

Where the Water Begins: A Field Guide to Six Streams Rising in the Knuckles Mountain Range, Sri Lanka

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This manuscript is a non-peer reviewed preprint submitted to EarthArXiv.

It has not been submitted to a journal.

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Field Guide

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Abstract

The Knuckles mountain range in central Sri Lanka is one of the wettest parts of the Mahaweli basin, and the streams that rise on its slopes feed the Victoria, Randenigala, Moragahakanda and Kalu Ganga reservoirs on which irrigation, hydropower and drinking water for a large part of the country depend. Walkers in the range meet these streams every day, yet there is no single account of where each one starts, what it passes and where its water goes. This field guide maps six streams that rise in the Knuckles: the Heen Ganga, Hulu Ganga, Hasalaka Oya, Kalu Ganga, Thelgamu Oya and Dankanda Oya, the upper course of the Amban Ganga. Each catchment was delineated on the 30 m Copernicus digital elevation model, after priority-flood conditioning and D8 flow routing, down to the point where the stream reaches the Mahaweli Ganga, the Amban Ganga or a reservoir. Together they drain 761.9 km² and 87% of the mapped Knuckles Conservation Forest. Main stems, traced as the longest flow paths, run 8.6 to 32.0 km and fall 1187 to 1706 m. For each stream the guide gives the source with coordinates, the villages, waterfalls, viewpoints and road crossings along the way, land cover and biomass, and the onward journey of 162 to 229 km to the sea at Koddiiyar Bay. Thematic maps show that 62% of the channel length is expected to flow all year and that most waterfalls lie on the steepest reaches. Each catchment has a large map with its summits, villages, waterfalls and viewpoints numbered, a map of its waterways by Strahler order, and three-dimensional views from four sides. The discussion links the streams to flood safety for walkers and to the canals built and being built to carry Knuckles water to the northern dry zone.

Keywords: Knuckles Range; Mahaweli Ganga; Amban Ganga; headwater streams; catchment delineation; Strahler order; longest flow path; perennial streams; time of concentration; water transfer; field guide; Sri Lanka

1. Introduction

Three raindrops fall a few metres apart on the summit ridge of Gombaniya, the highest ground in the Knuckles, during a north-east monsoon storm. Here the divides of three streams meet, and the slope under each drop decides its road. The first runs south-west down the Hulu Ganga, past more villages than any other stream in this guide, into Victoria Reservoir. It will pass the Victoria, Randenigala and Rantambe dams before it reaches the plains, and the sea at Koddiiyar Bay about 230 km later. The second runs north into the Kalu Ganga, whose whole catchment lies inside the protected forest, and gathers in the Kalu Ganga Reservoir. The third runs down the longest and narrowest valley in the range, the Thelgamu Oya, into Moragahakanda. The second and third drops may never see the sea. A tunnel between these two reservoirs is nearly complete, and an 82 km canal, a third of it in tunnel, is being built to carry their water north to the old tanks of the dry zone [1,2]. This guide follows such drops, and the six streams that carry them, from the first thread of water to the point where each stream arrives at a larger river or reservoir, and on towards the people who use the water.

Stand on any ridge of the Knuckles and the sound of water comes up from every valley. The range, a compact block of mountains north-east of Kandy, rises from about 60 m on the Mahaweli floodplain

to over 1900 m at Gombaniya, and it catches rain from both monsoons [3]. A forest-department account of the region puts the mean annual rainfall at about 5000 mm on the high ground and below 2500 mm on the drier eastern slopes, and estimates that the Knuckles supplies about 30% of the water in the Victoria, Randenigala and Rantambe reservoirs on the Mahaweli [4]. Further north, its streams fill the Kalu Ganga and Moragahakanda reservoirs, which store water for irrigation and drinking supply in the dry zone [5]. The International Water Management Institute estimates that about 1.3 million people depend on water from the range [6].

The Knuckles Conservation Forest is one of the three components of the Central Highlands of Sri Lanka, inscribed on the World Heritage List in 2010 for its montane forests and exceptional biodiversity [7]. Its valleys hold floristically unique forest [8] and a rich amphibian fauna [9]. They also hold villages, cardamom gardens under the forest canopy [10] and communities that rely on the forest in daily life [11]. As early as 1990, Bandaratilake [3] called the Knuckles one of the most critical watersheds in Sri Lanka and recommended hydrological study to understand how water is distributed across it.

Hikers know these streams by their pools, their waterfalls and the valleys that the trails follow. What is harder to find is the whole stream: where it begins, what it passes, where it meets a larger river and how far its water travels before it reaches the sea. This guide answers those questions for six streams that rise in the range. It is written for walkers, naturalists and students, but every number in it comes from a reproducible hydrological analysis, which is described in full so that the maps can be checked, reused and improved.

The guide has three aims:

1. to delineate the catchment of each stream from its source to the point where its water arrives at the Mahaweli Ganga, the Amban Ganga or a reservoir;
2. to describe, for each stream, the places that a walker meets along the main stem, from the source to the arrival point; and
3. to show how the water of each stream connects to the rivers, reservoirs and people downstream.

2. The Knuckles and Its Waters

The Knuckles range lies north-east of Kandy, separated from the main Central Highlands by the Dumbara valley (Figures 1 and 2). Its main ridge runs from Laggala in the north-west to Medamahawara in the south-east [3]. Bandaratilake lists its highest summits, from an earlier survey [3], as Gombaniya (6248 ft, about 1904 m), Knuckles (6112 ft, 1863 m), Kehelpothdoruwegala (6016 ft, 1834 m), Kirigalpotta (5403 ft, 1647 m), Dumbanagala (5385 ft, 1641 m) and Kalupahana (5341 ft, 1628 m).

The western slopes take heavy rain from the south-west monsoon between May and August, and the whole range is drenched by the north-east monsoon from October to January [3]. Mean annual rainfall in the three gauged catchments ranges from 2725 mm (Kalu Ganga) to 4282 mm (Heen Ganga), with rain on about 184 days a year, and the St. Martins station records 4470 mm [3]. Streams that rise above about 3500 ft (1067 m), within the wet montane forest, flow all year; those that rise lower are seasonal [3]. Applied to the mapped channels (Section 3.4), this rule makes 62% of the 990 km of channel in the six catchments perennial (Figure 5). The share is highest in the small, high Dankanda Oya (93%) and in the Hulu Ganga (77%), and lowest in the Heen Ganga (50%) and the Hasalaka Oya (53%), where many tributaries rise on the low ground near the Mahaweli. The difference between seasons is large. At Wellewala on the Kalu Ganga, 93.5% of the flow passed between October and April, and the mean monthly runoff fell from 92.4 million m³ in January to 1.93 million m³ in August [3].

The water leaves the range in two directions (Figures 2 and 4). South and east, the Hulu Ganga, Heen Ganga and Hasalaka Oya join the Mahaweli Ganga, the longest river in the country. North and west, the Kalu Ganga and the Thelgamu Oya (the Teligam Oya of older accounts) feed the Amban Ganga [3,4], which joins the Mahaweli near Manampitiya (Figure 10). Four large reservoirs now sit on these routes. Victoria, on the Mahaweli below the Hulu Ganga, has a gross storage of 728 million m³

and a 210 MW power station [12]. Moragahakanda, on the Amban Ganga, has an active storage of 521 million m³ and supplies irrigation and drinking water to the dry zone [5]. The Kalu Ganga reservoir, on the stream of the same name, was still a proposal in 1990, an irrigation and hydropower project with the Knuckles as its main catchment [3].

The Knuckles Conservation Forest is protected land. Entry to the reserve needs permission from the forest authorities, and the Department of Forest Conservation announced stricter action against unauthorised entry in 2024 [13]. Cyclone Ditwah, in late 2025, damaged villages such as Meemure and displaced thousands of people in the region [6]. Streams in steep valleys can rise quickly in heavy rain, especially during the north-east monsoon. Figure 3 shows the relief and the named summits of the range, Figure 4 its streams coloured by the catchment they feed, and Figure 7 the roads, trails and villages that give access to it.

The streams are steepest where they leave the main ridges (Figure 6). Measured link by link on the DEM (Section 3.4), 27% of the channel length around the range falls at 10% or more. Yet 7 of the 12 mapped waterfalls lie on such reaches, and the median gradient at a waterfall is 16.8%. A walker looking for falls will find most of them on the scarps below the high ridges, in the red and orange reaches of Figure 6.

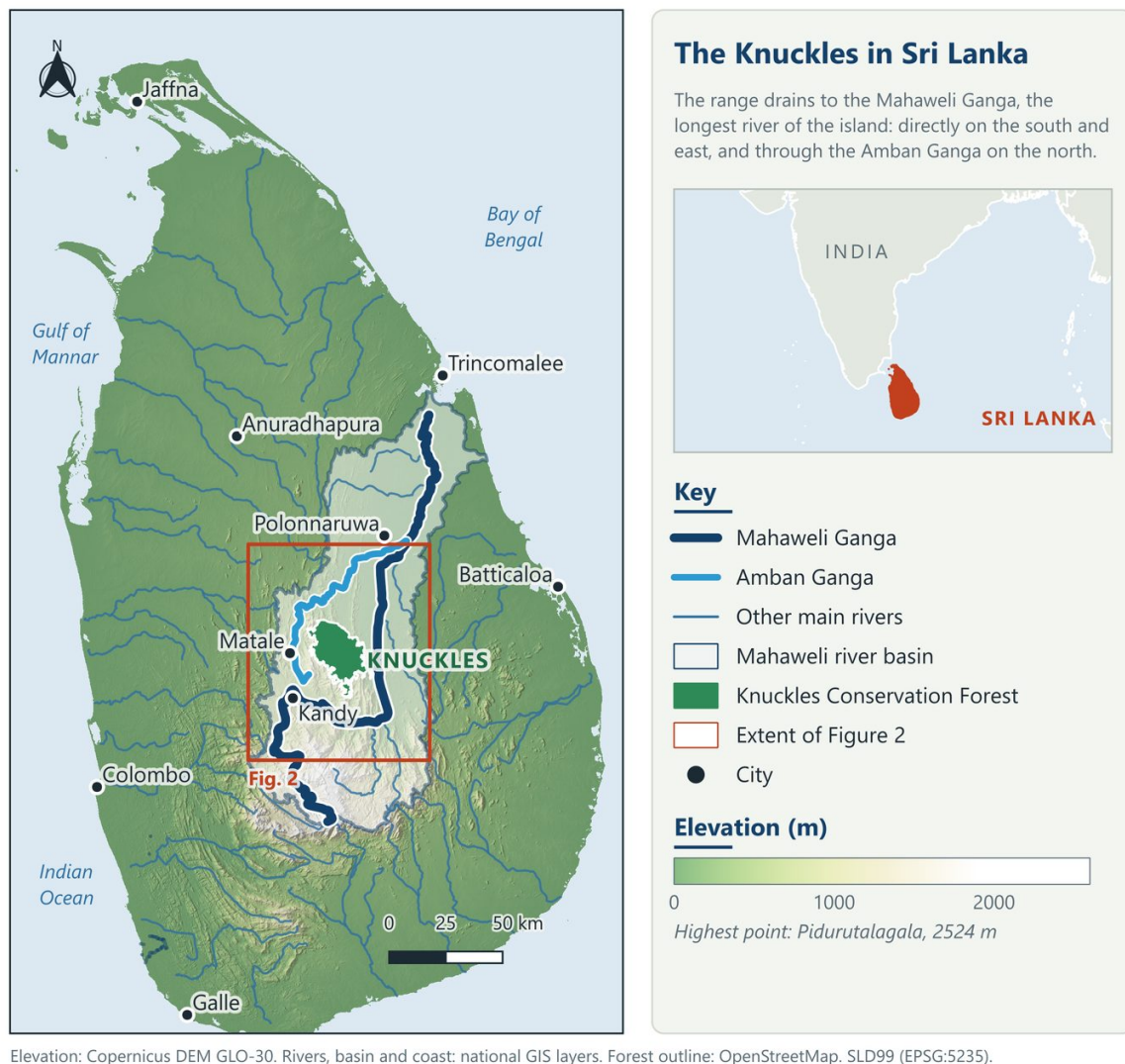


Figure 1. The Knuckles in Sri Lanka. The range drains to the Mahaweli Ganga directly on the south and east, and through the Amban Ganga on the north. The red box marks the extent of Figure 2.

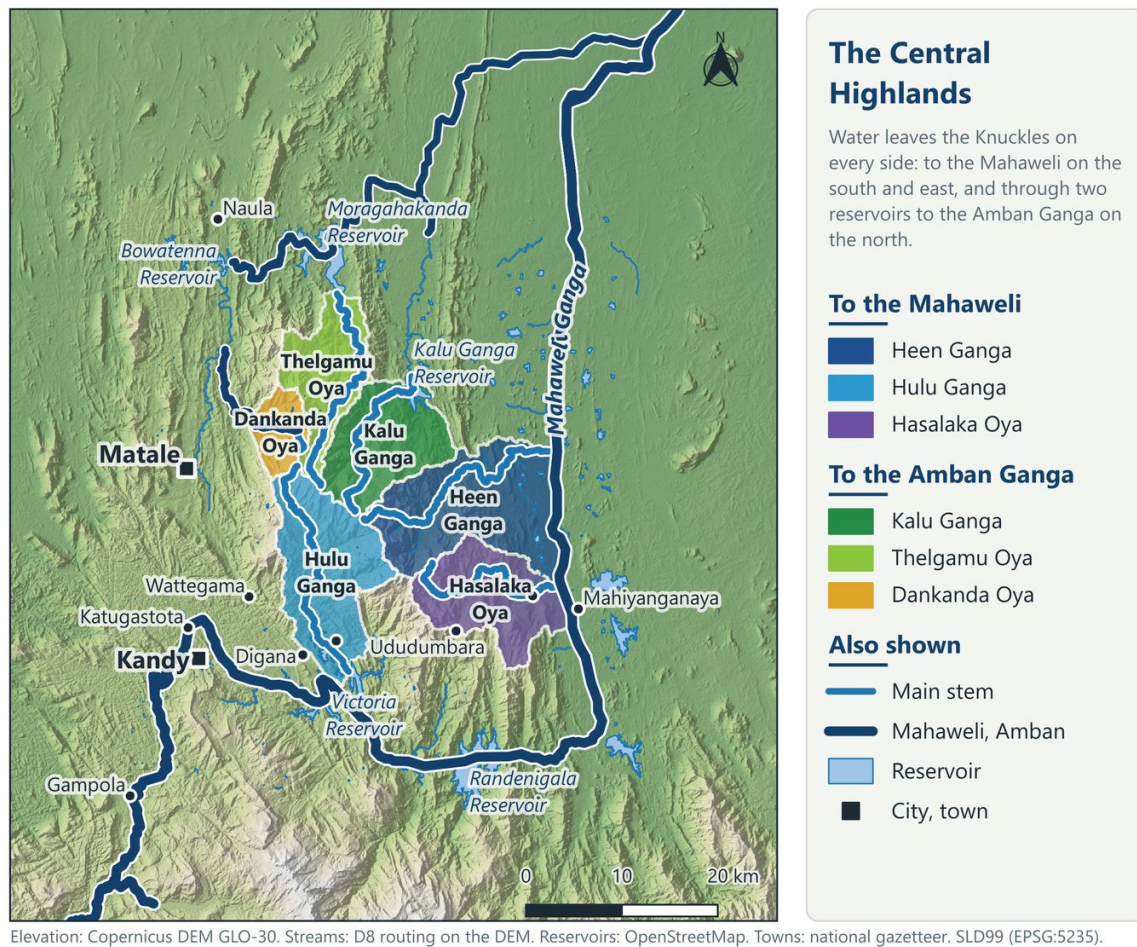


Figure 2. The Central Highlands around the Knuckles: the six study catchments in the colours used throughout this guide, their main stems, the reservoirs and the main towns.

