

The background features a grid pattern overlaid with various geometric shapes and lines in shades of blue, orange, and teal. A large, colorful diagonal gradient transitions from blue at the top right to purple and yellow at the bottom right. A white rectangular box is positioned in the center-left, containing the title and subtitle.

The Anatomy of Spatial Data

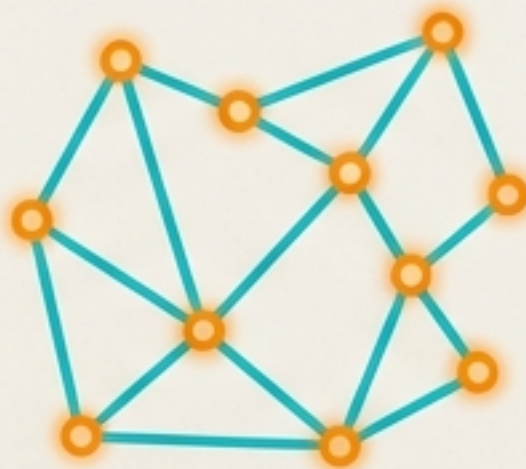
A visual reference guide to geographic information systems, vector geometries, and raster grids.

The Real World

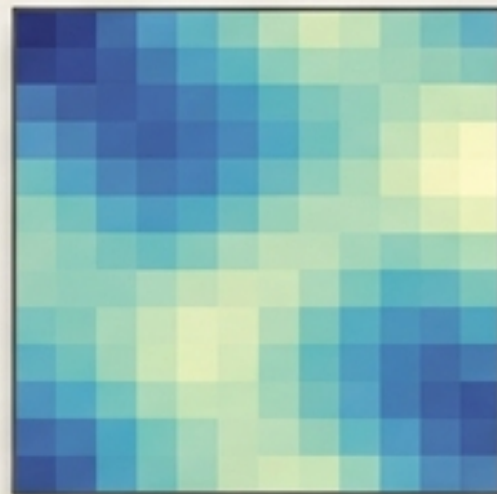


Spatial Data

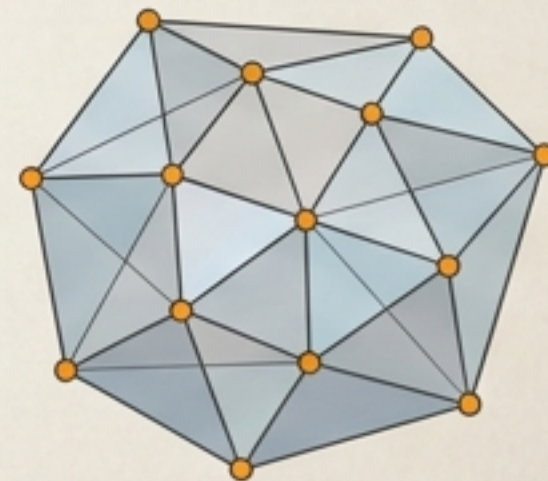
Vector (Discrete)



Raster (Continuous)



TIN (Mesh)



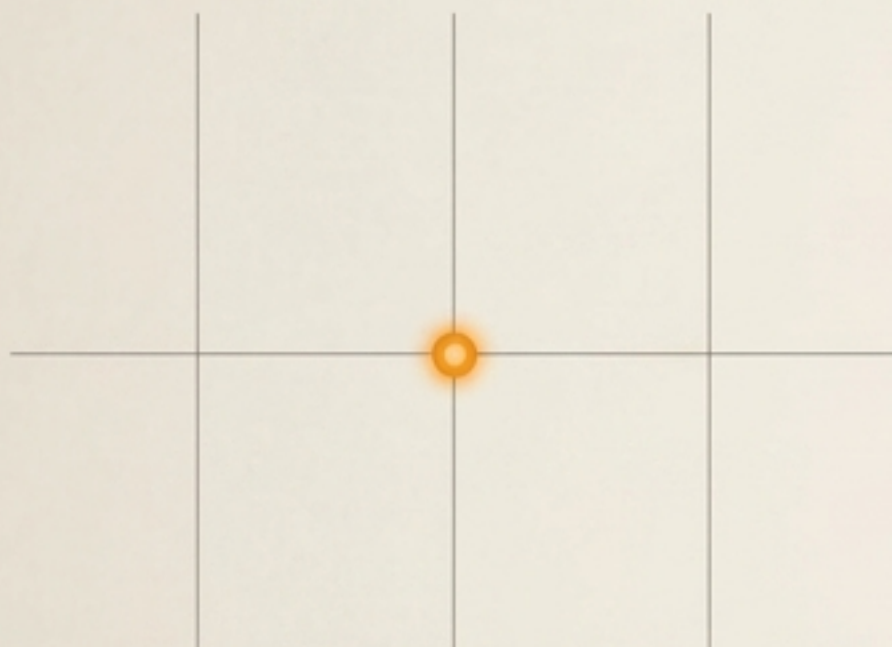
ID	Name	Age	Location	Date	Value
...	...	2	...	...	...
...	...	7	...	...	00
...	...	14	...	...	...
...	...	10	...	...	...
...	...	50	...	...	...
...	...	28	...	...	...
...	...	27	...	...	...
...	...	53	...	...	300
...	...	32	...	...	...

Non-Spatial Data

Infinite descriptive attributes stored in tabular formats.

1. The Vector Data Model

0D: Point



Coordinate: (X,Y)

Zero-dimensional entity. No length, no area.

Examples: Rain gauges, wells, confluences.

1D: Line / Polyline

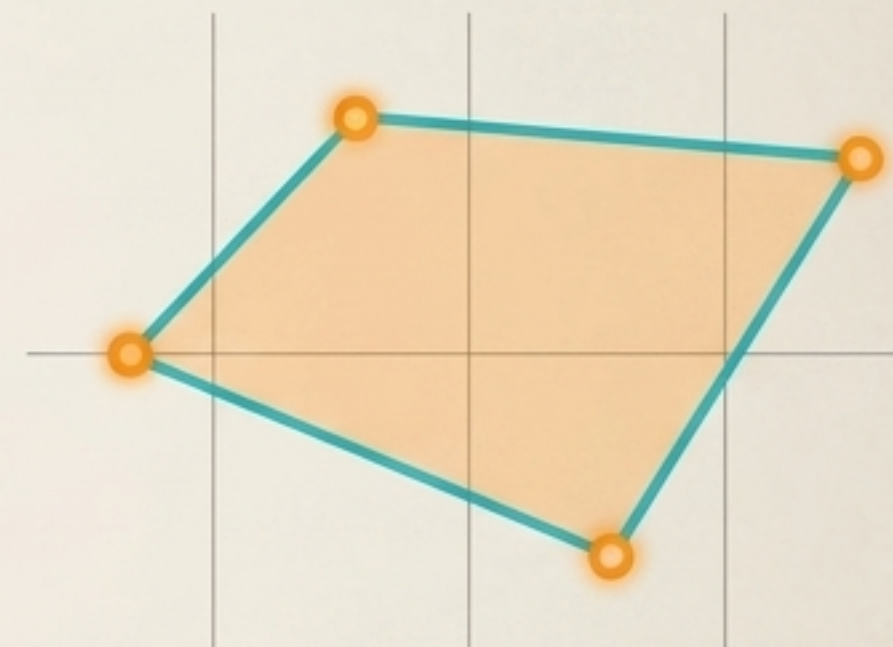


Coordinates: Series of connected points

One-dimensional entity. Has length, no area.

Examples: Rivers, pipelines, road networks.

