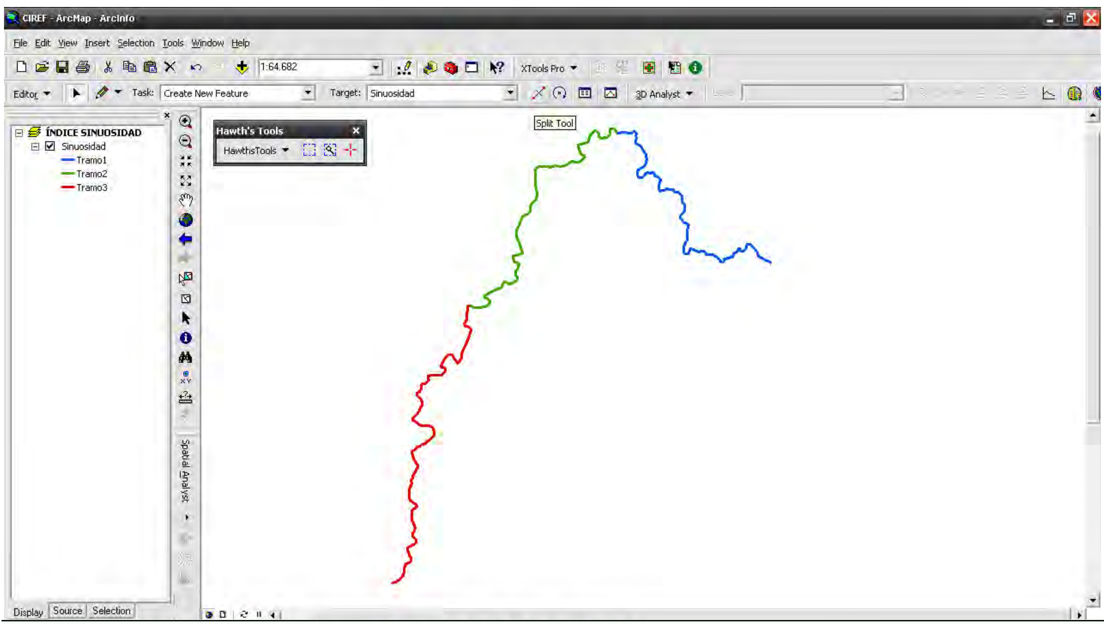

Figure 3. Modus operandi in calculating river sinuosity from ArcGis 9.x

3. Assessment and representation of the results

The results achieved in the GIS range may be exported in a (*.dbf) file to undergo other types of treatment. These post hoc procedures are mainly based on the application of diverse statistical tests which help establish more accurate classifications, and reveal, for example, the measure in which sinuosity varies in different rivers or stretches. Similarly, it is extremely interesting to also discover the correlation between sinuosity and the river gradient and sinuosity and lithology, which are good indicators of geomorphological types.

The representation of the sinuosity results may be produced, among other options, via linear cartography, or likewise with boxplots, as they combine both representation and high explicatory content (figure 4).

Some interesting conclusions:

• In general, straight riverbeds are rare in the natural world, and many of them are a result of structural controls (fractures/breaks) or stretches that connect a series of meanders with another.

• The structure – lithology and tectonic – influences the sinuosity, and therefore, the models or types of river.

• In sections where tectonic control is less powerful than other variables, the meandering is more influenced by the gradient, lithology and river surroundings. As such, with low gradients the interaction between the energy of the current and the resistance of the substrate is more dynamic, creating cut-offs, river migrations, etc.

• Phenomenons of antecedence imply a river network that has not adapted, in other words, it was there before the current valley, a fact that explains the existence of meandering form sections that stretch over strongly resistant rocky outcrops, commonly known as 'fitted meanders'.

• The riverbed gradient is usually declared to be one of the most heavily weighted explanations when it comes to the origin of sinuosity. In heavily marked tectonic areas, the correlation between both variables loses intensity and its values become more stable or reveal more positive trends, that is, with the increasing gradient the curved stretches also increase. On the other hand, in regions where the river network is not so closely connected to the tectonic, the correlations are generally negative and display a more pronounced trend.

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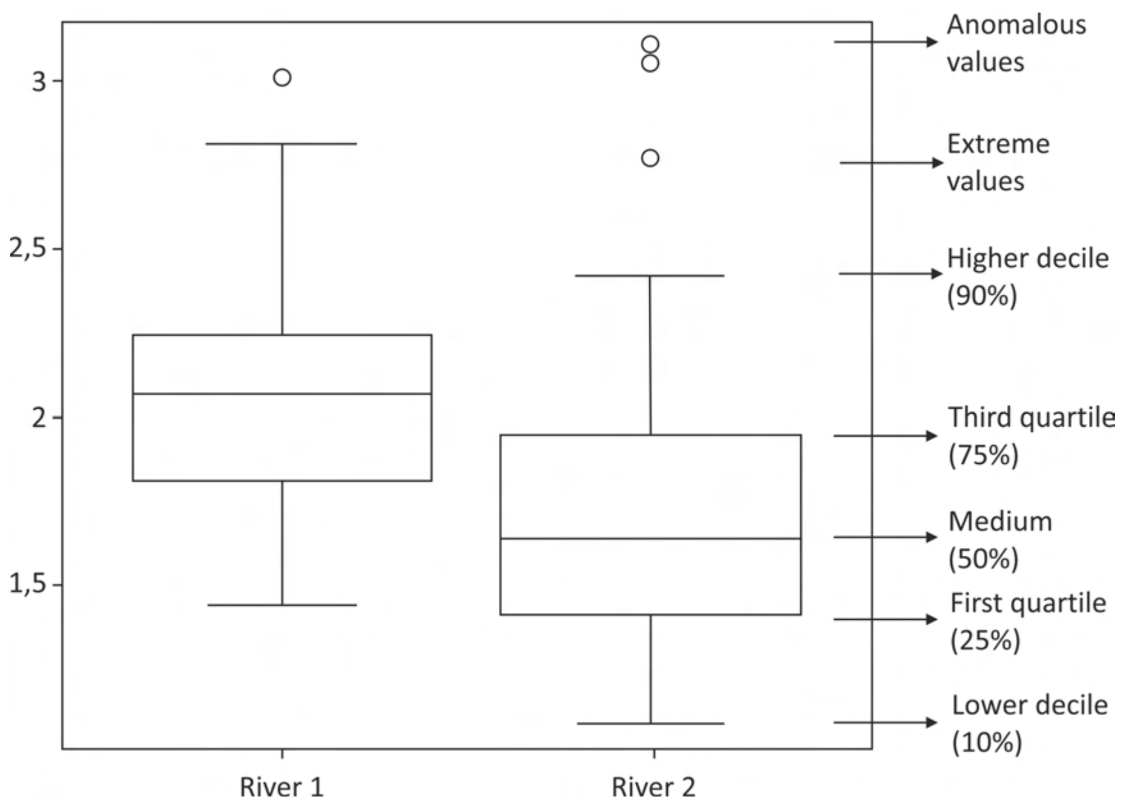

Figure 4. Box diagram (boxplot) depicting the sinuosity index