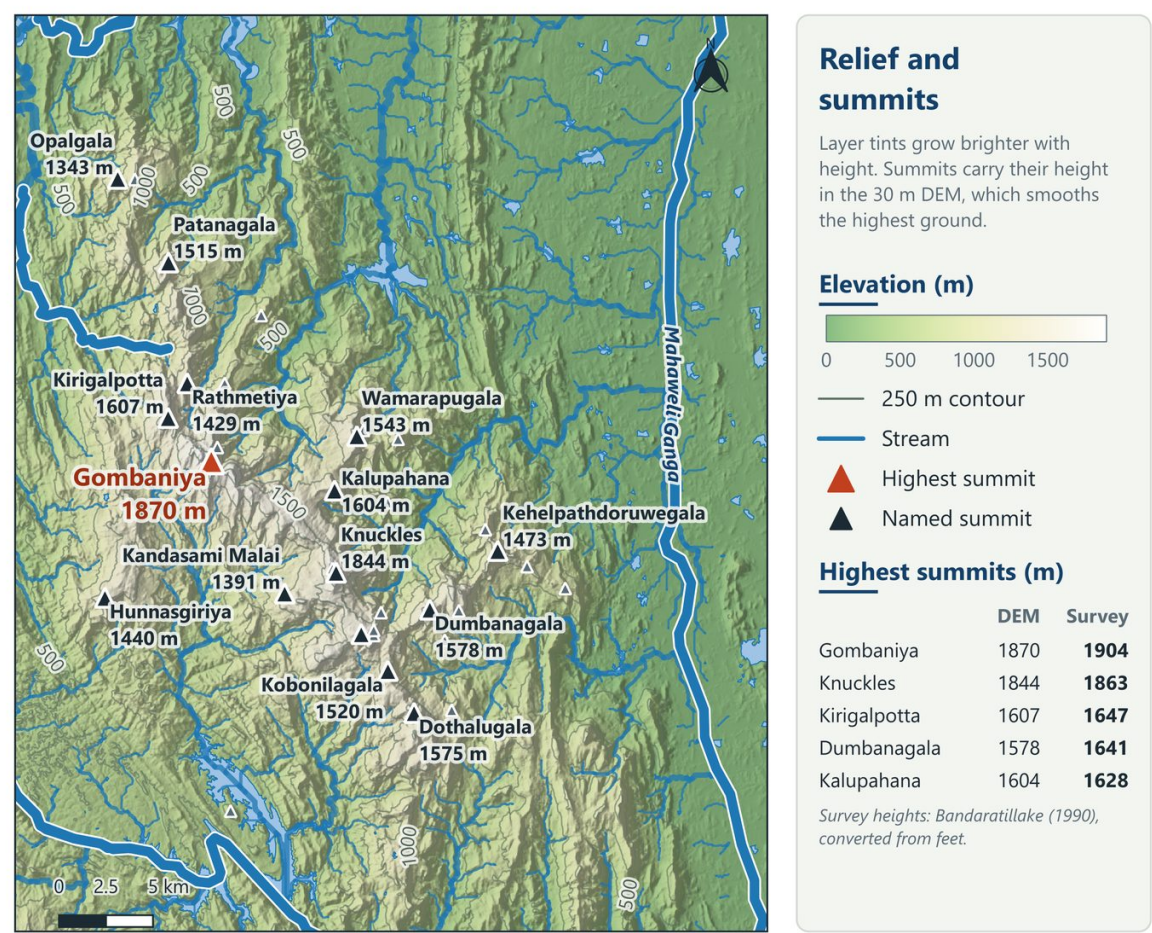


Figure 3. Relief and summits of the Knuckles: layer tints, 250 m contours and the fifteen highest named summits with their DEM heights. The key compares the DEM and surveyed heights of five summits.

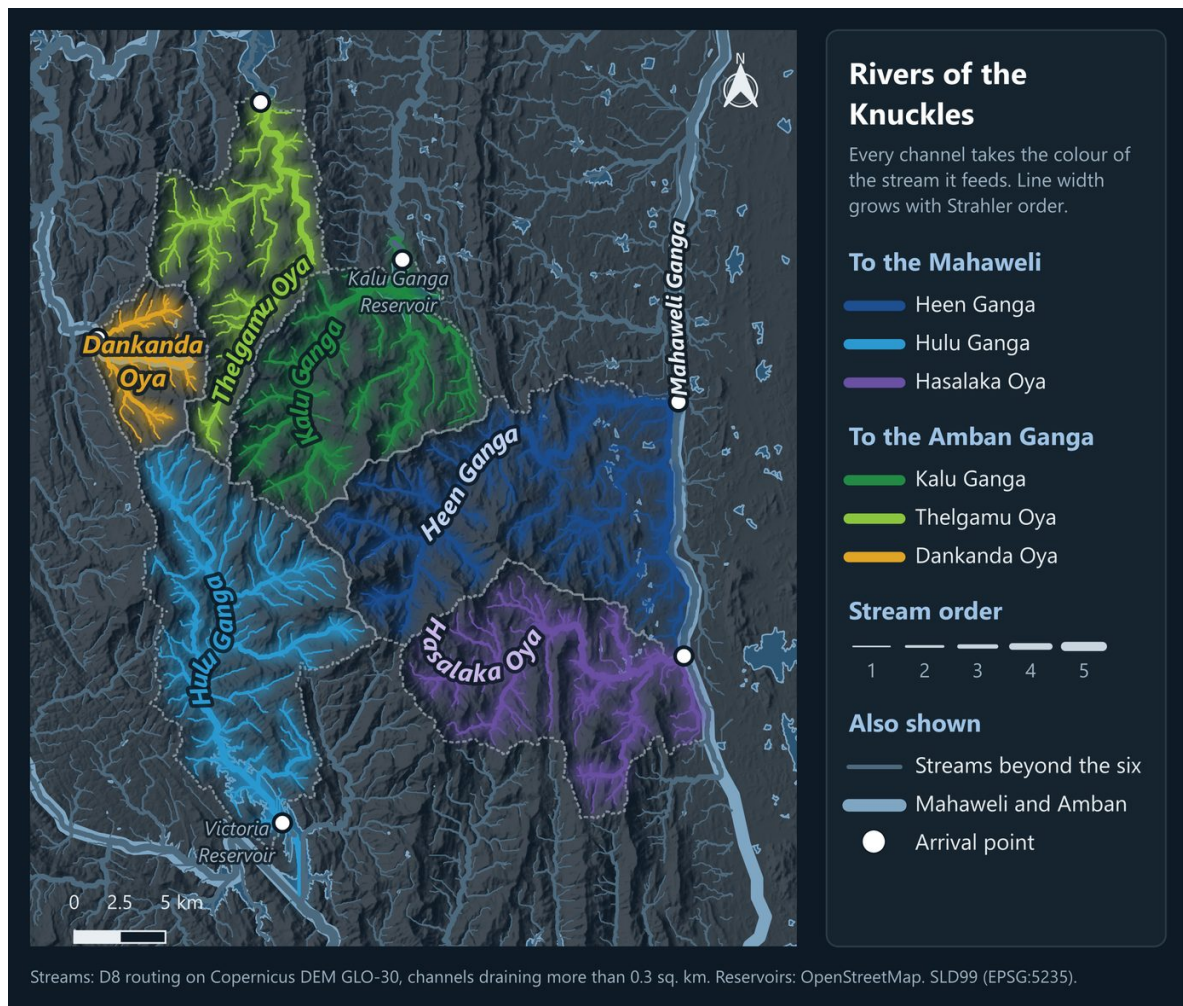
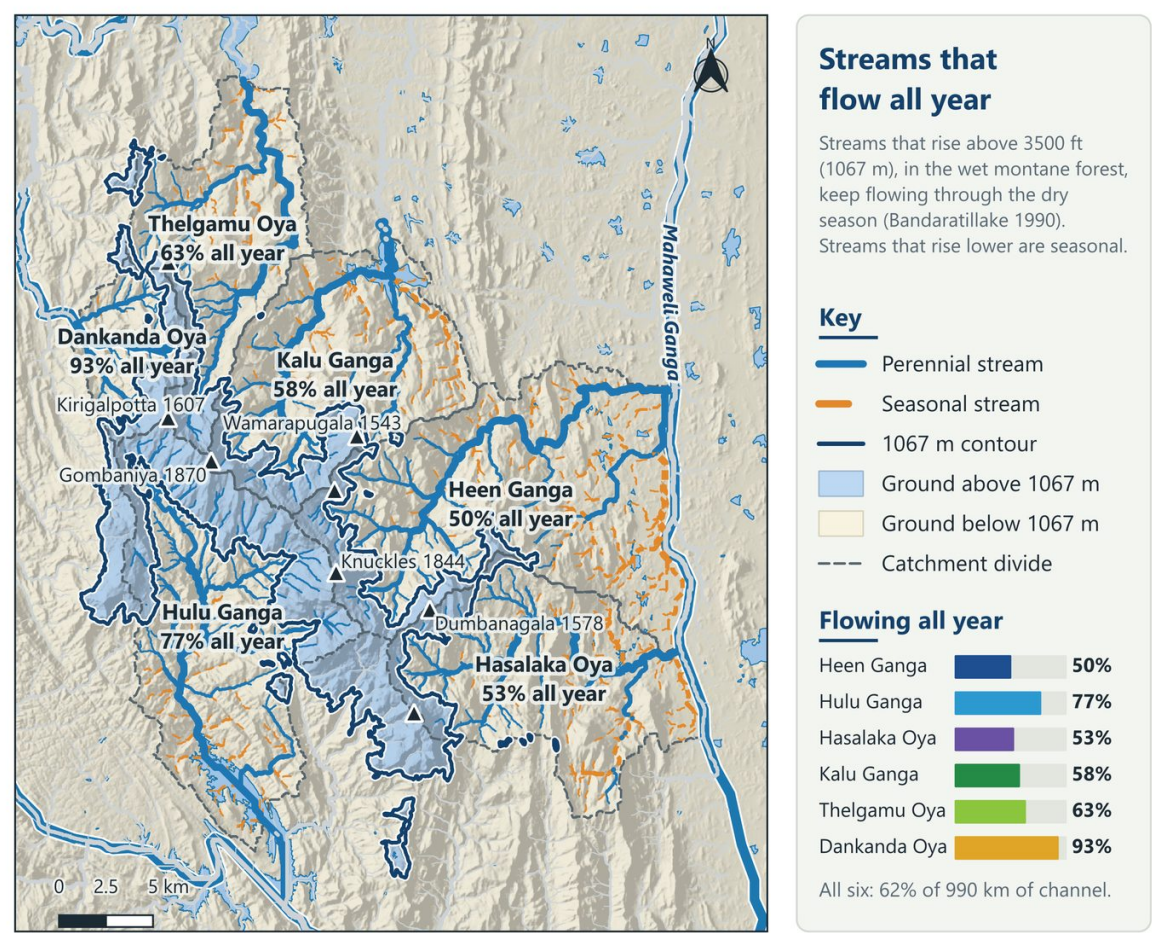
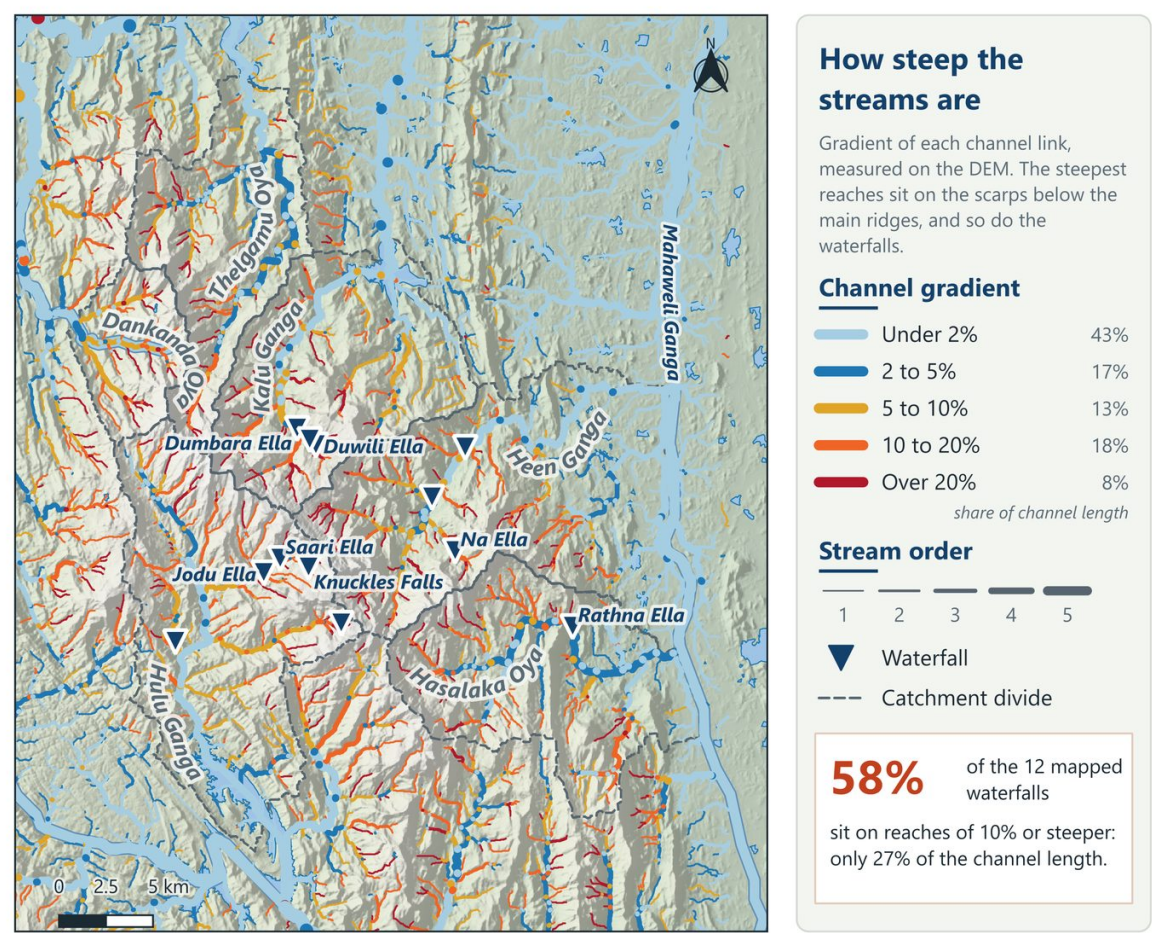


Figure 4. Rivers of the Knuckles: every channel draining more than 0.3 km², coloured by the catchment it feeds, with a line width that grows with Strahler order. Cool colours reach the Mahaweli directly; green and gold reach it through the Amban Ganga.



Streams: D8 on Copernicus DEM GLO-30 (over 0.3 sq. km). A link is perennial when ground upstream of it reaches 1067 m. SLD99 (EPSG:5235).