2D: Polygon



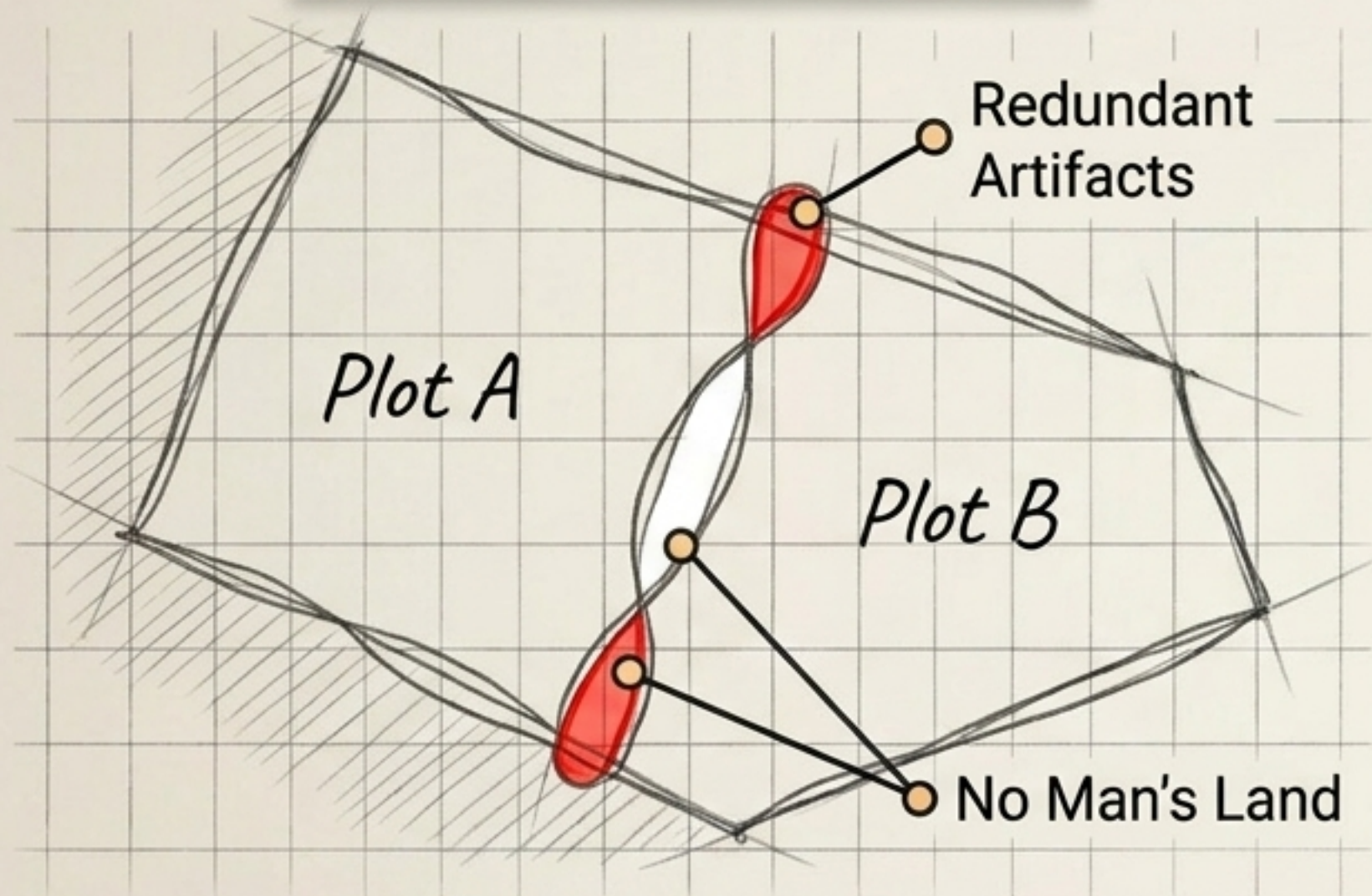
Coordinates: Closed loop of lines

Two-dimensional entity. First and last coordinates are identical.

Examples: Catchments, reservoirs, soil zones.

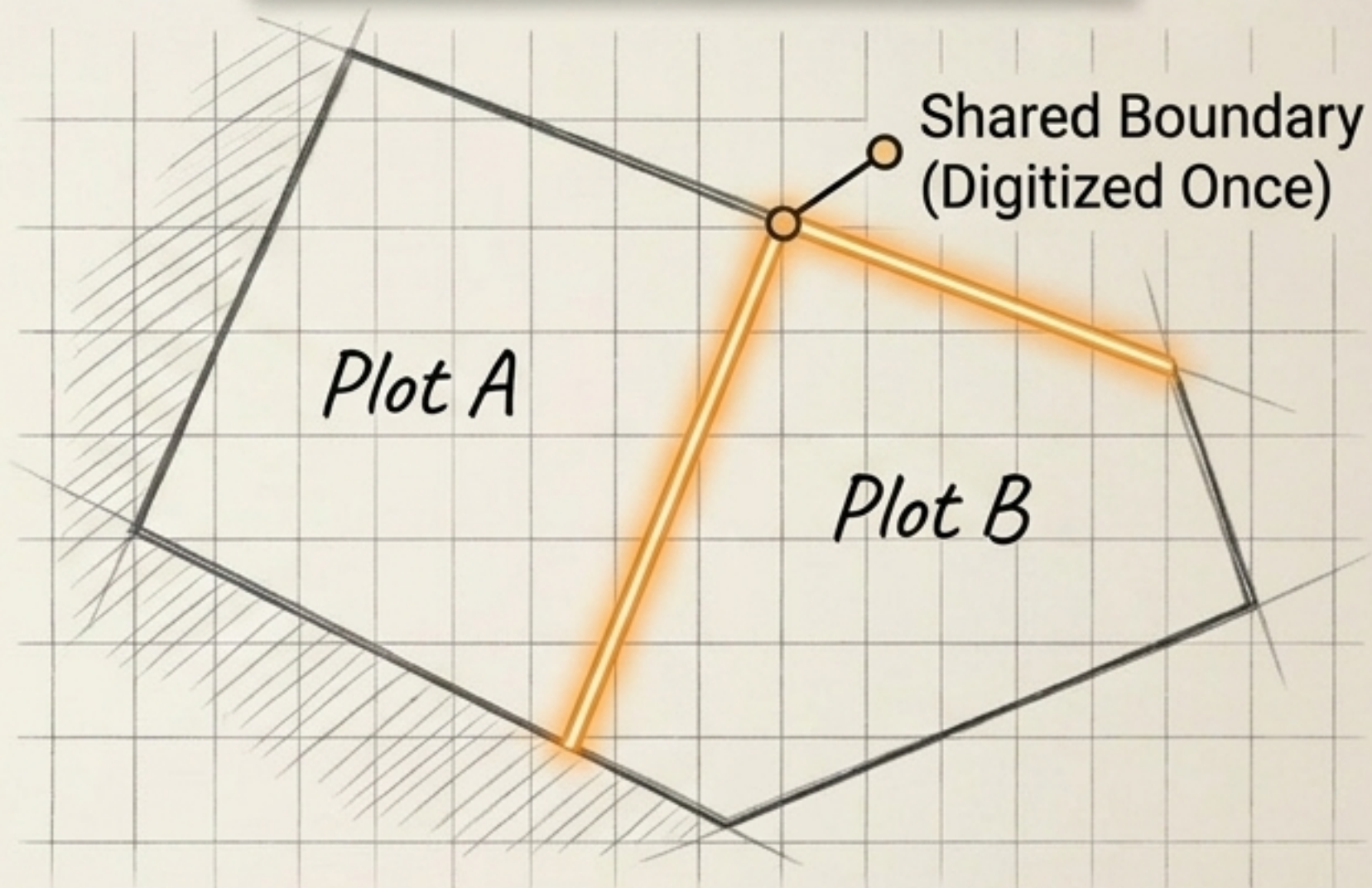
Digitization: The Spaghetti Data Model vs. Topology

The Spaghetti Model



Lines exist in isolation. Redundant digitization of shared boundaries leads to inevitable artifacts and spatial errors.

The Topological Concept

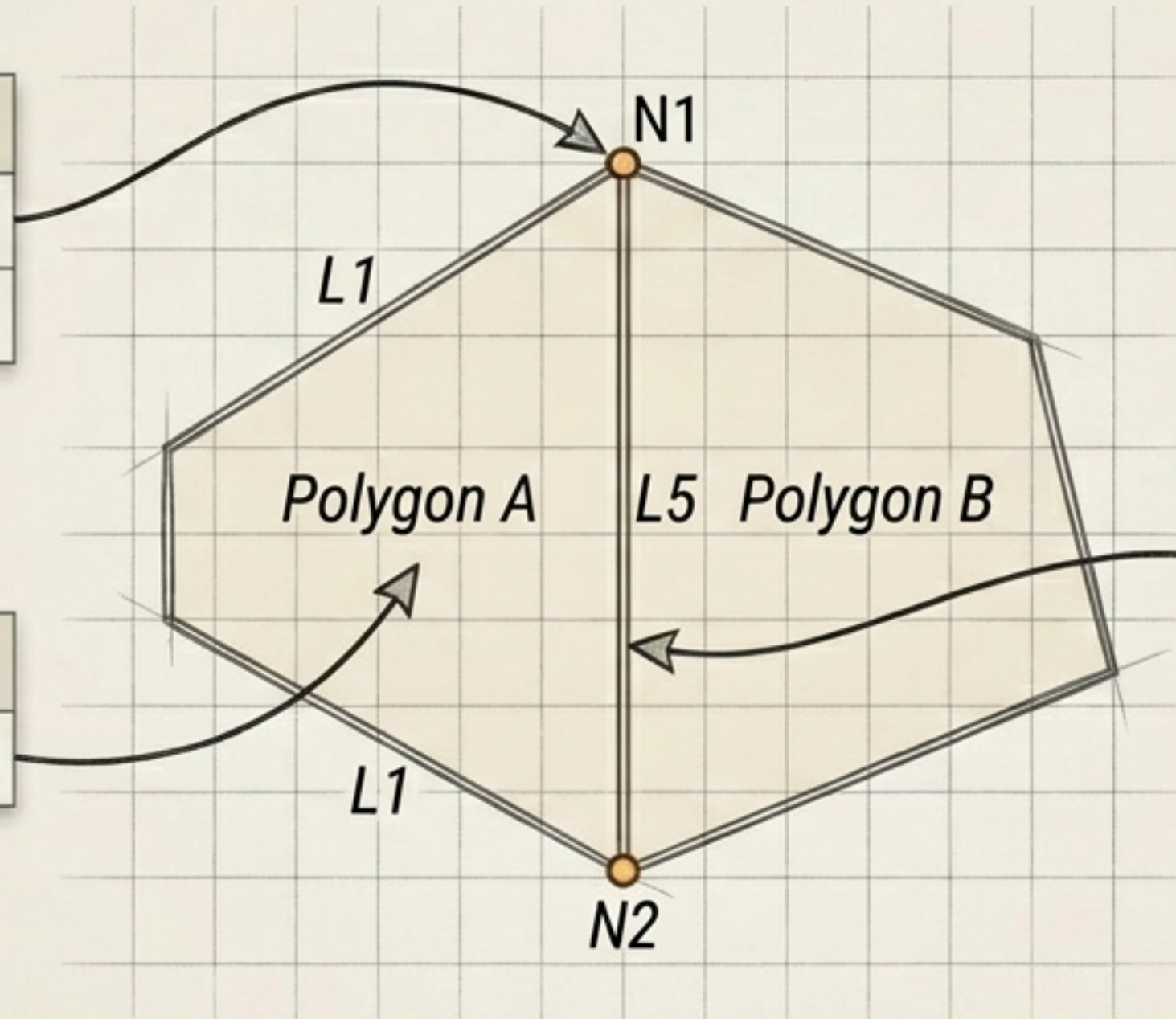


Planar enforcement. The system recognizes spatial relationships. Common boundaries are digitized once, eliminating gaps and overlaps.