Figure 5. Streams that flow all year. A channel is drawn as perennial when the ground upstream of it reaches 1067 m (3500 ft), after Bandaratillake [3]. The bars give the perennial share of channel length in each catchment.



Streams: D8 on Copernicus DEM GLO-30 (over 0.3 sq. km); gradient = drop over link length. Waterfalls: OpenStreetMap. SLD99 (EPSG:5235).

Figure 6. How steep the streams are: the gradient of each channel link, with the mapped waterfalls. Seven of the twelve falls lie on reaches of 10% or steeper.



Figure 7. Getting there: A and B roads with their route numbers, footpaths and trails, the towns and villages (hamlets unlabelled) and the conservation forest.

3. Materials and Methods

3.1. Data

All analysis was carried out in the Sri Lanka Datum 1999 Transverse Mercator projection (SLD99, EPSG:5235). Table 1 lists the inputs. Terrain comes from the 30 m Copernicus digital elevation model (DEM) [14]. Twelve tiles were mosaicked, then resampled by averaging to 120 m for the national map, to 40 m for the Central Highlands and for downstream routing, and kept at 30 m for the study area itself. Roads, trails, villages, waterfalls, viewpoints, peaks and reservoir outlines were taken from OpenStreetMap [15]. Land cover is ESA WorldCover 2021 [17] and above-ground biomass is the ESA Climate Change Initiative biomass map for 2021 [18]. National river and basin boundaries were used for the location maps and for the Mahaweli below the edge of the routing DEM. The outline of the Knuckles Conservation Forest is an approximate OpenStreetMap outline of 470.5 km²; it is used for reference only and never as a hydrological boundary.

Table 1. Data used in this guide.

Dataset	Resolution or scale	Used for	Source
Copernicus DEM GLO-30	30 m	flow routing, catchments, slope, terrain shading, 3D views	ESA [14]
OpenStreetMap	vector	roads, trails, villages, peaks, waterfalls, viewpoints, reservoirs, named waterways, forest outline	OpenStreetMap contributors [15]
GeoNames	points	summit and stream names	GeoNames [16]
ESA WorldCover 2021 v200	10 m	land cover (majority to 30 m), ground colour of the 3D views	Zanaga et al. [17]
ESA CCI Biomass v7.0, 2021	100 m	above-ground biomass	Santoro and Cartus [18]
National rivers and river basins	1:50,000 class	location maps, Mahaweli to the sea	author's national GIS layers
Stream gauge summaries	three stations	runoff and rainfall, as published	Bandaratillake [3]

3.2. Terrain Conditioning and Flow Routing

A DEM contains pits, some real and many artefacts, that would trap simulated flow. The study tile (1472 by 1806 cells at 30 m) was conditioned with the priority-flood algorithm [19]. Cells on the tile edge are placed in a priority queue keyed on elevation; the lowest cell is removed, and each unvisited neighbour is raised, if necessary, to the elevation of the cell it was reached from plus a small increment (10^{-3} m), so that every cell keeps a strictly descending path to the edge. Lakes and reservoirs, which the DEM records as flat water surfaces, are drained across in the same way.

Flow directions were assigned with the D8 method [20]: each cell drains to the one of its eight neighbours with the steepest descent,

$$d(i) = \arg \max_{k \in N_8(i)} \frac{z_i - z_k}{\ell_{ik}}, \quad \ell_{ik} \in \{c, \sqrt{2}c\}, \quad (1)$$

where z is the conditioned elevation and c the cell size. The contributing area of a cell is the number of cells that drain through it, including itself, multiplied by the cell area:

$$A(i) = c^2 \left(1 + \sum_{j: d(j)=i} \frac{A(j)}{c^2} \right). \quad (2)$$

It was accumulated by visiting cells from the highest conditioned elevation downwards.

3.3. Channel Network and Stream Order

A cell was treated as part of a channel when its contributing area exceeded 0.30 km^2 . The threshold was chosen to show the headwater streams at the scale of the figures. Channels were ordered after Strahler [21]: a channel with no tributaries is of order 1; where two channels of the same order u meet, the stream below is of order $u + 1$; where channels of different orders meet, the larger order continues. Cells were processed from small to large contributing area so that every tributary is ordered before the channel it joins, and the network was written as links that break wherever the order changes.

A stream of order u was counted where it begins, either at a channel head ($u = 1$) or where two streams of order $u - 1$ meet. The bifurcation ratio R_b was taken from Horton's law of stream numbers [22], $\log_{10} N_u = a - u \log_{10} R_b$, fitted by least squares across all orders. Each basin has exactly one stream of its highest order. Drainage density is the total channel length divided by the catchment area.

3.4. Perennial Reaches and Channel Gradient

Two attributes were added to every channel link for the thematic maps. The first applies Bandarattillake's observation that streams rising above 3500 ft (1067 m) flow all year [3]. The highest elevation draining to each cell was carried down the D8 network, from cells of small to large contributing area, and a link was marked perennial when the highest ground upstream of its upper end reaches 1067 m. The 1067 m contour itself was traced on the 40 m DEM. The rule is a field observation, not a flow record, so the map shows where flow is expected all year, not where it was measured. The second attribute is the channel gradient, the fall in DEM elevation between the two ends of a link divided by its length, in percent. Gradients were grouped into five classes: below 2, 2 to 5, 5 to 10, 10 to 20 and above 20%. Each mapped waterfall was given the gradient of the nearest link within 150 m. The source areas of the perennial streams were measured as the ground above 1067 m in each catchment on the 30 m DEM, together with the share of that ground inside the mapped conservation forest.

3.5. Delineating Each Catchment to Its Arrival Point

A catchment is defined by its pour point, and the choice of pour point decides what the catchment means. Here each catchment ends where its stream's water arrives at something larger: the Mahaweli Ganga, the Amban Ganga or a reservoir. Three rules were used.

1. For a stream that joins a river (Heen Ganga, Hasalaka Oya and Dankanda Oya), the pour point is the downstream end of the stream's own mapped centreline, snapped to the highest-accumulation cell within two cells of each vertex. Taking the cell of greatest accumulation near the confluence fails, because that cell lies on the larger river, and the whole river above the confluence would be delineated instead.
2. For a stream that ends in a reservoir (Thelgamu Oya), the pour point is the highest-accumulation cell whose D8 step enters the reservoir polygon.
3. The Kalu Ganga was delineated to the outflow cell of its reservoir, the highest-accumulation reservoir cell whose D8 step leaves the water (7.5593° N , 80.8359° E , 160 m). This gathers every stream that enters the reservoir. The Hulu Ganga was anchored to the outlet of an earlier, independent delineation of the river by the author, and followed downstream until it entered the Victoria reservoir.

Each catchment is then the set of cells whose D8 path passes through its pour point. A catchment nested inside another was removed from its parent.

Two independent checks support the result. The Thelgamu Oya catchment (101.8 km²) and the Hulu Ganga catchment (166.9 km²) agree within 1% with the author's earlier delineations of the same rivers (102.5 and 166.0 km²). The 1960s gauge on the Hulu Ganga at Teldeniya drained 160.6 km² [3], close to the 166.9 km² found here at the reservoir edge. The Hulu Ganga catchment is 8.8% of the 1891 km² that drain to Victoria, which matches the figure of about 9% given by Bandaratilake [3].

3.6. Main Stem and Source

The main stem of each stream was taken as its longest flow path: the D8 path from the catchment cell farthest upstream, measured along the flow, to the pour point. The head of that path is the source given in this guide, with its coordinates and DEM elevation. Some sources sit on a summit, because the longest path begins at the divide.

3.7. Places Along the Way

To list what a walker meets, every village, waterfall and visitor site in OpenStreetMap was projected onto the nearest point of the main stem, and was kept if it lies within 1500 m of the stream (1000 m for waterfalls). The distance from the source and the offset from the stream were recorded for each. Road and trail crossings are the intersections of the main stem with the A roads, B roads and footpaths, with repeated crossings of the same kind within 200 m merged. The forest edge was recorded wherever the main stem leaves the conservation forest outline. A peak was assigned to a catchment's divide if it lies within 500 m of the catchment boundary. For the maps, every summit on or inside the divide, every town, village and hamlet inside the catchment, and every waterfall, viewpoint and visitor site within 300 m of it was given a number. Numbers run through summits (highest first), then towns, villages, waterfalls, viewpoints and other sites, each group in order down the main stem, and a place keeps its number in all the figures of its stream. Duplicate entries were merged where two points lie within 400 m and share the distinctive part of their name, and two names in Sinhala script were romanised.

3.8. Downstream Journeys

The onward course of each stream was traced by D8 on a 40 m DEM covering the Central Highlands and the northern plains to 612 km north in SLD99 grid coordinates, conditioned in the same way. On the flat Mahaweli floodplain, D8 runs the Amban Ganga and the Mahaweli side by side for several kilometres past their real junction, a known weakness of single-direction routing on flats. The junction was therefore placed where the national Amban Ganga line meets the Mahaweli, and each trace was cut at its cell nearest to that point. Beyond the edge of the DEM, the Mahaweli was followed along the national river line to Koddigar Bay at Trincomalee. D8 paths on a grid run slightly longer than the real channel, and the national line is generalised, so the journey lengths are given to the nearest kilometre and should be read as approximate.

3.9. Basin Shape, Land Cover and Biomass

Mean slope was computed from the 30 m DEM with Horn's method [25]. The hypsometric integral [24] is $HI = (\bar{z} - z_{\min}) / (z_{\max} - z_{\min})$ over the cells of each catchment. The elongation ratio and relief ratio follow Schumm [23],

$$R_e = \frac{2\sqrt{A/\pi}}{L}, \quad R_h = \frac{H}{L}, \quad (3)$$

with the main stem length as the basin length L , the catchment area A , and the fall H from source to arrival point.

WorldCover classes were aggregated from 10 m to 30 m by majority. Biomass was resampled to 30 m by nearest neighbour for combination with land cover, and split into three classes at the terciles of its distribution within the six catchments (70 and 120 Mg ha⁻¹). Total biomass in each catchment is the sum of cell values times the cell area.

3.10. Flood Response

How quickly a stream rises after heavy rain on its upper slopes was judged from its time of concentration, the time that water takes to travel from the farthest point of the catchment to the arrival point. Two classical formulas were applied to each main stem [26,27]:

$$t_K = 0.0195 L^{0.77} S^{-0.385}, \quad t_G = \frac{4\sqrt{A} + 1.5 L_{\text{km}}}{0.8\sqrt{H_m}}, \quad (4)$$

where t_K (Kirpich) is in minutes, with the main stem length L in m and its mean gradient S (fall over length); and t_G (Giandotti, in the form given by Ravazzani et al. [27]) is in hours, with the catchment area A in km^2 , the main stem length L_{km} in km and H_m the mean elevation of the catchment above the arrival point, in m. Kirpich's formula was fitted on small agricultural catchments and Giandotti's on larger mountain basins, and the two can differ by a factor of two, so they are reported together as a range of indicative values, not as forecasts.

3.11. Cartography

All maps were composed with PyQGIS print layouts in QGIS 3.40 [28] and GDAL [29]. Relief is shown by layer tints in which higher ground is brighter, over a hillshade. Each map is laid out at the printed width of the page, with its key beside or under it, and no lettering on a map is smaller than 7.4 pt. On the catchment maps, places are shown by numbered badges in a colour for each kind of place and named in a list, which keeps the map clear where villages crowd together. Where two badges would overlap, one is moved aside and joined to its place by a thin line. Each catchment map is drawn at the largest scale that fits the page with its list, from about 1:58,000 to 1:148,000. Streams, the subject of the guide, are drawn in strong blues with a width that grows with Strahler order and a thin white glow that lifts them off the relief; the main stem of each stream is the darkest blue. Each of the six catchments keeps one colour in every figure. On the waterway maps, a tributary is named where OpenStreetMap has a named waterway along it, or where a GeoNames stream point lies within 400 m of a channel of order two or more; such a name is carried up the larger branch to the source and down to the next larger stream, and points that carry two different names were left out. One QGIS project per figure is kept with the data so that every map can be opened and edited.

The three-dimensional views (Figures 13 to 35) were drawn from open data only. The Copernicus DEM was resampled by cubic convolution to about 2200 cells across each block, and all heights were multiplied by 1.5. The ground was coloured from WorldCover land cover, with forest drawn darker where the CCI biomass is higher, and lit by a sun in the north-west with cast shadows and slightly darker valley floors. Streams, main stems, roads, trails and divides were rendered by QGIS on the same grid and laid on top. The block was drawn by marching a ray for each column of the image across the height field, from near to far, so that ridges hide the ground behind them, with a level camera so that vertical lines stay vertical, and with a slight haze towards the horizon. Each catchment is seen from the north, east, south and west, from a distant camera looking down at 20 to 34 degrees (less steeply along a long catchment, so that it fills the frame), so that the near and far ends of the catchment are drawn at nearly the same scale. Only the six highest summits, the towns and the places to visit are numbered in the views, each only where it can be seen from that side, and the list under each pair of views names every number on the page.

4. Forest, Biomass and Water

The six catchments, whose outlines are drawn on Figure 8 and described in Section 5, are mostly tree-covered: from 81% in the Heen Ganga to 94% in the Thelgamu Oya (Table 2, Figure 8d). Tree cover here may include cardamom grown under the forest canopy and the shade trees of home gardens, which WorldCover does not separate from forest. Grassland, including the montane grassland of the high ridges, covers 3 to 10%. Cropland is significant only in the lower Heen Ganga (13%) and the

Hasalaka Oya (6%), on the plains near the Mahaweli. Open water is the reservoir edge of the Hulu Ganga (3%) and the Kalu Ganga (6%).

The catchments hold about 7.6 million tonnes of above-ground biomass, a mean of 100 Mg ha⁻¹. Biomass is highest in the Dankanda Oya (131 Mg ha⁻¹) and in the wet western and northern forests of the Hulu Ganga, Kalu Ganga and Thelgamu Oya (110 to 112 Mg ha⁻¹), and lowest in the drier eastern Hasalaka Oya (72 Mg ha⁻¹). Even within tree cover, mean biomass ranges from 79 Mg ha⁻¹ in the Hasalaka Oya to 136 Mg ha⁻¹ in the Dankanda Oya. The combined map (Figure 8c) separates high-biomass forest from lower-biomass tree cover, which on these slopes is often disturbed forest, cardamom or regrowth [10].