Topological Data Architecture

Node Topology		
Node	N1 connects to:	L1
N1		L5

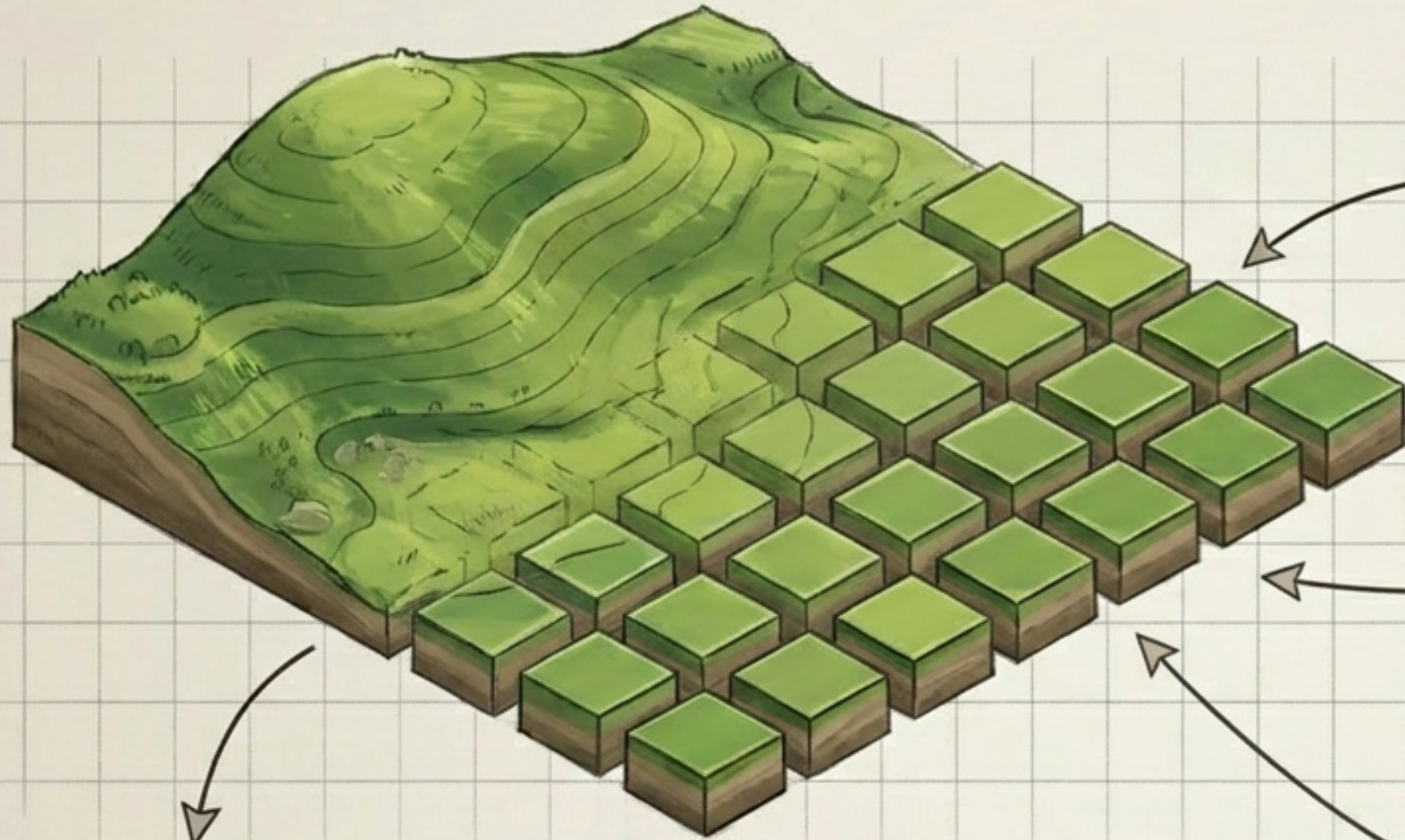
Polygon Topology	
Polygon A bounded by: L1, L5	



Link Topology	
Link	
L5	Start: N1 End: N2 Left: Polygon A Right: Polygon B

Topological rules enable advanced spatial analysis (adjacency, connectivity, containment) without redundant coordinate storage.

The Anatomy of Raster Data



Shannon's Sampling Theory

Continuous physical reality is averaged down. Every feature within a cell is homogenized into a single representative value.



The Uniformity Rule

The overall shape of a raster dataset must be a rectangle or square. The shape of a single operational unit (cell) must always be a square.



The Single-Attribute Rule

Unlike vector features, which can hold infinite database attributes, a single raster cell can only hold exactly one numeric value.

85	87	89	90
82	84	86	88
79	81	83	85

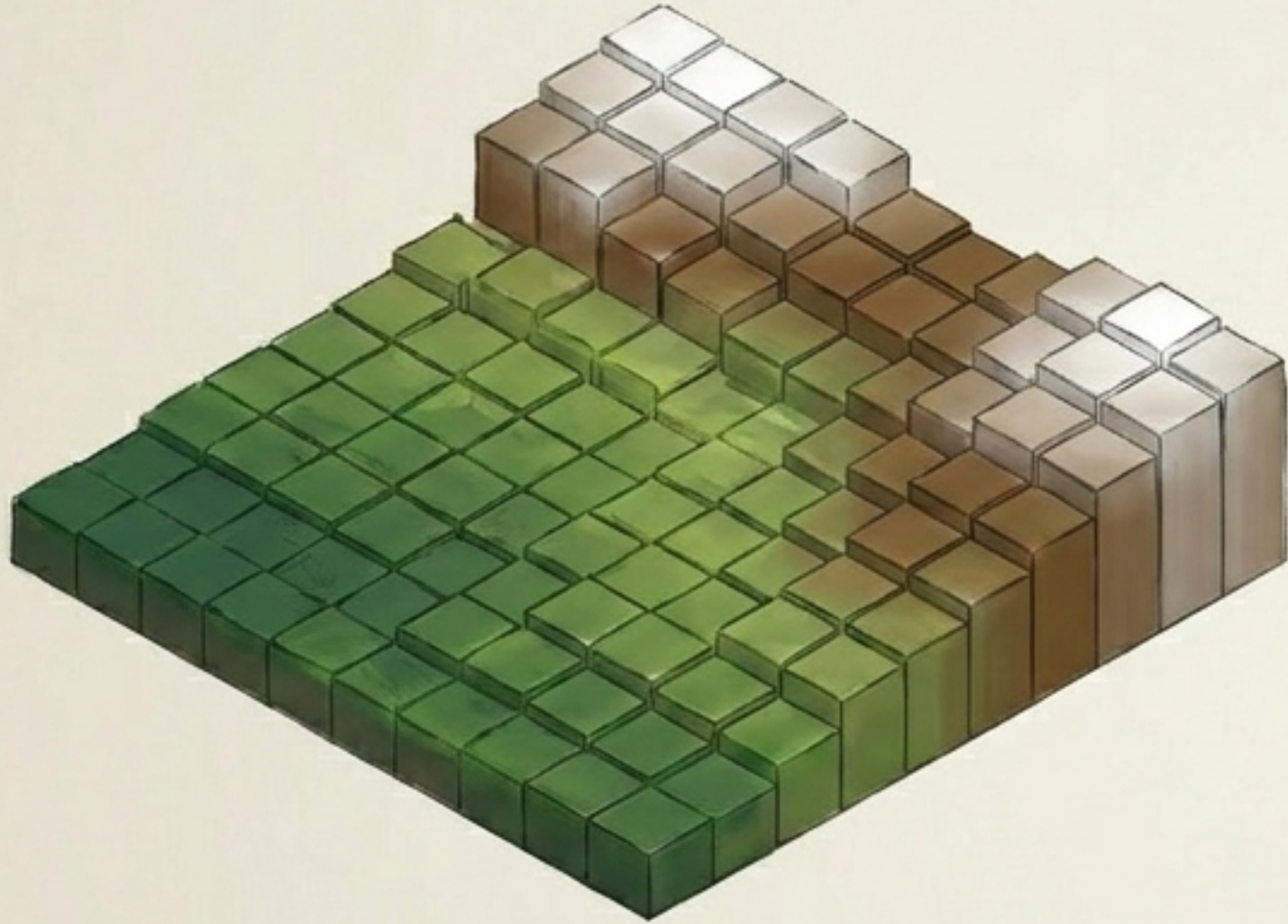
← Raster Grid Cells

Each cell represents a square area on the ground (e.g., 30m x 30m) containing a single value such as elevation in meters.



Raster Data Type Constraints

Raster Grid



Unit Name: Cell

Constraint: $[-\infty, 0, +\infty]$

Capacity: Stores positive integers, negative integers, or real (floating-point) numbers.

Application: Used for analytical surfaces like elevation (DEMs) or temperature where values fall below zero or require decimals.

Raster Image



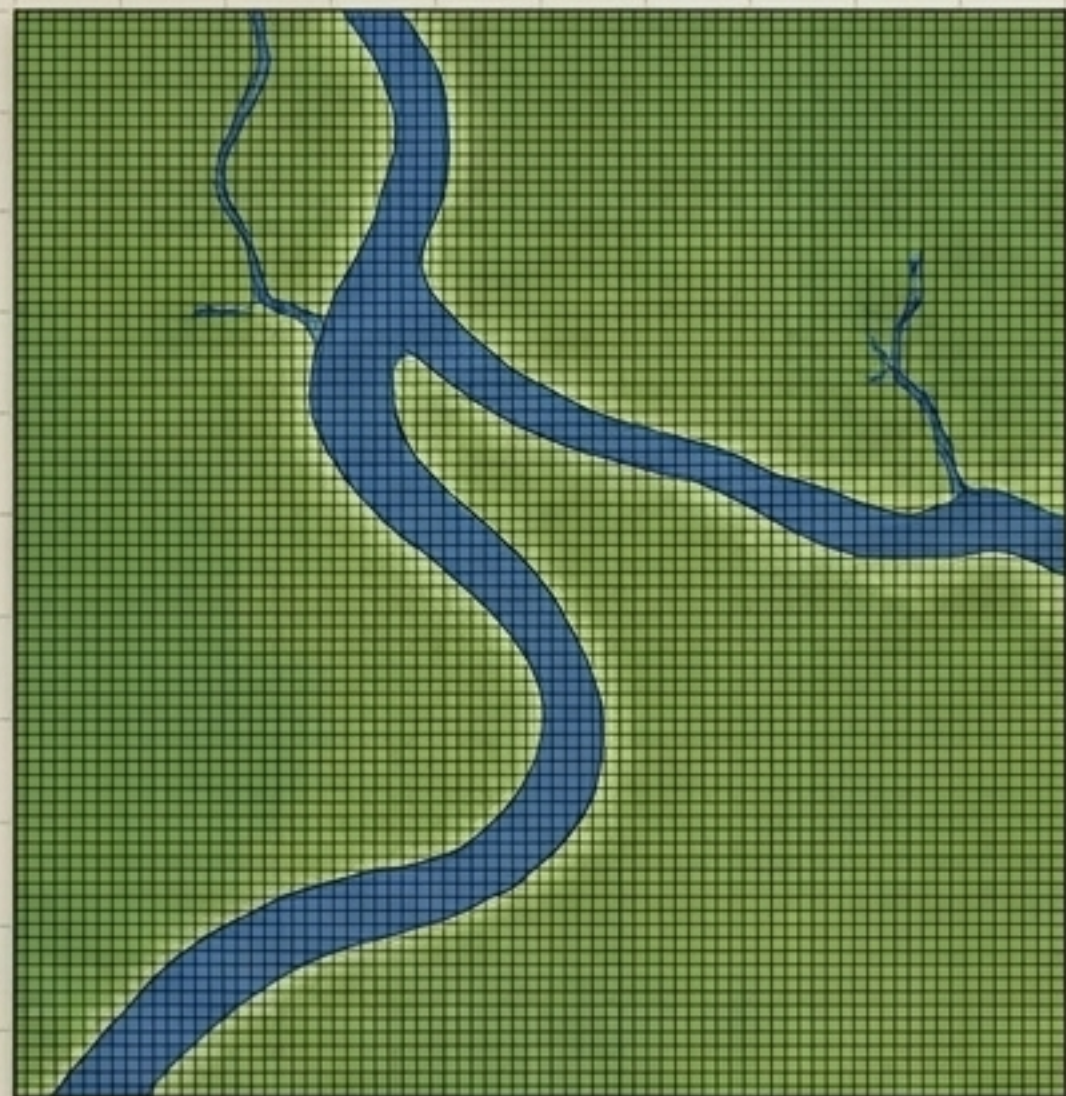
Unit Name: Pixel (Picture Element)

Constraint: $[0, +\infty]$

Capacity: Strictly positive integers. Cannot process negative numbers or fractions (often 0-255).

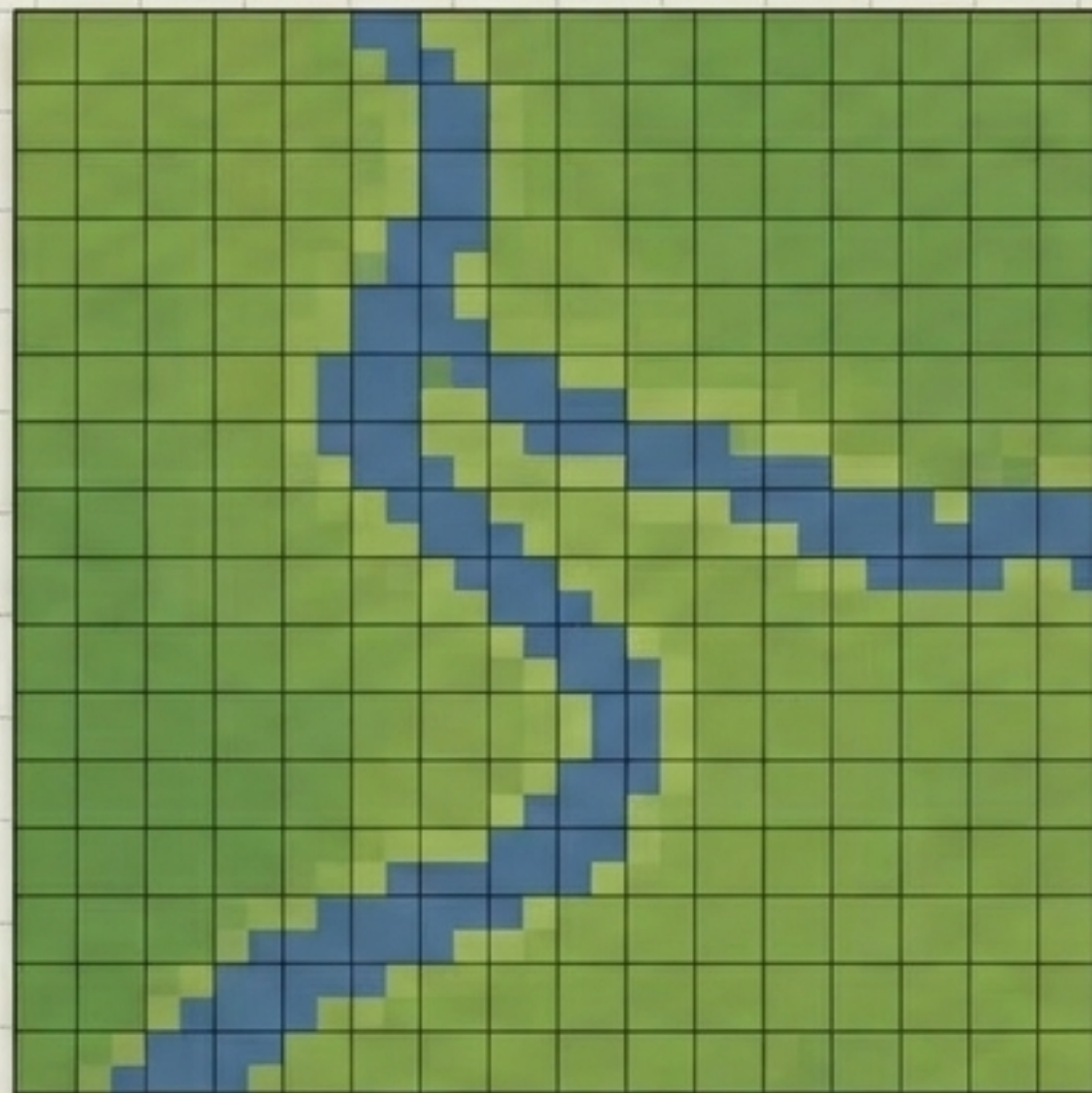
Application: Used for visual outputs, digital photography, or remote sensing reflections.

The Resolution Degradation Model



10m Resolution

High spatial fidelity. Resolves adjacent contrasting features clearly.



30m Resolution

Requires 9x less storage space than 10m, but generalizes minor features.