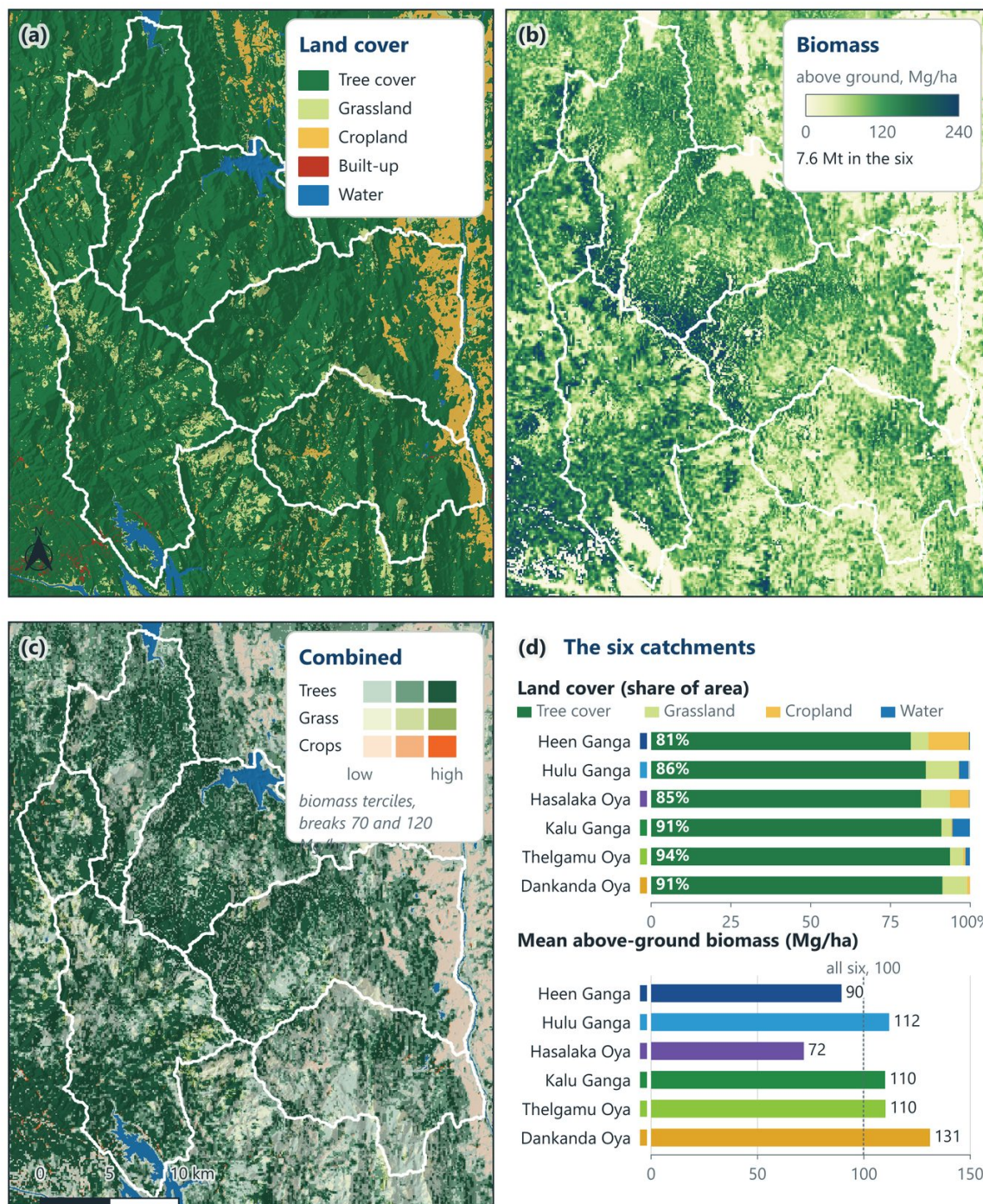
Table 2. Land cover (ESA WorldCover 2021) and above-ground biomass (ESA CCI Biomass, 2021) in the six catchments.

Stream	Tree cover (%)	Grassland (%)	Cropland (%)	Water (%)	Biomass, mean (Mg ha ⁻¹)	Biomass in tree cover (Mg ha ⁻¹)	Biomass, total (Mt)
Heen Ganga	81.4	5.5	12.7	0.3	90	105	1.76
Hulu Ganga	86.1	10.1	0.3	3.0	112	120	1.86
Hasalaka Oya	84.6	9.0	6.0	0.1	72	79	0.92
Kalu Ganga	91.0	3.0	0.4	5.5	110	119	1.38
Thelgamu Oya	93.7	4.1	0.7	1.4	110	115	1.12
Dankanda Oya	91.3	7.7	0.9	0.0	131	136	0.54
All six					100		7.58

Forest cover matters for water as much as for carbon. Bandaratilake [3] found that the share of rainfall leaving the Kalu Ganga as runoff rose through the 1960s, and read it as the hydrological signature of land degradation upstream. He argued that protecting and enriching forest in the source areas, above about 1067 m where streams flow all year, would raise dry-season flow by letting more rain soak into the soil. That argument still holds. The streams in this guide carry very little water in the dry months: at Wellewala, only 6.5% of the year's flow passed between May and September [3]. What little flows then comes from water stored in the forest soils of the high ground.

5. The Six Streams at a Glance

The six catchments (Figure 9, Table 3) cover 761.9 km² and drain 411 km², or 87%, of the mapped conservation forest. The Kalu Ganga catchment lies entirely inside it, and the forest covers 76% of the Thelgamu Oya and 68% of the Heen Ganga catchments. By contrast, the Hulu Ganga and Hasalaka Oya rise in the forest but soon leave it, and less than a quarter of either catchment lies within it.



Land cover: ESA WorldCover 2021 v200, majority to 30 m. Biomass: ESA CCI Biomass v7.0, 2021, 100 m. White lines: the six catchments. SLD99 (EPSG:5235).

Figure 8. (a) Land cover, (b) above-ground biomass, (c) the two combined, with biomass in terciles within each land cover group (grass includes shrub; crops include built-up land), and (d) land cover and mean biomass in each of the six catchments. White lines are the six catchments.

Table 3. The six streams, from source to arrival point. Heights are DEM values at the ends of the main stem; fall is the difference. Forest is the share of the catchment inside the mapped conservation forest.

Stream	Area (km ²)	Main stem (km)	Source (m)	Arrival (m)	Fall (m)	Forest (%)	Arrives at
Heen Ganga	197.7	32.0	1606	64	1542	68	Mahaweli Ganga
Hulu Ganga	166.9	29.4	1615	427	1188	19	Victoria Reservoir
Hasalaka Oya	128.4	24.5	1623	72	1551	21	Mahaweli Ganga
Kalu Ganga	125.8	22.7	1570	160	1410	100	Kalu Ganga Reservoir dam
Thelgamu Oya	101.8	27.8	1869	163	1706	76	Moragahakanda Reservoir
Dankanda Oya	41.3	8.6	1547	360	1187	42	Amban Ganga
Total	761.9						

The streams are steep (Table 4). Mean slopes are 17 to 21 degrees, and the main stems fall 1187 to 1706 m, mostly in their first few kilometres: every main stem drops steeply off the main ridge and then runs gently across the valley floor (Figures 11 to 32). The networks are of order 4 or 5, with bifurcation ratios of 3.3 to 5.3, within the range of 3 to 5 that Horton and Strahler found typical where geology does not strongly control the drainage [21,22]. Drainage densities are similar everywhere, 1.2 to 1.4 km of channel per square kilometre, because the same channel threshold was used throughout. The Heen Ganga has the lowest hypsometric integral (0.24): most of its area is low valley floor, and its high ground is a narrow rim. The small, steep Dankanda Oya has the highest (0.43) and is the most compact (elongation ratio 0.84), while the Thelgamu Oya, a long, narrow valley running north, is the most elongated (0.41).

Table 4. Basin shape and drainage network. N_u : number of Strahler streams of order 1 to the highest order. R_b : bifurcation ratio. D_d : drainage density. HI : hypsometric integral. R_e , R_h : elongation and relief ratios (Equation 3).

Stream	Highest order	N_u	R_b	D_d (km/km ²)	Mean slope (°)	HI	R_e	R_h
Heen Ganga	5	193, 90, 19, 4, 1	3.9	1.30	16.7	0.24	0.49	0.048
Hulu Ganga	4	143, 76, 14, 1	5.3	1.40	17.9	0.34	0.49	0.040
Hasalaka Oya	4	121, 62, 15, 1	4.9	1.33	17.5	0.36	0.52	0.063
Kalu Ganga	5	108, 50, 12, 4, 1	3.3	1.25	19.7	0.30	0.56	0.062
Thelgamu Oya	4	96, 28, 6, 1	4.6	1.20	19.7	0.30	0.41	0.061
Dankanda Oya	4	38, 20, 6, 1	3.4	1.27	21.3	0.43	0.84	0.138

Three of the catchments were gauged by the Irrigation Department in the 1960s (Table 5). The Heen Ganga at Uduwelwala produced 2358 mm of runoff a year, more than half the rain that fell on it. The Kalu Ganga had the largest catchment above its gauge and carried the largest volume. Bandarattillake read its rising ratio of runoff to rainfall over the 1960s as a sign of land degradation in the upper catchment [3]. These are the only published flow records for the range that the author could find. The stations recorded for only a few years, and the Kalu Ganga station closed in 1972 [3].

Table 5. Gauged rainfall and runoff in three Knuckles catchments, as reported by Bandarattillake [3] from Madduma Bandara (1985). The gauged areas end at the stations, not at the arrival points used in this guide.

Stream (station)	Area (km ²)	Rainfall (mm)	Runoff (mm)	Runoff ratio (%)	Runoff (million m ³)
Hulu Ganga (Teldeniya)	160.6	3032	1482	48.9	237.9
Kalu Ganga (Wellewala)	194.3	2725	1637	60.1	317.9
Heen Ganga (Uduwelwala)	115.3	4282	2358	55.1	271.8

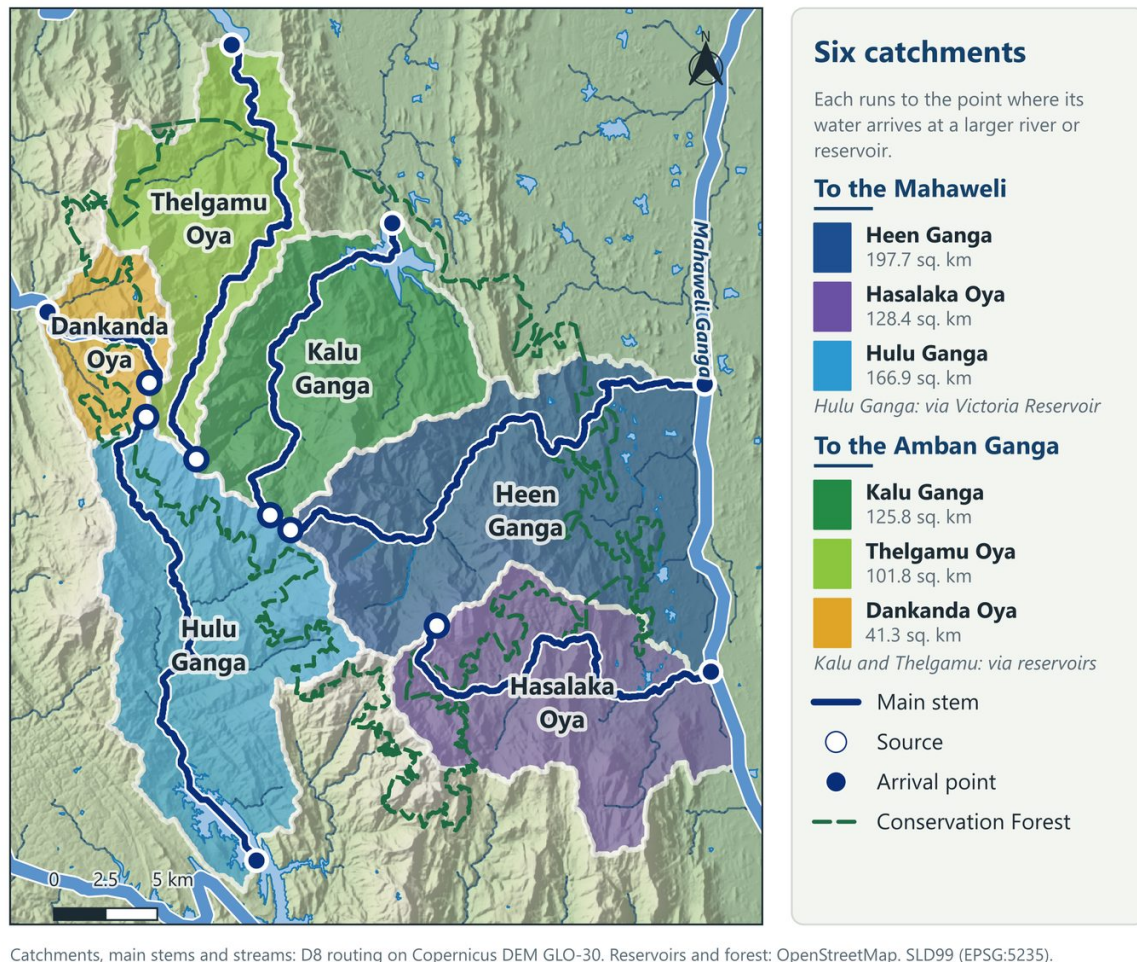


Figure 9. The six streams that rise in the Knuckles, each delineated to where its water arrives, with its main stem, source and arrival point. Cool colours reach the Mahaweli Ganga or Victoria Reservoir; green and gold reach the Amban Ganga, two of them through the Kalu Ganga and Moragahakanda reservoirs.

Seen in three dimensions from four sides (Figures 13 to 35), each catchment shows its shape at a glance, and many of its falls and viewpoints lie on the steep slopes below the divides, where the streams fall fastest (compare Figure 6). The Heen Ganga opens as a wide, low valley floor under a narrow, high rim, the shape behind its low hypsometric integral. The Thelgamu Oya climbs as one long trough to Gombaniya. The Dankanda Oya is a short, steep bowl, and the Kalu Ganga and Hulu Ganga end in the still water of their reservoirs.

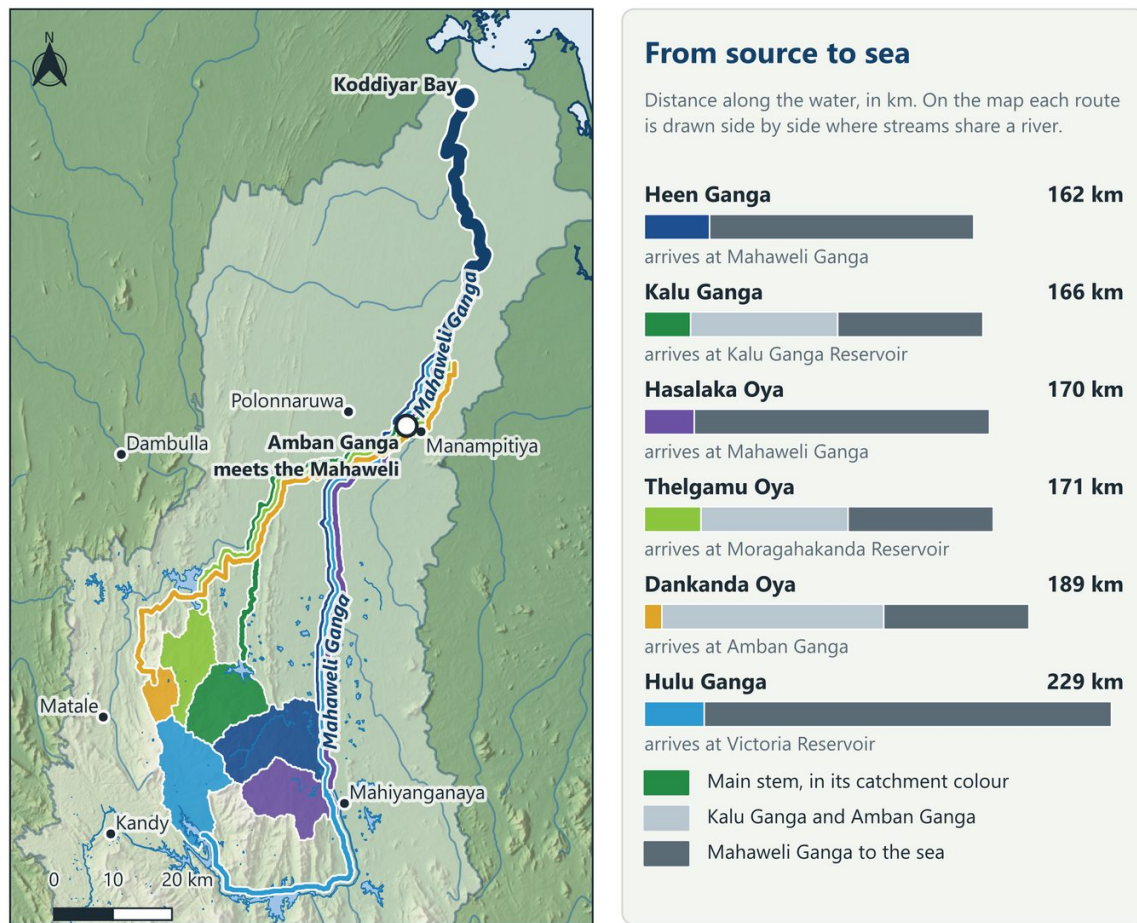
6. Where the Water Goes

All six streams end in the Mahaweli Ganga and reach the sea at Koddiyar Bay near Trincomalee, but by different roads (Figure 10, Table 6). The Heen Ganga and Hasalaka Oya join the Mahaweli below

Victoria and Randenigala and flow north past Mahiyangana. The Hulu Ganga enters the Mahaweli at Victoria and so passes three dams and power stations before reaching the plains. The Kalu Ganga leaves the range through its own reservoir, the Thelgamu Oya fills Moragahakanda, and the Dankanda Oya passes through Bowatenna and then Moragahakanda on the Amban Ganga, which carries all three about 70 km east to the Mahaweli near Manampitiya. Water reaching the reservoirs can also leave them by canal and tunnel, for irrigation and drinking supply in the dry zone [5]. From Bowatenna, water is already sent west to the Dambulu Oya, and a new canal project is extending that route into the North Western Province [1], so a drop of the Dankanda Oya may end in a paddy field rather than the sea (Section 8.4). The distances in Table 6 follow the river channel only.