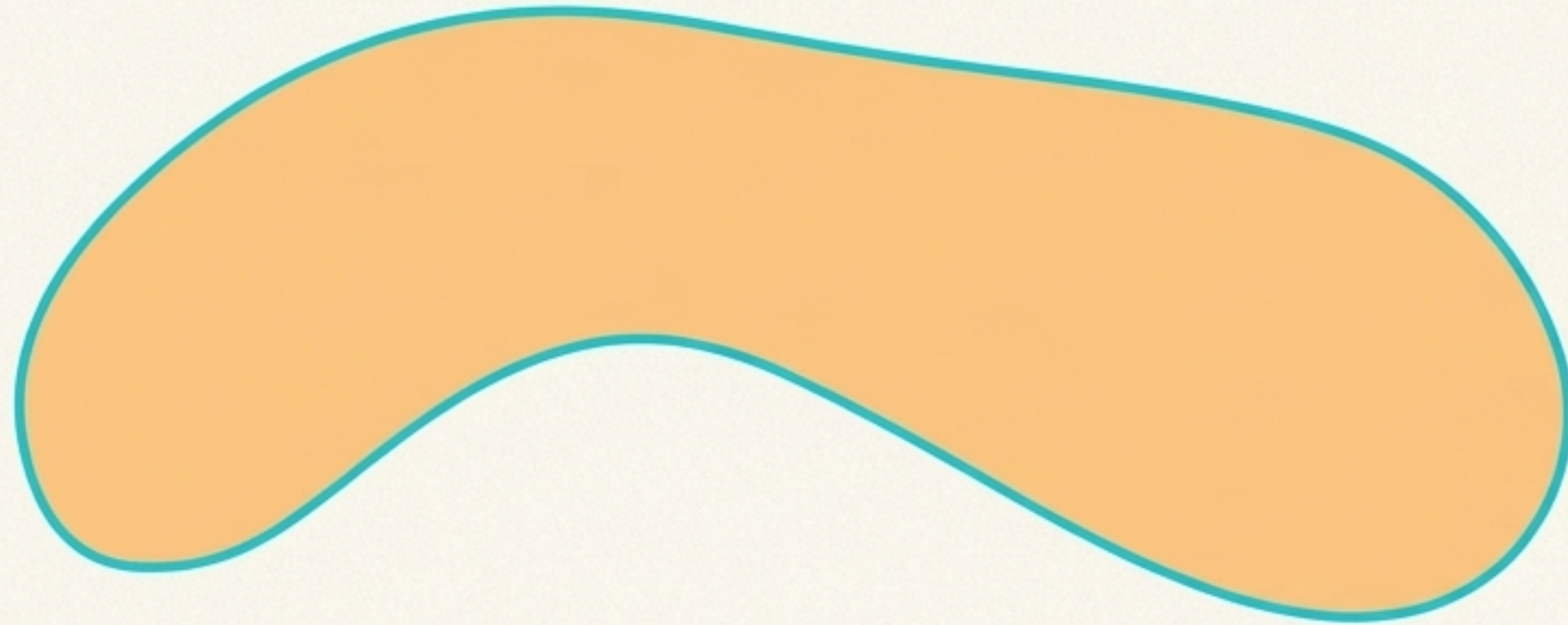


110m Resolution

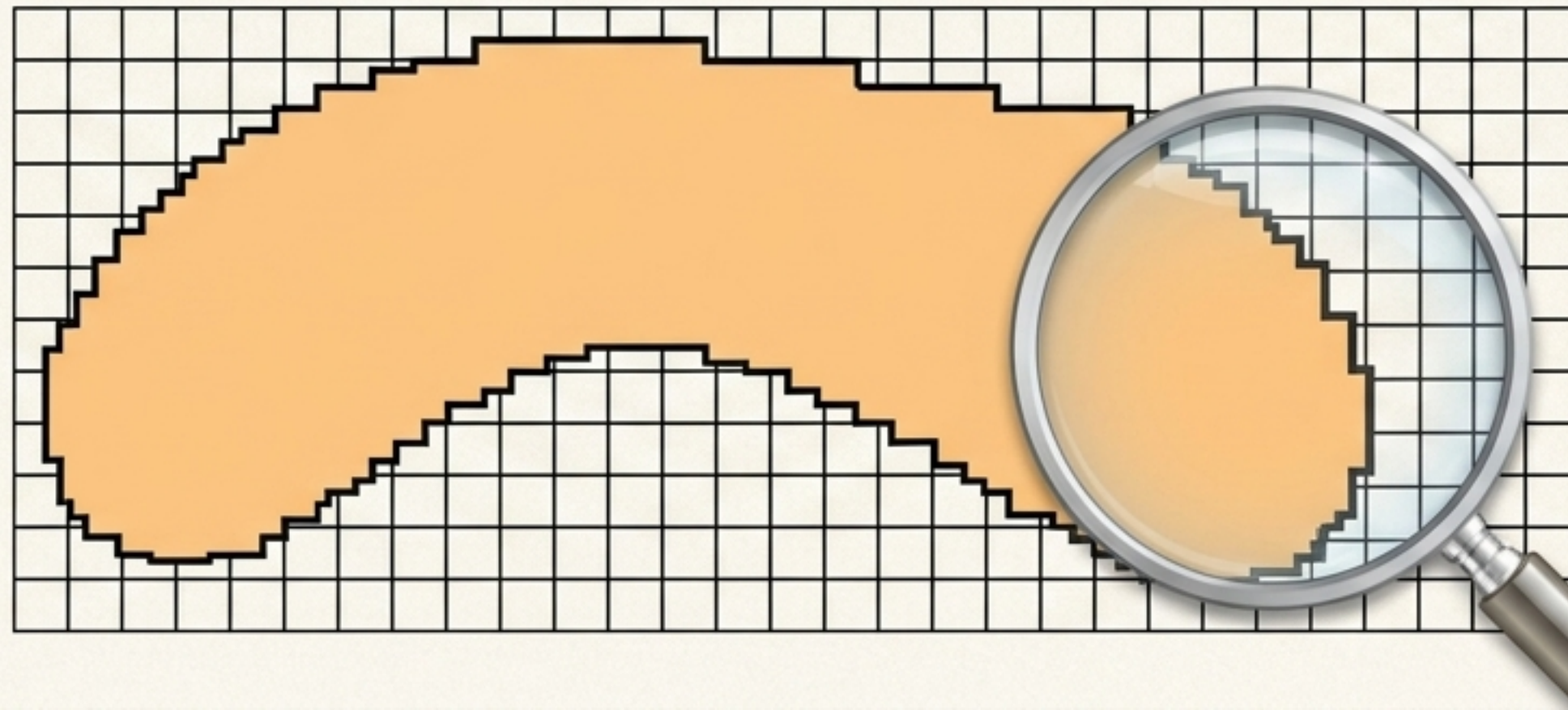
Coarse spatial resolution. Major data homogenization.

Spatial resolution dictates the clarity of real-world representation versus required processing power.

Data Conversion & The Edge Effect



Native Vector:
Infinite Positional
Accuracy



Converted Raster:
The Edge Effect

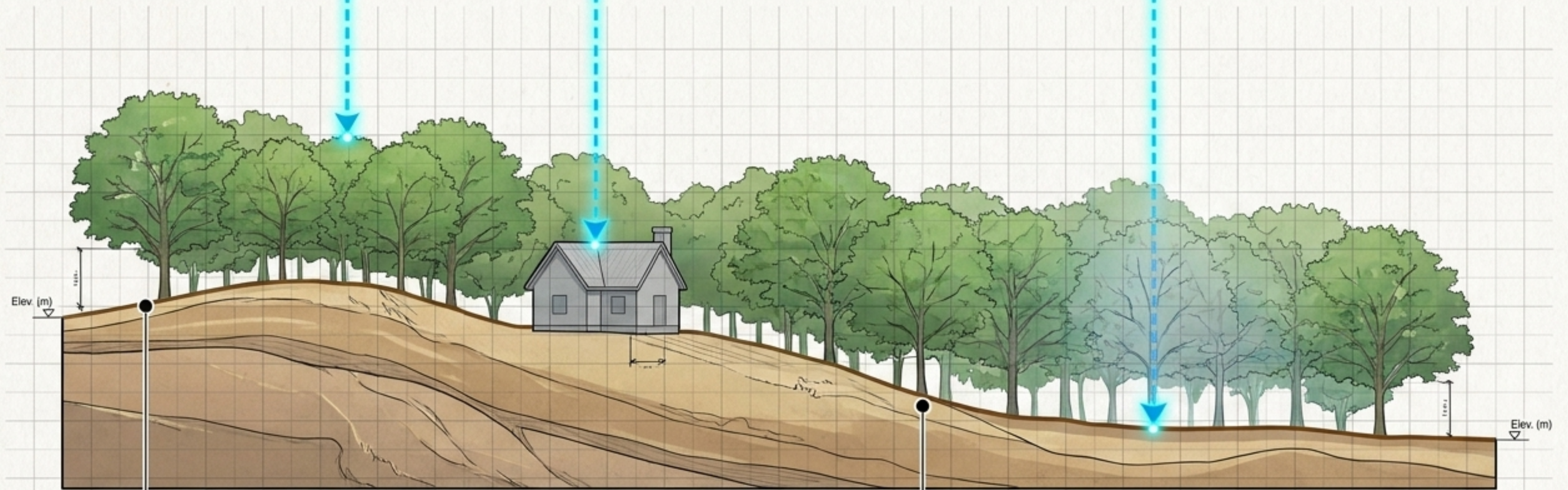
The Conversion Friction

Converting vectors to rasters requires polynomial equations to map precise (X,Y) coordinates to nearest (Row, Column) grid cells. Because raster cells are rigid squares, smooth boundaries are compromised.

The Golden Rule

Conversion introduces inevitable data loss. Keep data in its native format unless conversion is strictly required for mathematical map algebra.

Modeling the Third Dimension



Digital Surface Model (DSM)

Captures the highest elevations, including all natural and artificial features. Crucial for urban flood modeling or line-of-sight analysis.

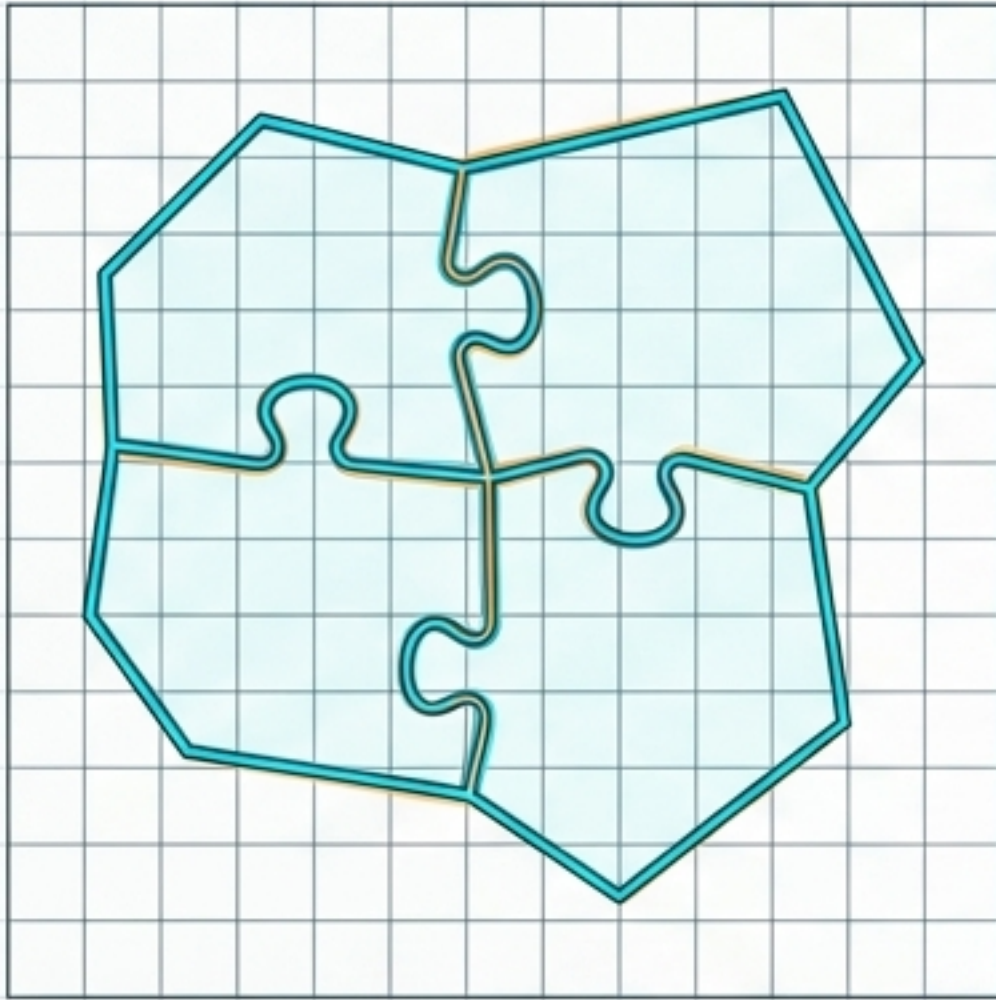
Digital Terrain Model (DTM)

Represents bare earth. Always use DTM for hydrological modeling to ensure water flows along the ground topography, not over treetops.

Diagnostic Matrix: Vector vs. Raster

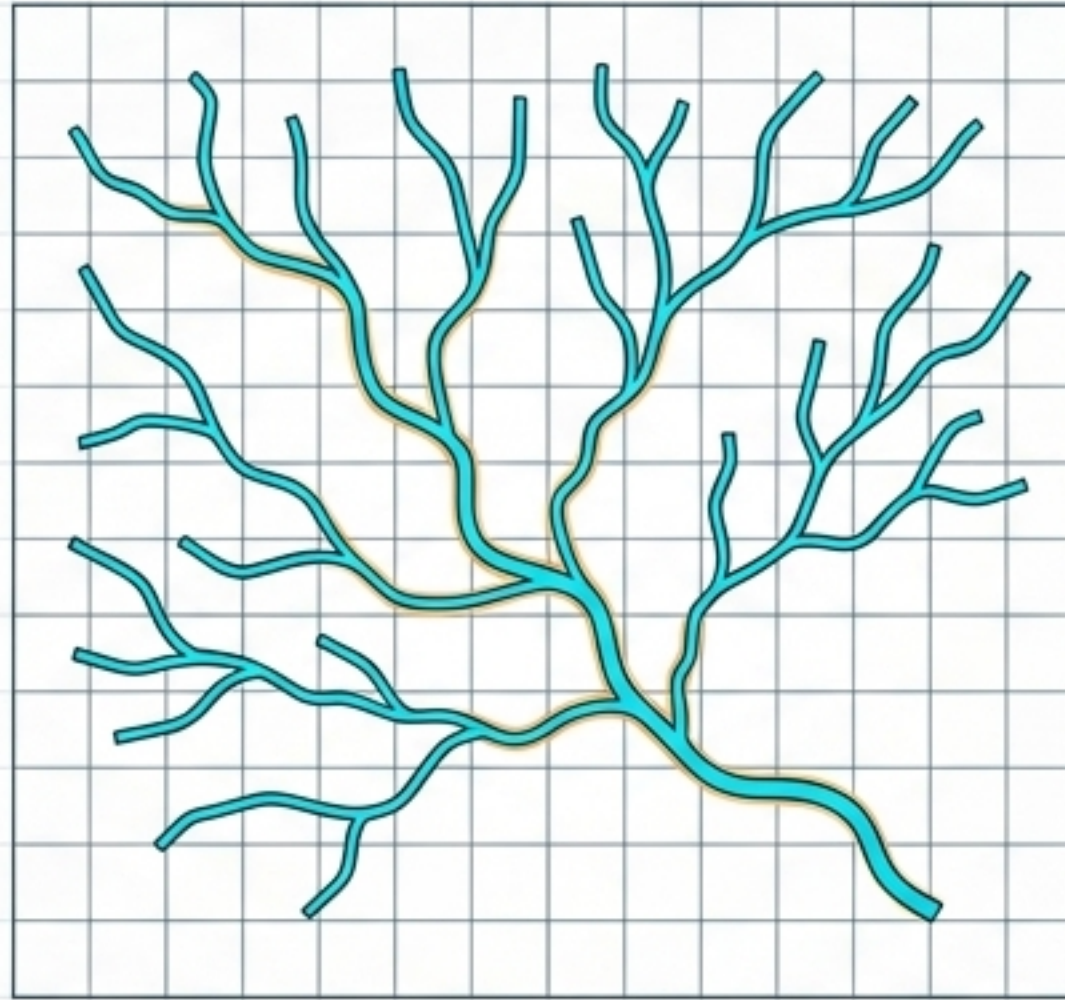
Capability / Feature	Vector Data Model	Raster Data Model
Precision	High geometric accuracy. Exact coordinates.	Limited by cell size. Generalized boundaries.
Data Storage	Highly efficient for discrete structures.	Exponentially larger file sizes at high resolutions.
Topology	Native capability. Essential for networks.	Poor. No native neighbor relationships.
Overlay Operations	Complex coordinate intersection math.	Lightning-fast cell-by-cell map algebra.
Continuous Modeling	Difficult. Requires TINs or contours.	Natural and native for gradients.
File Formats	Shapefile, GeoPackage, GeoJSON	GeoTIFF, NetCDF, JPEG2000

Applied Vector Models: Discrete Datasets



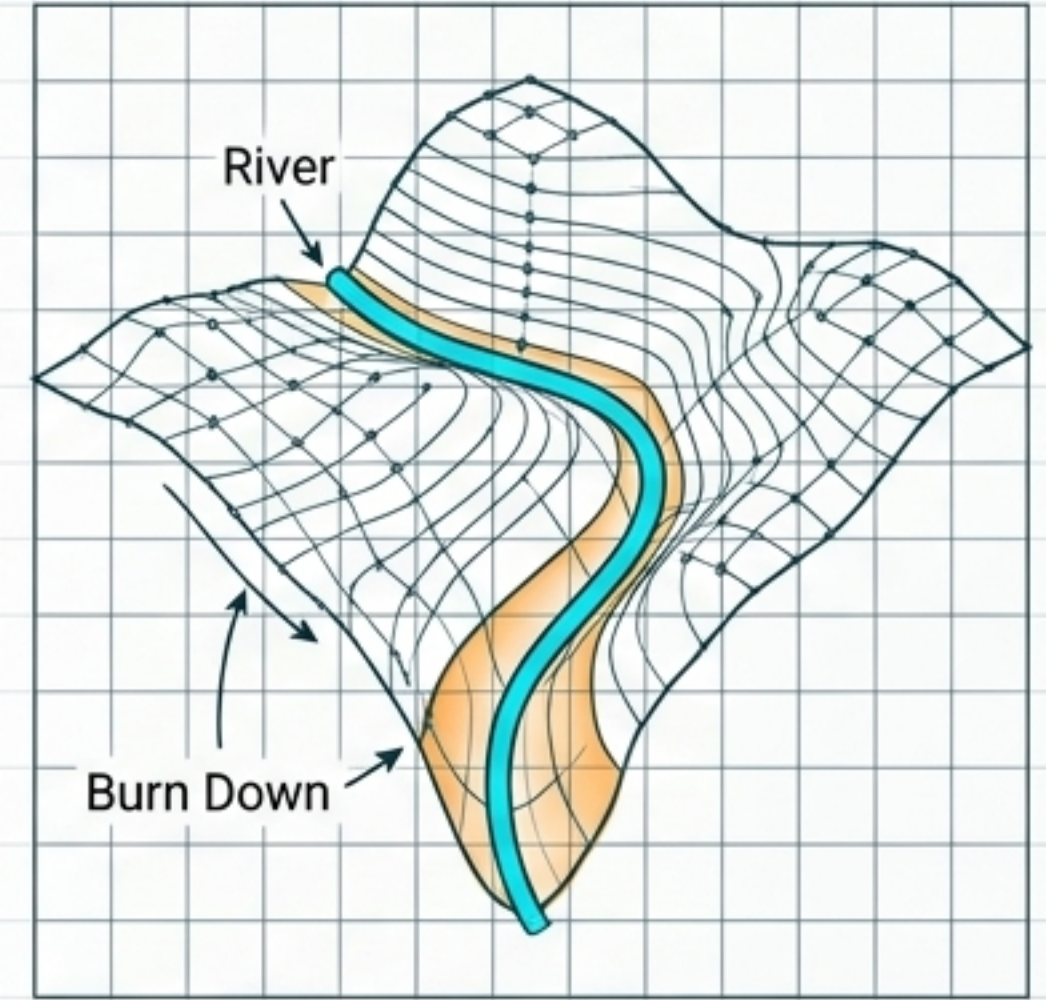
Administrative Boundaries

Essential for calculating regional statistics. Topology rules must enforce strict adjacency to prevent overlapping jurisdictions.