Table 6. The journey of each stream to the sea, along the river channels (approximate; Section 3.8).

Stream	Main stem (km)	To the Mahaweli (km)	Mahaweli to the sea (km)	Source to sea (km)
Heen Ganga	32	0	130	162
Kalu Ganga	23	72	71	166
Hasalaka Oya	24	0	145	170
Thelgamu Oya	28	72	71	171
Dankanda Oya	9	109	71	189
Hulu Ganga	29	0	200	229



Routes: D8 traces on a 40 m DEM, then the national river line to Koddiyar Bay (approximate). Terrain: Copernicus DEM GLO-30. SLD99 (EPSG:5235).

Figure 10. Where each stream goes: its route to the Mahaweli and on to Koddiyar Bay, with routes drawn side by side where they share a river, and the distance from source to sea.

On these routes the water of the Knuckles turns turbines at Victoria, Randenigala and Rantambe, fills Moragahakanda and the Kalu Ganga reservoir, irrigates rice in the dry zone and reaches taps far from the hills. The 1.3 million people who depend on Knuckles water [6] mostly live downstream and will never see its streams. For anyone walking the range, the streams in this guide are where that water starts.

7. Stream by Stream

Each stream has four figures (five for the Hulu Ganga). The plate (Figures 11, 15, 20, 24, 28 and 32) has a header in the catchment's colour with a summary of the stream, and a large map of the catchment on which every summit, town, village, waterfall, viewpoint and visitor site carries a numbered badge, named in the list beside or under the map. The Hulu Ganga, with 68 numbered places, has its plate in two parts: summits and places to visit, then towns, villages and roads. The waterway map that follows shows only the stream network, coloured and sized by Strahler order, with its named tributaries, the summits and the villages. Two pages of three-dimensional views then show the catchment from the north, east, south and west, at a vertical exaggeration of 1.5, with only the main summits, the towns and the places to visit marked. A place keeps its number in all the figures of its stream, so that a waterfall found on the plate can be followed into the views. Distances below are along the main stem, measured from the source. Places are those within 1.5 km of the stream (1 km for waterfalls). Source coordinates are the DEM head of the longest flow path. They mark where the longest thread of water begins, not a spring that can necessarily be visited.

7.1. Heen Ganga

The Heen Ganga drains the eastern heart of the range and has the largest catchment of the six (197.7 km²; Figures 11 to 14). Its longest thread starts at 1606 m (7.4251° N, 80.7916° E), on the divide between Kalupahana, 2.6 km to the north-east, and the Knuckles peaks, whose three summits stand 3.1 to 3.4 km to the south-east on the same divide at 1800 to 1844 m in the DEM. It drops more than 1200 m in its first 8 km, more than any other stream in the guide, and at 7.8 km, at 355 m, it reaches a cluster of pools and falls: the Heen Ganga natural pool and a confluence waterfall at 7.8 to 7.9 km, then Sliding Rock and Kali's Mouth at 10.6 km. Two unnamed falls lie at 10.6 and 14.3 km, and the stream crosses four footpaths between 15.7 and 16.7 km. It leaves the conservation forest at 21.2 km and again at 22.5 km, crosses a B road at 24.7 km and passes Nugagolla, Sonuththa and Kolongoda in the lowlands before it joins the Mahaweli Ganga at 64 m, 32.0 km from the source.

Most of the catchment is valley floor, which gives it the lowest hypsometric integral of the six (0.24). It also has the most cropland (13%), on the lowland plain near the Mahaweli. Its gauged runoff, 2358 mm a year, is the highest of the three gauged streams (Table 5). From its arrival point the water has about 130 km more to travel down the Mahaweli to the sea.

7.2. Hulu Ganga

The Hulu Ganga drains the south-western face of the range (166.9 km²; Figures 15 to 19). Its longest thread starts at 1615 m (7.4744° N, 80.7283° E), on the top of Kirigalpotta, 170 m from its summit and about 3 km north of Gombaniya, the highest summit, and it leaves the conservation forest only 1.4 km from the source. Of the six it is the stream with the most villages along it. Within 1.5 km of its main stem are 28 villages, estates and hamlets, from Kelebokka (5.3 km) and Wattekele (8.2 km) on the upper slopes, through Madulkelle and Huluganga, to Teldeniya, Udawela and Rambukwella on the shores of Victoria. At 11.7 km the stream passes the village of Huluganga, where it crosses a B road and falls over the Huluganga Ella, and at 9.1 km it passes the Thaliya Wetuna Ella. The A26 crosses it at 22.4 km near Orutota. From 23 km on, the stream runs at reservoir level, and it arrives in Victoria Reservoir at 427 m, 29.4 km from the source.

Because it ends in Victoria, the Hulu Ganga has the longest onward journey of the six: its water passes the Victoria, Randenigala and Rantambe dams and then runs the whole lower Mahaweli, about 200 km more, to the sea. Its catchment is 8.8% of the area draining to Victoria (Section 3.5). The 30%

share of Victoria, Randenigala and Rantambe water attributed to the Knuckles [4] also includes the Heen Ganga and Hasalaka Oya, which join below Victoria and pass through Randenigala.

7.3. *Hasalaka Oya*

The Hasalaka Oya drains the south-eastern end of the range (128.4 km²; Figures 20 to 23). Its longest thread starts at 1623 m (7.3833° N, 80.8558° E), on the divide at Dumbanagala (1578 m in the DEM), Dothalugala and Kobonilagala. Winding along the edge of the forest, it leaves the forest outline five times, first at 2.1 km near Loolwatta and finally at 14.3 km. At 15.0 km it drops over the Rathna Ella. The Daha Ata Wanguwa viewpoint, named for the eighteen hairpin bends of the Kandy to Mahiyangana road [30], stands 1.1 km from the stream. The stream then passes Gurulupotha, crosses a B road at 20.4 km and runs past the town of Hasalaka before it joins the Mahaweli at 72 m, 24.5 km from the source. Its catchment has the lowest mean biomass of the six (72 Mg ha⁻¹), consistent with the drier eastern slopes.

7.4. *Kalu Ganga*

The Kalu Ganga drains the northern heart of the range, and its whole catchment lies within the conservation forest (125.8 km²; Figures 24 to 27). Its longest thread starts at 1570 m (7.4316° N, 80.7827° E), in the high ground between Kalupahana, 3.2 km to the east-north-east, and Gombaniya, 4.3 km to the north-west. Its headwaters rise on the western slope of the Kalupahana ridge, only about 500 yards from those of the Meemure Oya, a tributary of the Heen Ganga, on the eastern slope [3]. Its upper course holds two named falls, Duwili Ella and Dumbara Ella, with the Infinity Pool and the Dumbara Ella pool, between 5.5 and 6.3 km from the source. Below them the valley opens. The stream passes Rambukoluwa at 12.8 km and the old village of Pallegama at 18.3 km and reaches the Kalu Ganga Reservoir. Laggala Old Town stands near the shore at 20.1 km, and the stream's water leaves the reservoir at its dam at 160 m, 22.7 km from the source.

Bandaratillake found that the Kalu Ganga carried the largest volume of the three gauged rivers [3]. Below the dam, the river runs north for about 25 km and joins the Amban Ganga below Moragahakanda.

7.5. *Thelgamu Oya*

The Thelgamu Oya has the highest source of the six (Figures 28 to 31). Its longest thread begins at 1869 m (7.4560° N, 80.7503° E), on the summit ridge of Gombaniya itself, where the divides of the Hulu Ganga, Kalu Ganga and Thelgamu Oya meet. From there it runs north down the longest and narrowest valley in the range (elongation ratio 0.41). It passes Etanwala at 8.0 km, the Wedda Peni Ella near the trail crossing at 8.3 km, and Rathkinda, Pitawala and Mahalakotuwa. It crosses a B road at 11.8 km near Illukkumbura. The Sera Ella fall and the viewpoint at Karagahatenna lie in the north-west of its catchment. It leaves the forest at 20.9 km and arrives in Moragahakanda Reservoir at 163 m, 27.8 km from the source, after a fall of 1706 m, the greatest in the guide. Bandaratillake describes it as the headwater of the Kambarawa Ganga, a tributary of the Amban Ganga [3]. Today it fills Moragahakanda.

7.6. *Dankanda Oya*

The Dankanda Oya is the smallest of the six (41.3 km²) and the steepest (mean slope 21.3°; Figures 32 to 35). Its longest thread starts at 1547 m (7.4893° N, 80.7297° E), on the northern slope of Kirigalpotta, 1.6 km north of its summit and 1 km west of Rathmetiya. It leaves the forest at 2.4 km, passes Midlands and crosses the B road at 3.5 km, then runs west past Weralugasthenna, Madakumbura and Dankanda. At 360 m near Rattota, only 8.6 km from the source, it meets the mapped course of the Amban Ganga and goes on as that river. Bambarakiri Ella lies on a tributary west of the main stem, and Riverston lies on the eastern edge of the catchment. The Dankanda Oya is the upper course of the Amban Ganga, and in OpenStreetMap its lower course already carries that

name. This guide uses the name Dankanda Oya for the stream above Rattota. The catchment has the highest mean biomass of the six (131 Mg ha^{-1}).

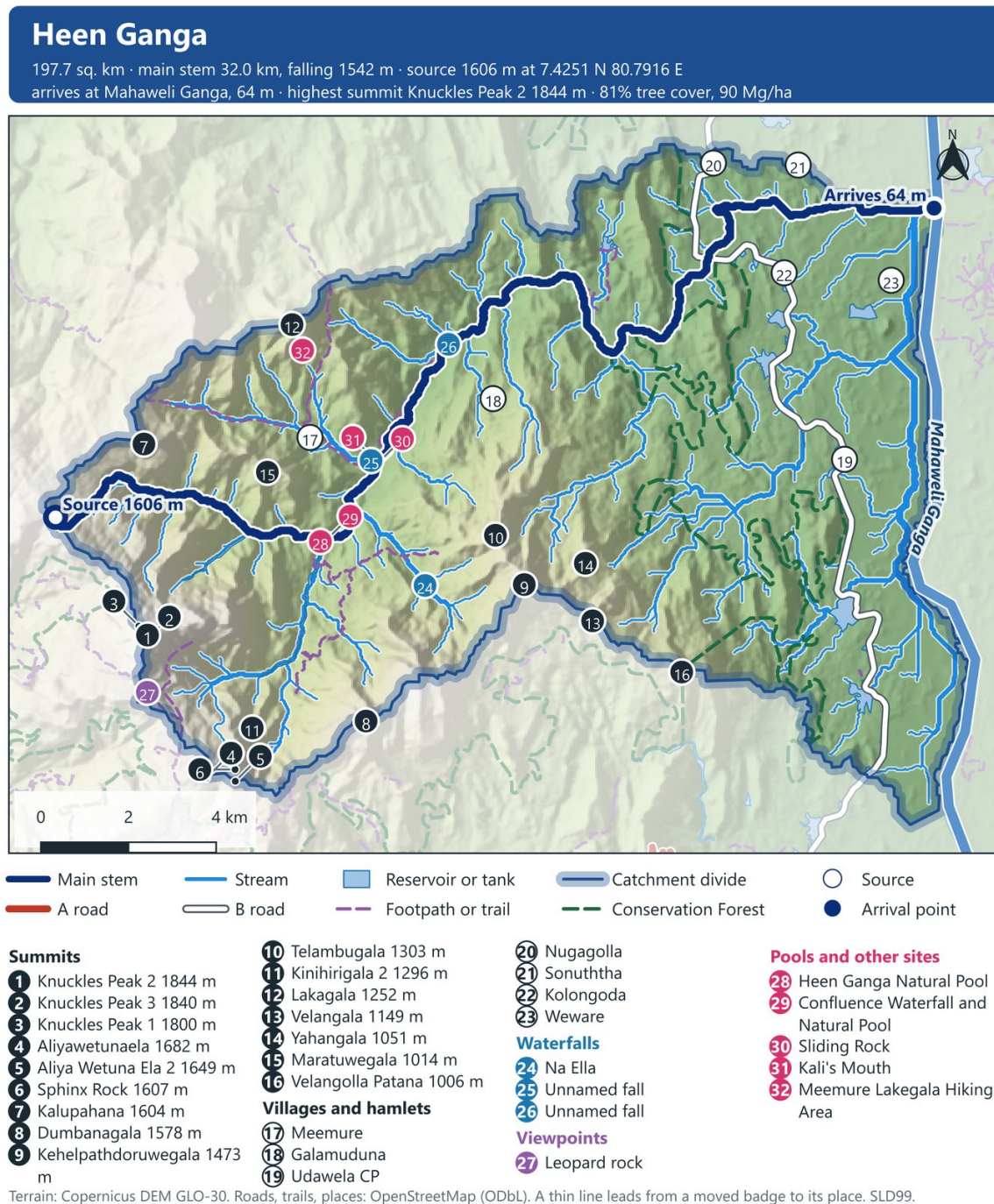


Figure 11. Heen Ganga: the catchment with its streams, source, arrival point, roads, trails and the conservation forest. Every summit, town, village, waterfall, viewpoint and visitor site is numbered, and the list names them, in order down the stream within each group. The same numbers are used in Figures 12 to 14.

8. Discussion

8.1. What the Maps Can and Cannot Tell a Walker

The maps are built from a 30 m DEM, and the DEM smooths the highest ground. For eight named summits that can be matched to the heights reported by Bandarattillake [3], the DEM summit is on average 28 m lower: Gombaniya by 34 m, Kirigalpotta by 40 m and Dumbanagala by 63 m.