Drainage Networks

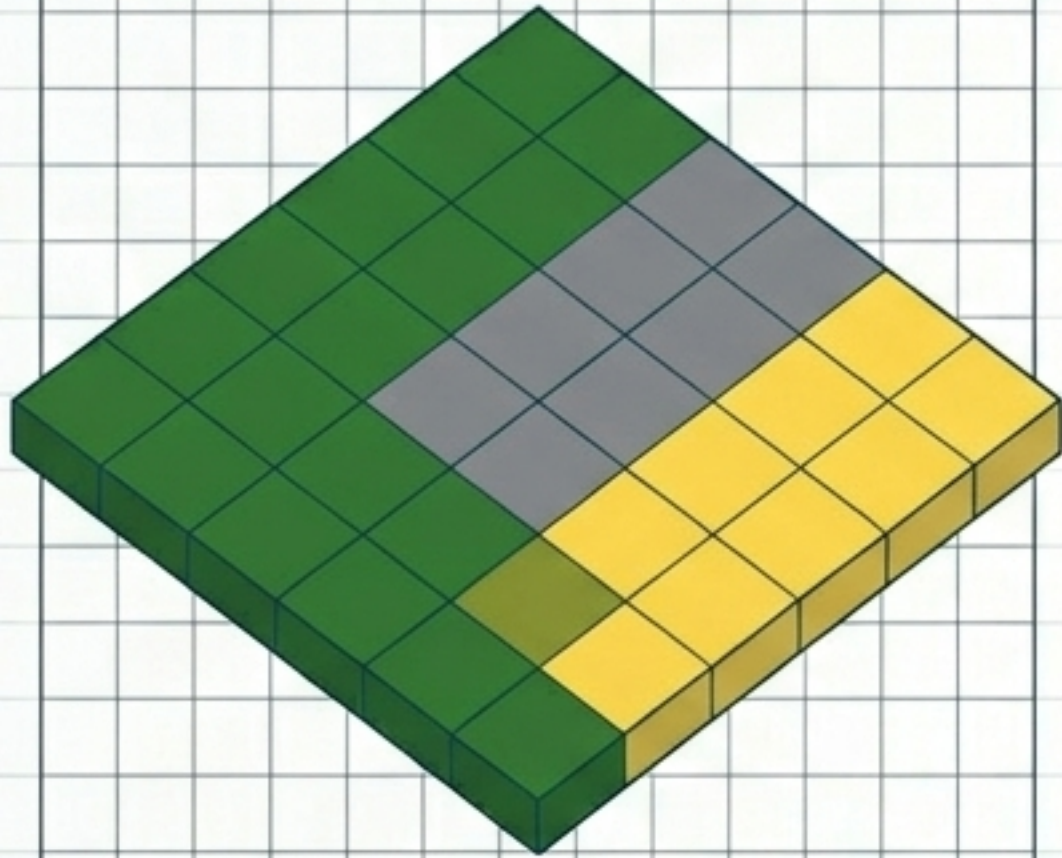
1D polylines are critical for routing flow, calculating stream channel travel times, and modeling hydraulic networks.



Stream Burning

Hydrologists use accurate vector lines to mathematically "burn" (lower) the elevation of raster DEMs, forcing calculated flow paths to match real-world rivers.

Applied Raster Models: Continuous Datasets



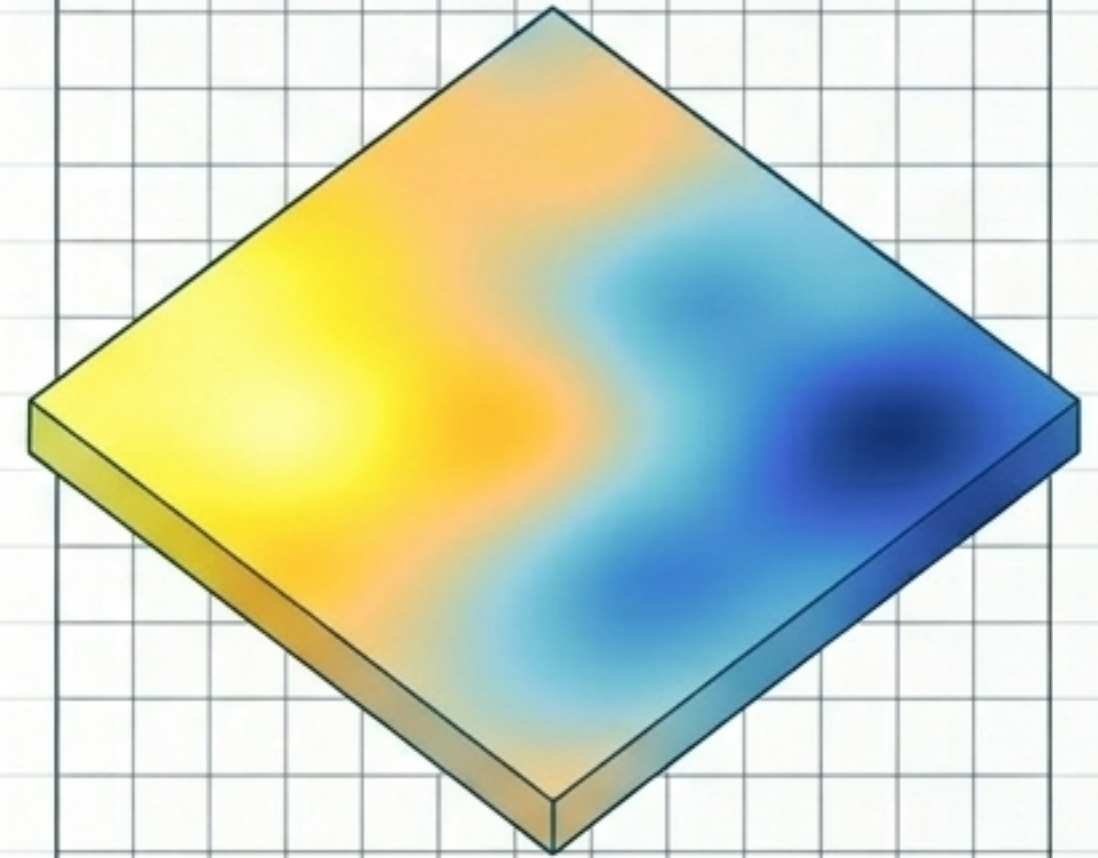
Land Use / Land Cover

Integer grids mapping categories. Used to determine runoff potential (e.g., Forest = Permeable vs. Urban = Impermeable).



Satellite Imagery

Multi-band grids. Optical measures solar reflection; SAR measures radar backscatter for mapping floods through cloud cover.