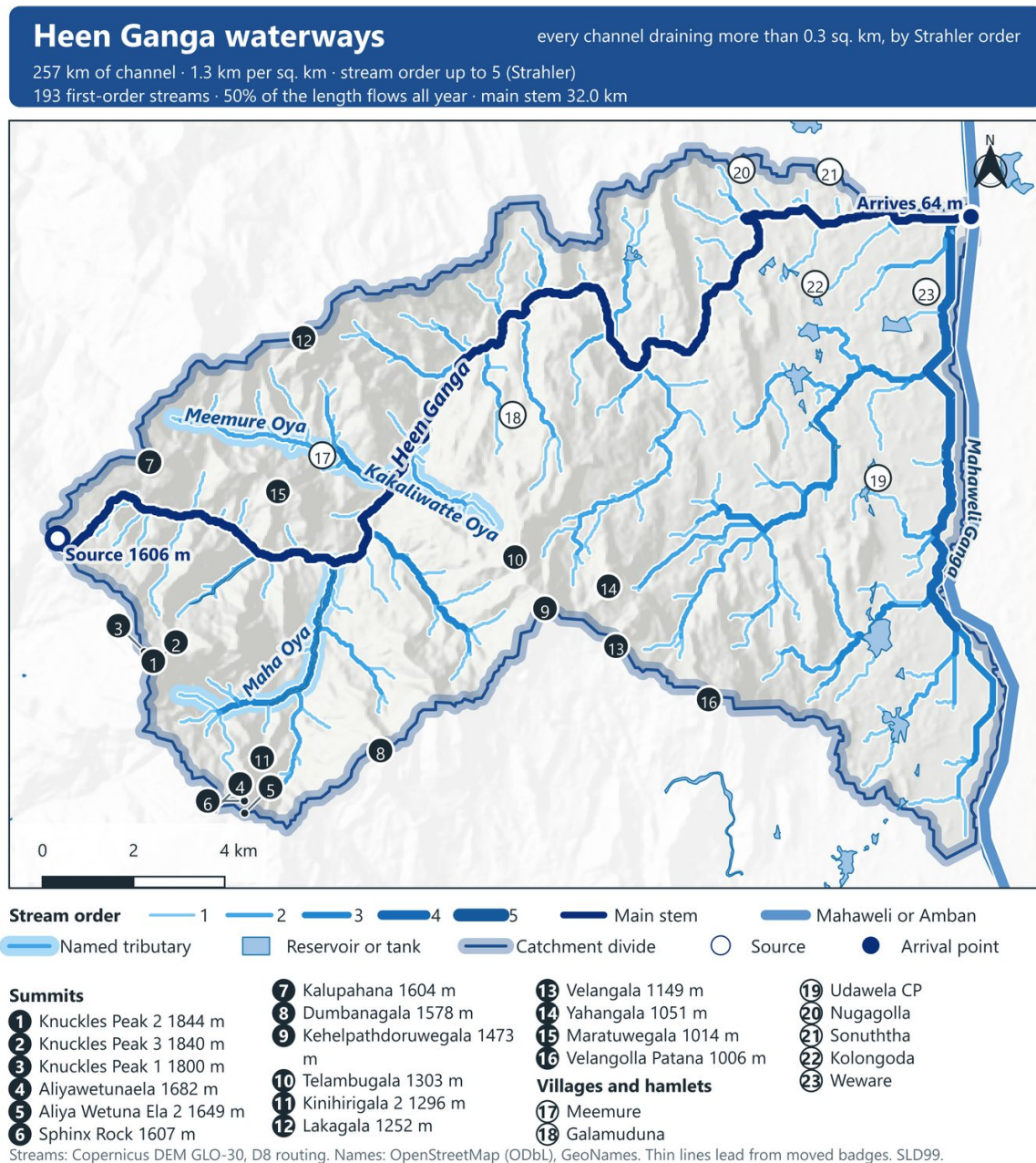
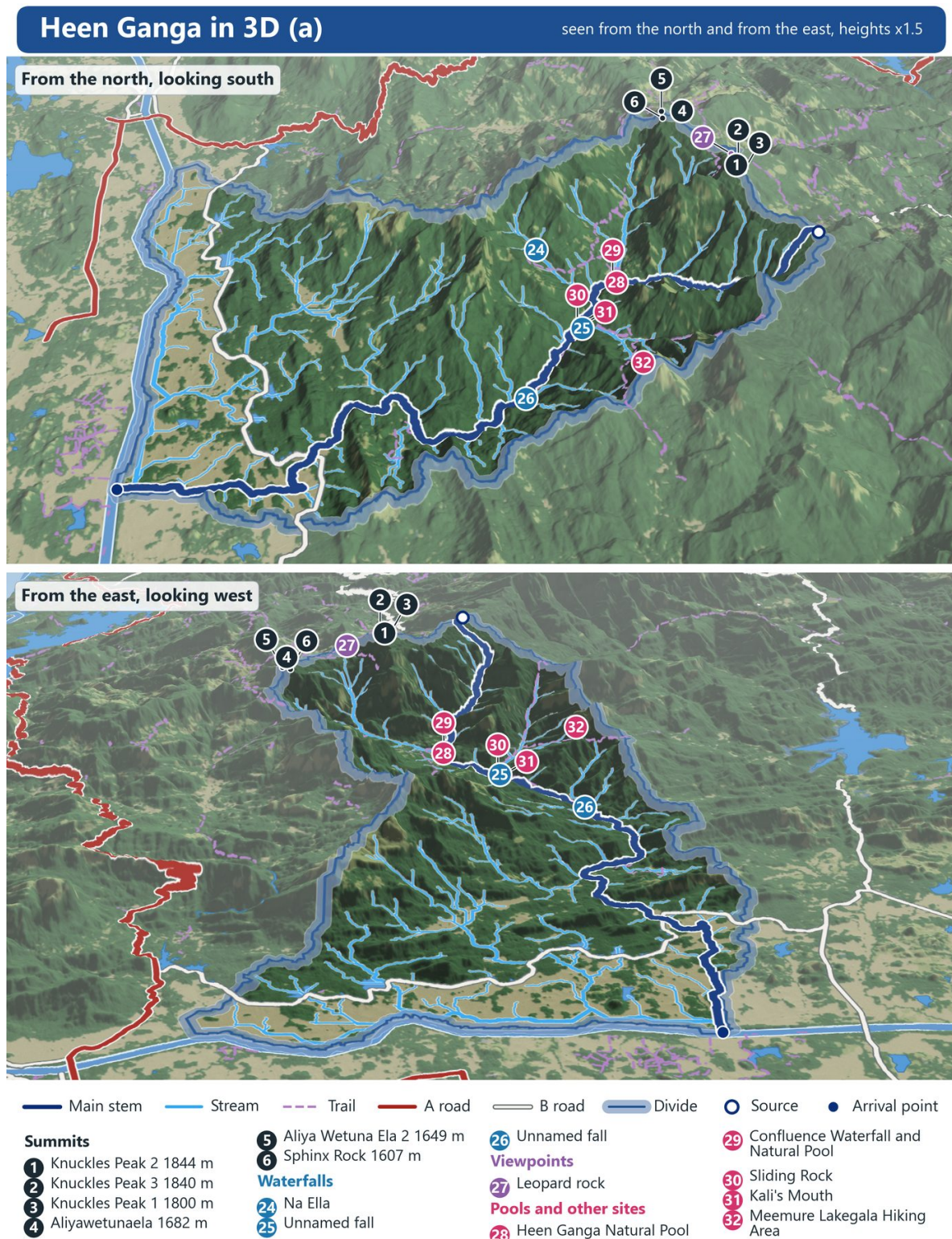
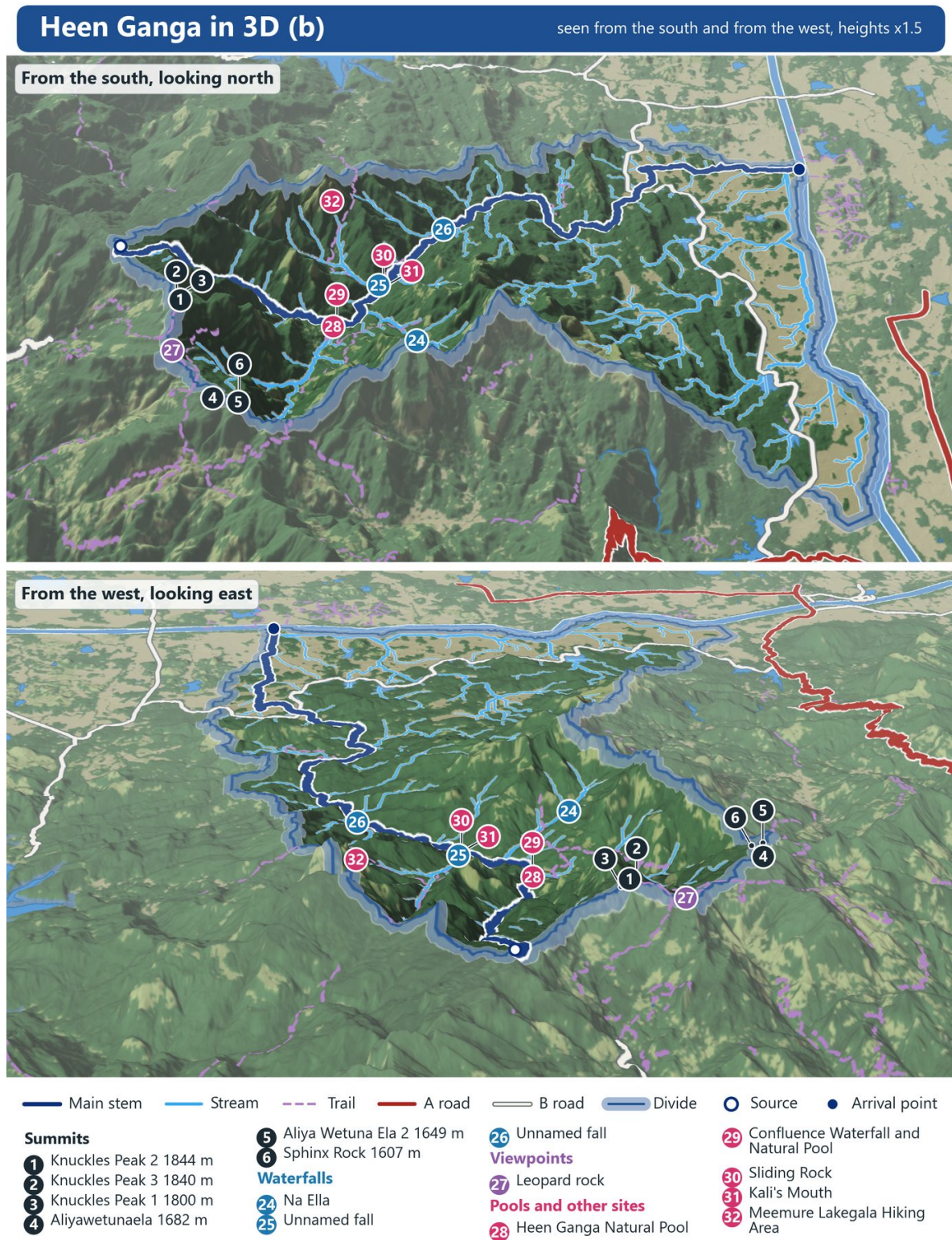


Figure 12. Heen Ganga waterways: every channel draining more than 0.3 km², coloured and sized by Strahler order, with the tributaries that have a name in OpenStreetMap or GeoNames picked out and named, the reservoirs and tanks, and the summits and villages numbered as in Figure 11.



Numbers as on the plate. Ground colour: ESA WorldCover 2021, CCI Biomass. Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap.

Figure 13. Heen Ganga in three dimensions, seen from the north (top) and from the east (bottom), at a vertical exaggeration of 1.5. Only the six highest summits, the towns and the places to visit (waterfalls, viewpoints, pools and sites) are numbered, as in Figure 11, where they can be seen from each side; villages are on the plate. Ground colours show land cover.



Numbers as on the plate. Ground colour: ESA WorldCover 2021, CCI Biomass. Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap.

Figure 14. Heen Ganga in three dimensions, seen from the south (top) and from the west (bottom), as in Figure 13.

Hulu Ganga (a): summits and places to visit

166.9 sq. km · main stem 29.4 km, falling 1188 m · source 1615 m at 7.4744 N 80.7283 E

arrives at Victoria Reservoir, 427 m · highest summit Gombaniya 1870 m · 86% tree cover, 112 Mg/ha

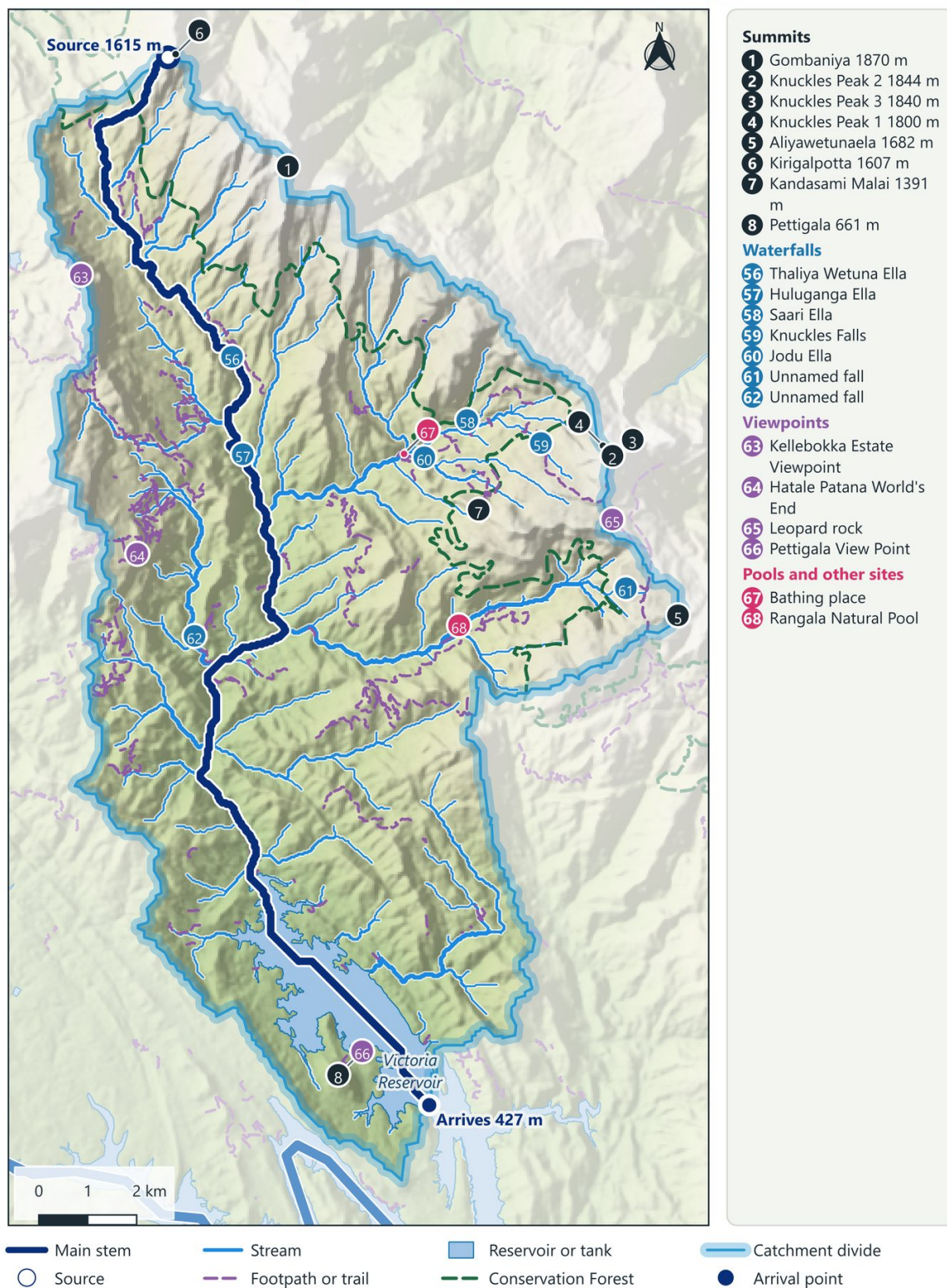


Figure 15. Hulu Ganga (a): the catchment with its summits and the places to visit (waterfalls, viewpoints, pools and sites), its streams, trails and the conservation forest. With 68 numbered places, the plate of this stream is drawn in two parts; the numbers are the same in both and in Figures 17 to 19. The catchment ends where the stream enters Victoria Reservoir.

Hulu Ganga (b): towns, villages and roads

166.9 sq. km · main stem 29.4 km, falling 1188 m · source 1615 m at 7.4744 N 80.7283 E
arrives at Victoria Reservoir, 427 m · highest summit Gombaniya 1870 m · 86% tree cover, 112 Mg/ha



Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap (ODbL). A thin line leads from a moved badge to its place. SLD99.

Figure 16. Hulu Ganga (b): the towns, villages and hamlets, with the A and B roads, numbered as in Figure 15.



Figure 17. Hulu Ganga waterways, as in Figure 12.

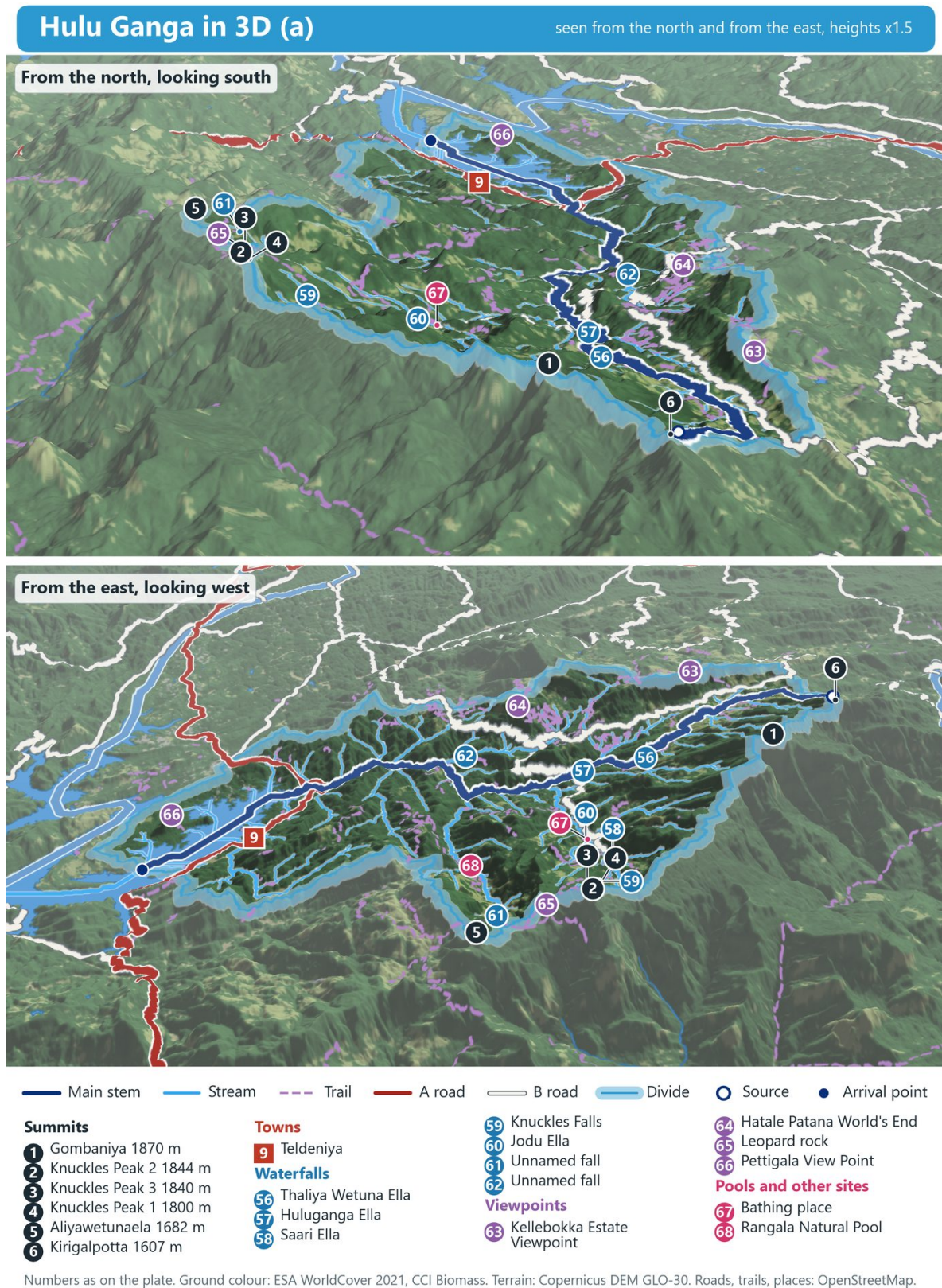


Figure 18. Hulu Ganga in three dimensions, seen from the north (top) and from the east (bottom), as in Figure 13.

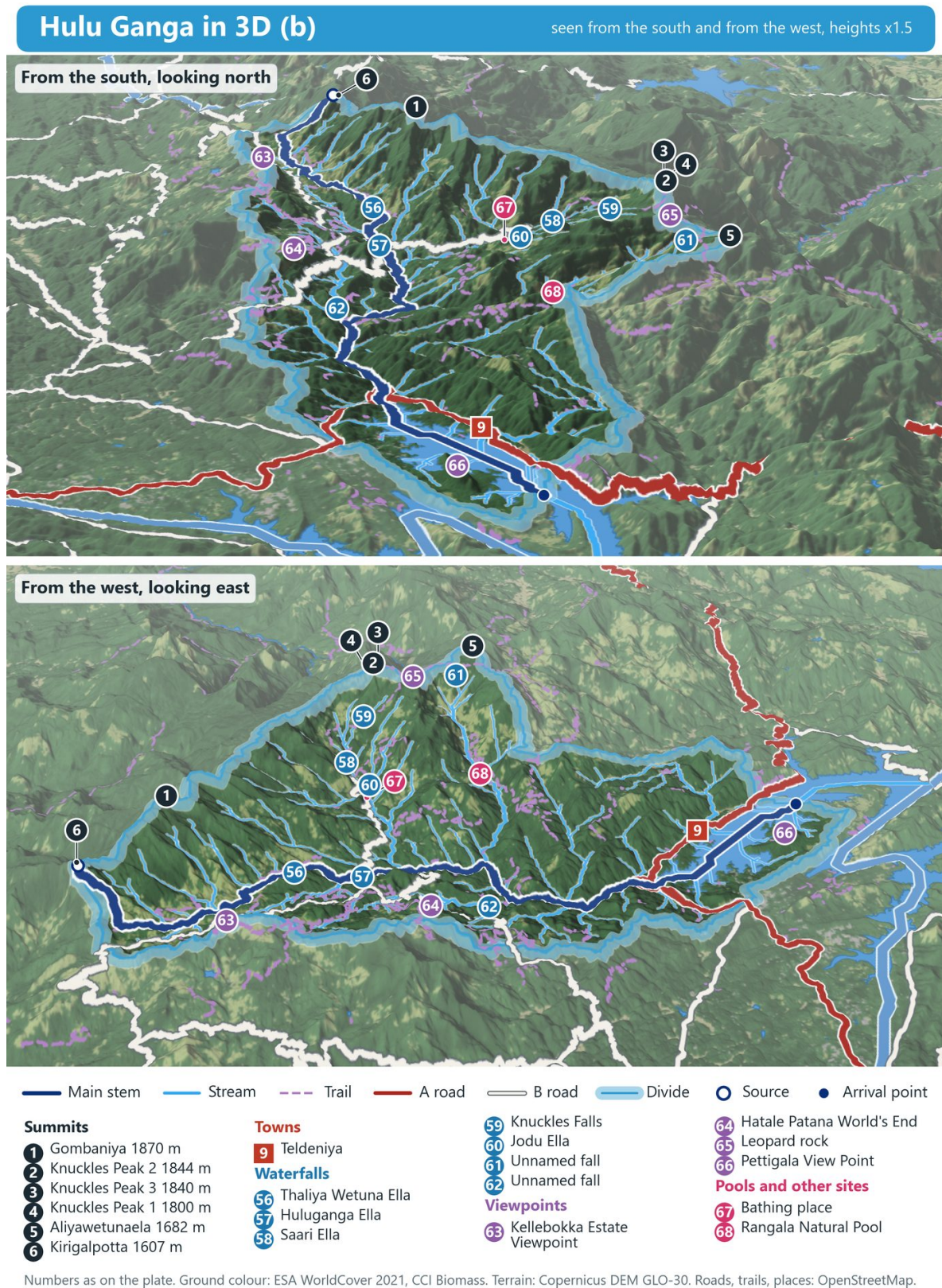


Figure 19. Hulu Ganga in three dimensions, seen from the south (top) and from the west (bottom), as in Figure 13.

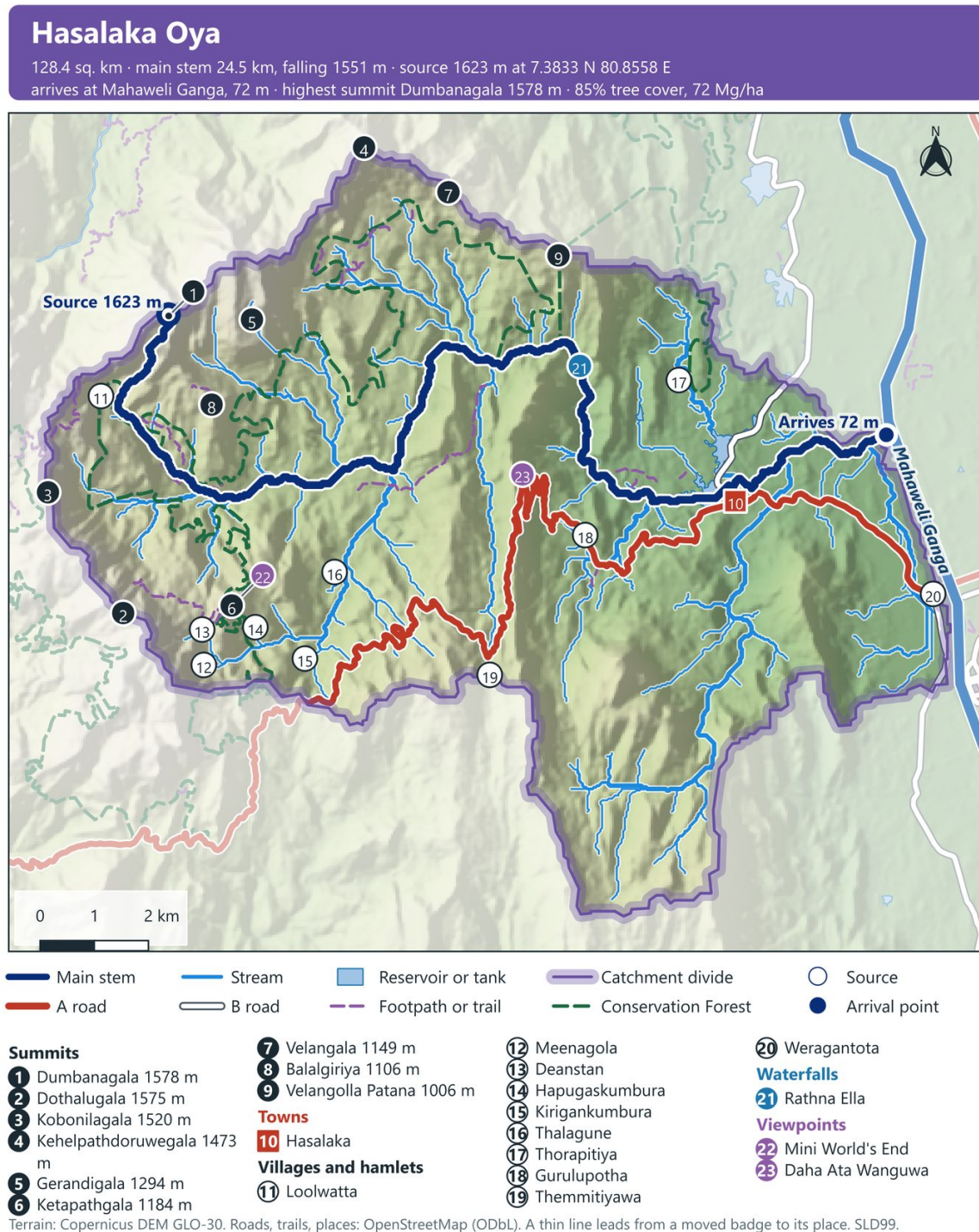


Figure 20. Hasalaka Oya, as in Figure 11.