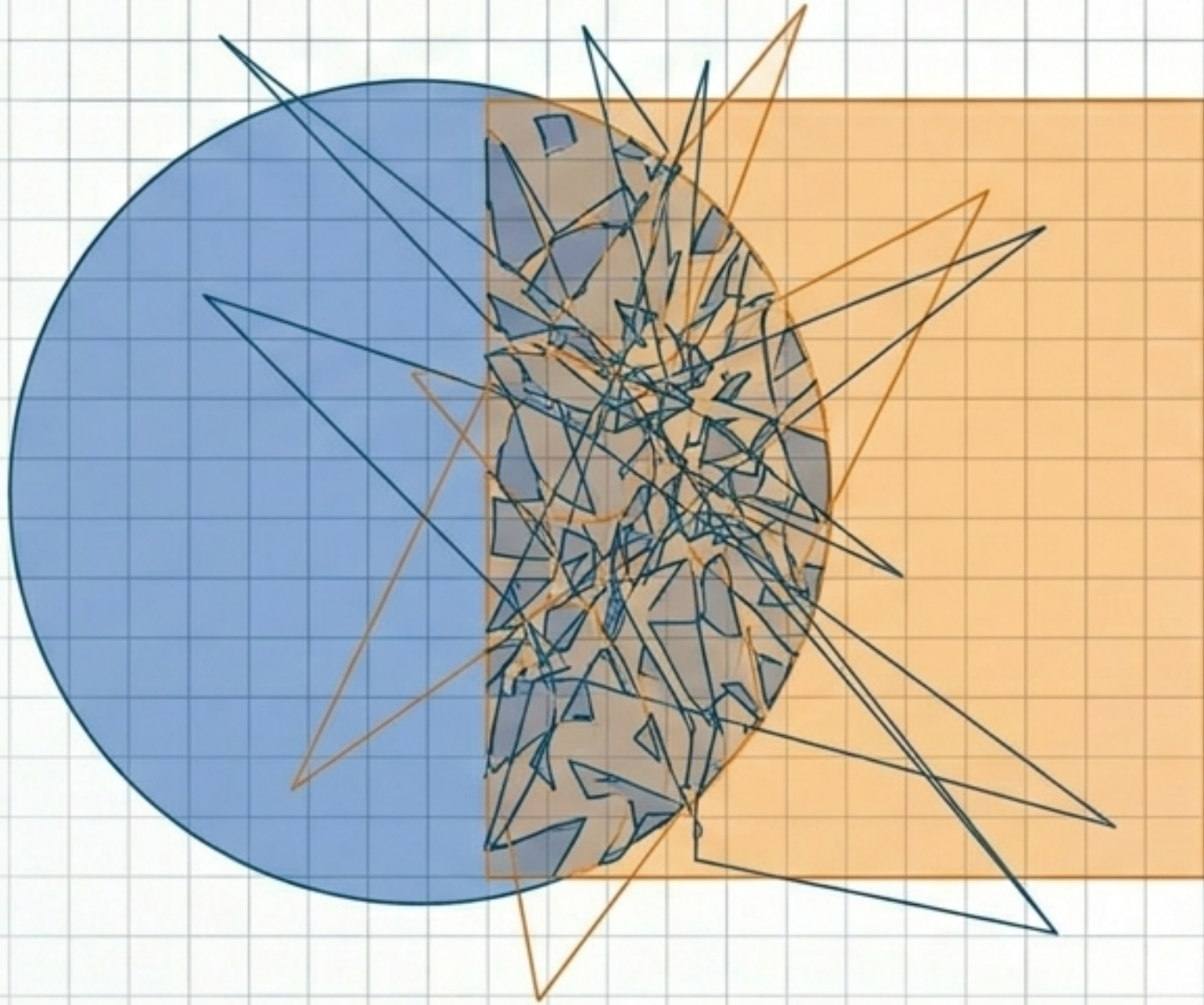


Precipitation Datasets

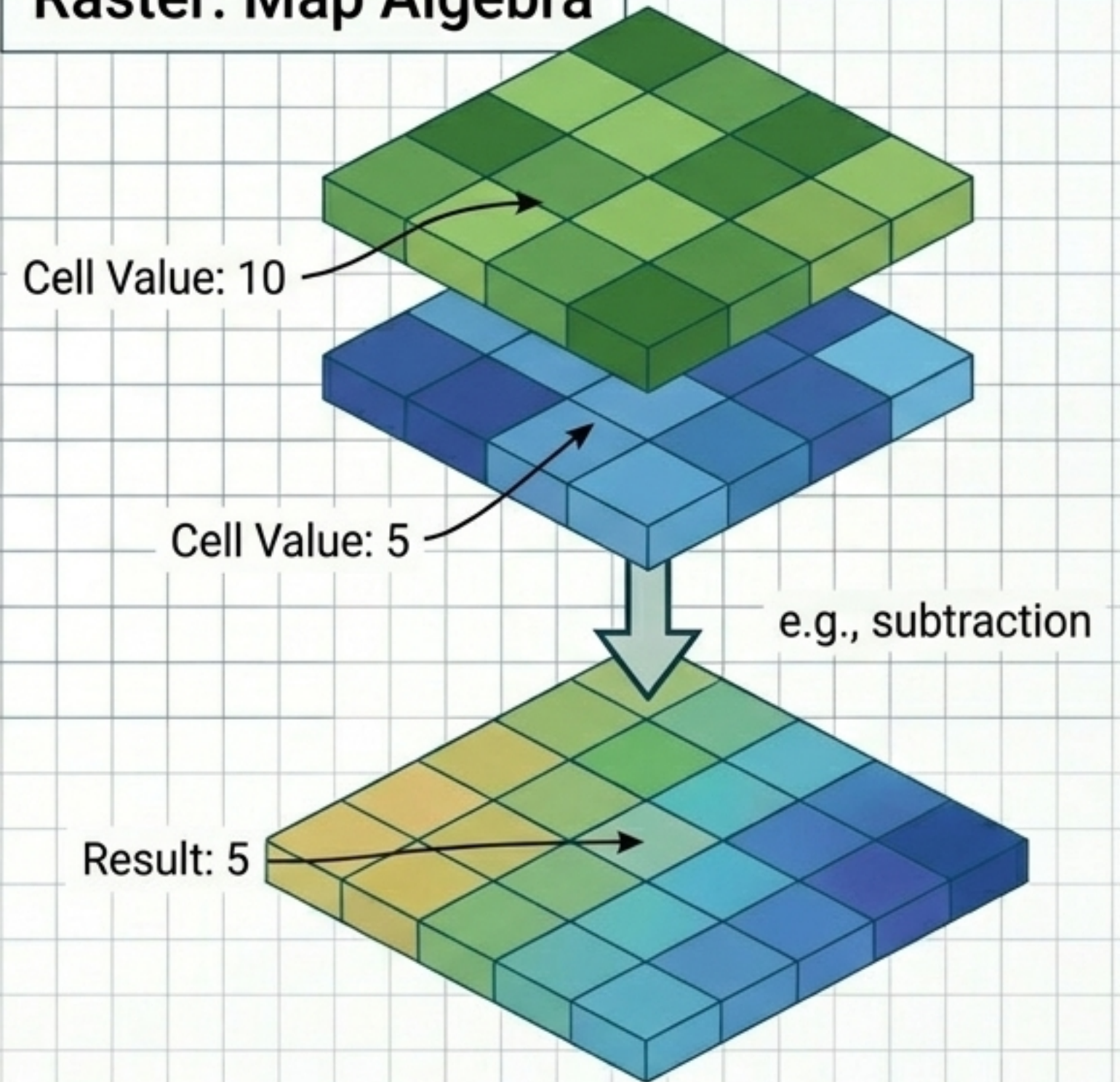
Floating-point grids. Point rain gauge data is interpolated into continuous surfaces (e.g., CHIRPS 5km) so every cell receives a rainfall value.

Analytical Overlay Behaviors

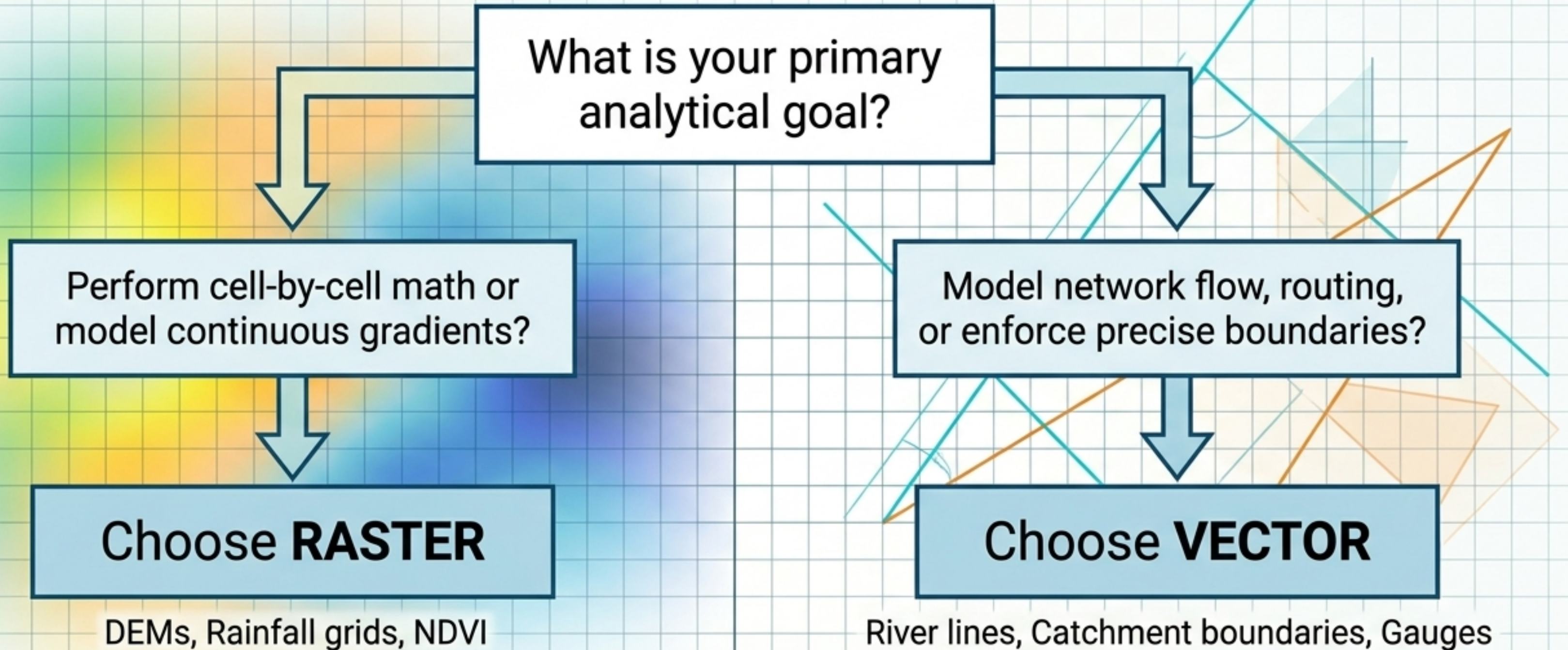
Vector: Complex Intersection Math



Raster: Map Algebra



The Hydrological Decision Framework



Understanding the fundamental architecture of spatial data prevents systemic errors and ensures the correct mathematical model is applied to geographic reality.