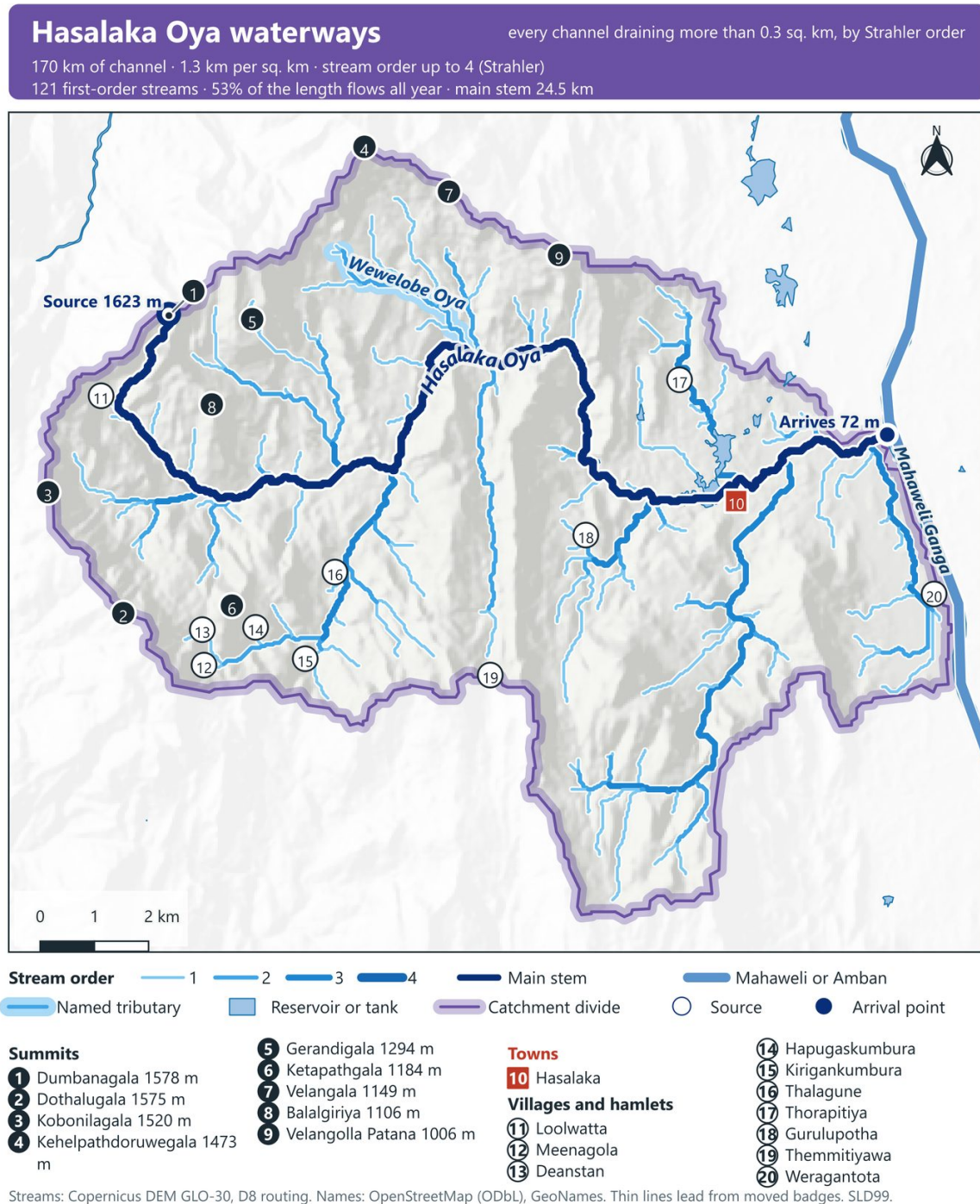
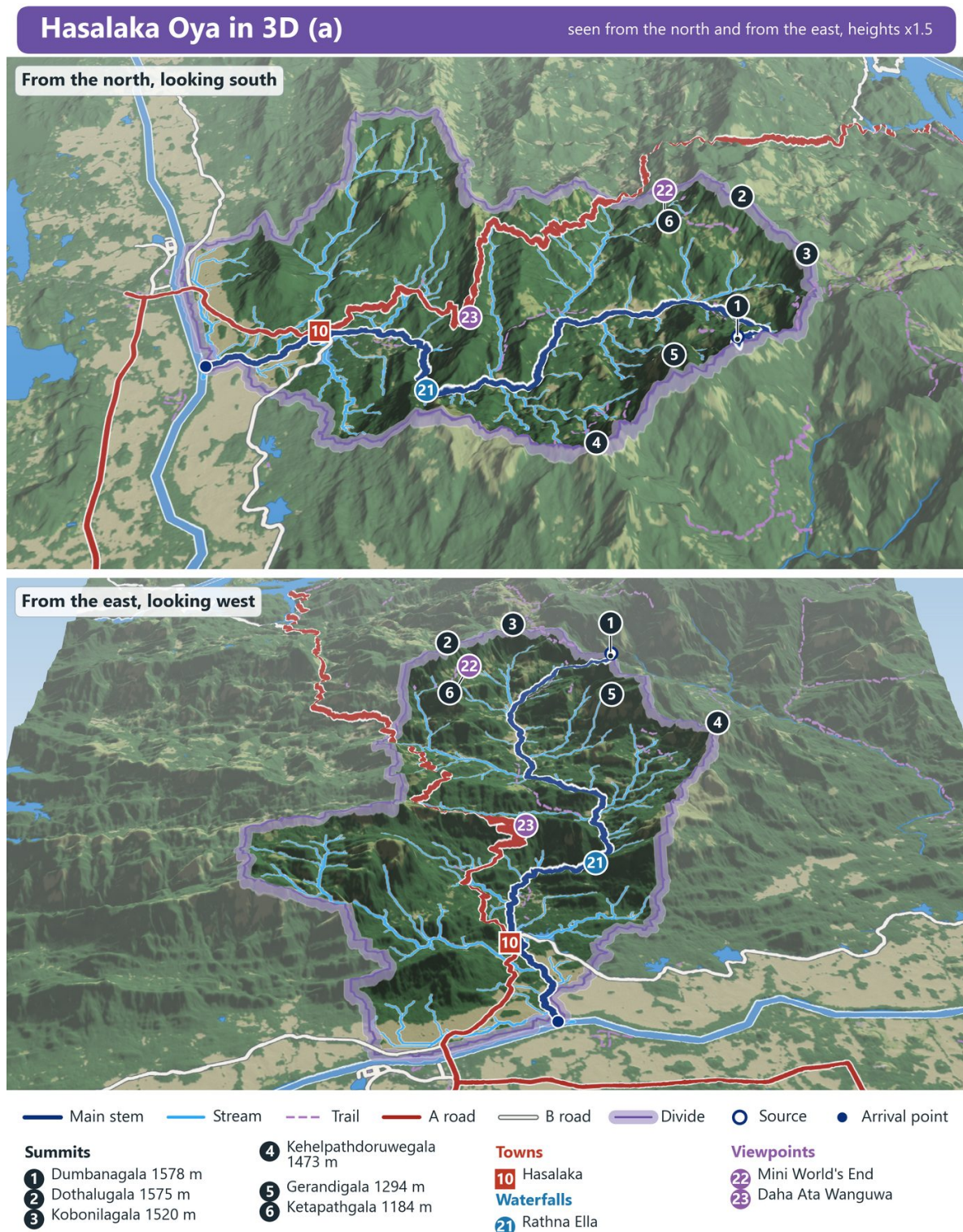
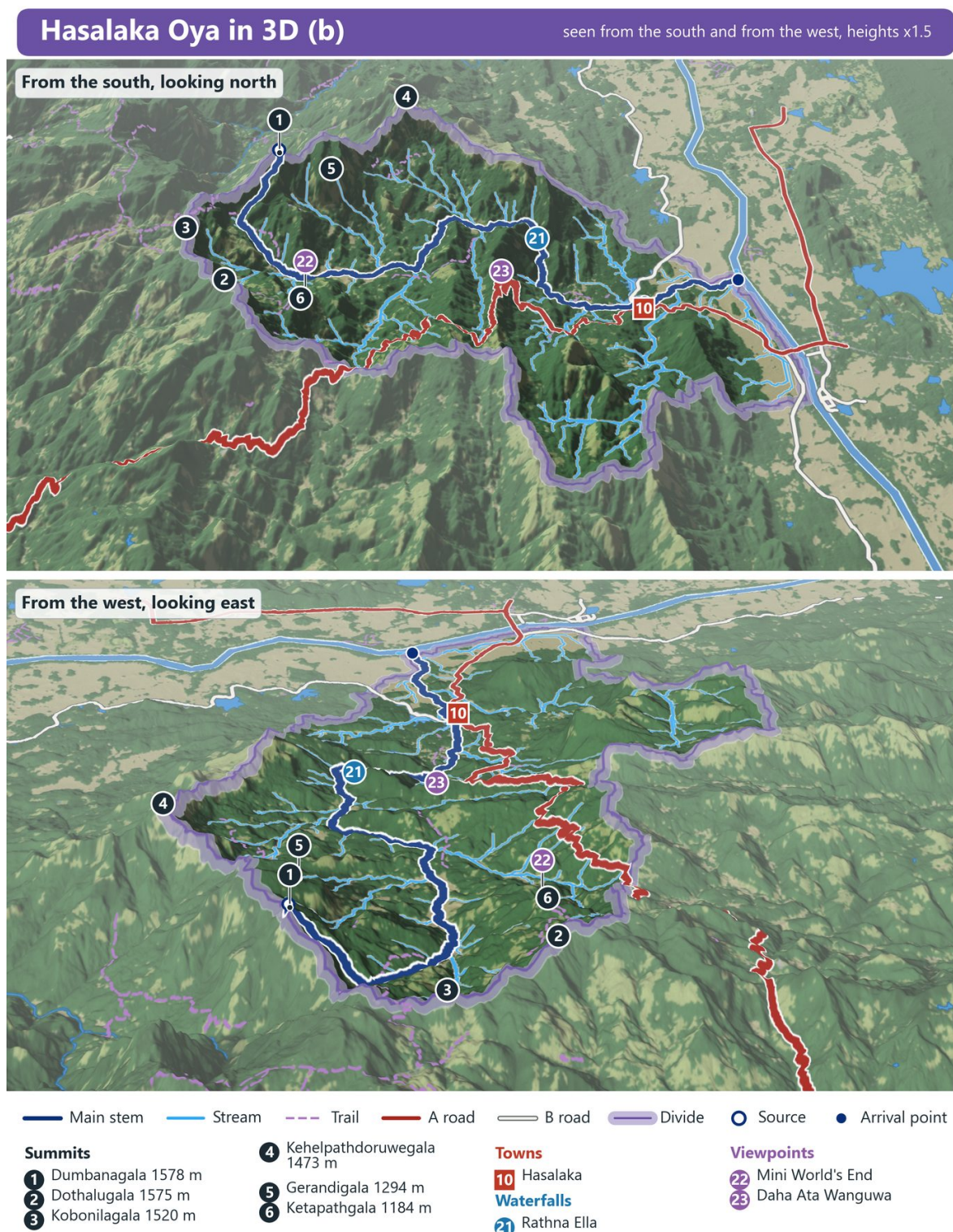


Figure 21. Hasalaka Oya waterways, as in Figure 12.



Numbers as on the plate. Ground colour: ESA WorldCover 2021, CCI Biomass. Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap.

Figure 22. Hasalaka Oya in three dimensions, seen from the north (top) and from the east (bottom), as in Figure 13.

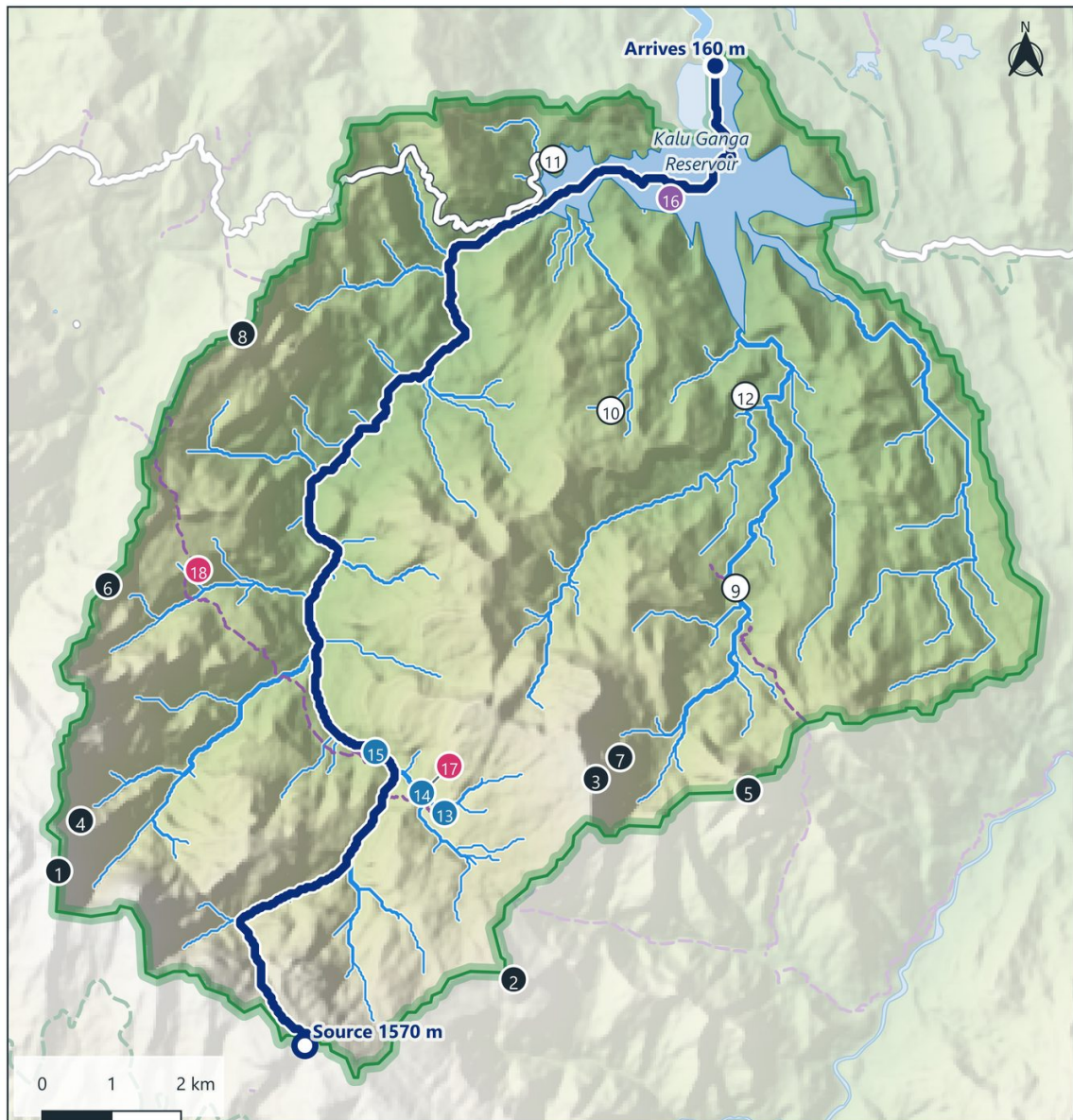
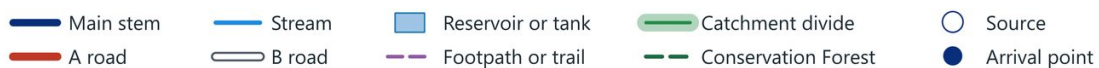


Numbers as on the plate. Ground colour: ESA WorldCover 2021, CCI Biomass. Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap.

Figure 23. Hasalaka Oya in three dimensions, seen from the south (top) and from the west (bottom), as in Figure 13.

Kalu Ganga

125.8 sq. km · main stem 22.7 km, falling 1410 m · source 1570 m at 7.4316 N 80.7827 E
arrives at Kalu Ganga Reservoir, 160 m · highest summit Gombaniya 1870 m · 91% tree cover, 110 Mg/ha



Summits

- ① Gombaniya 1870 m
- ② Kalupahana 1604 m
- ③ Wamarapugala 1543 m
- ④ Yakunegala 1369 m
- ⑤ Lakagala 1252 m

- ⑥ Lahumanagala 1170 m
- ⑦ Katukitalegala 1149 m
- ⑧ Rambukoluwa 1084 m

Villages and hamlets

- ⑨ Narangamuwa
- ⑩ Imadoowa

- ⑪ Pallegama Old Village
- ⑫ Halminiya

Waterfalls

- ⑬ Duwili Ella
- ⑭ Unnamed fall
- ⑮ Dumbara Ella

Viewpoints

- ⑯ Laggala Old Town

Pools and other sites

- ⑰ Infinity Pool
- ⑱ Walpolamulla

Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap (ODbL). A thin line leads from a moved badge to its place. SLD99.

Figure 24. Kalu Ganga, as in Figure 11. The catchment ends at the dam of the Kalu Ganga Reservoir.

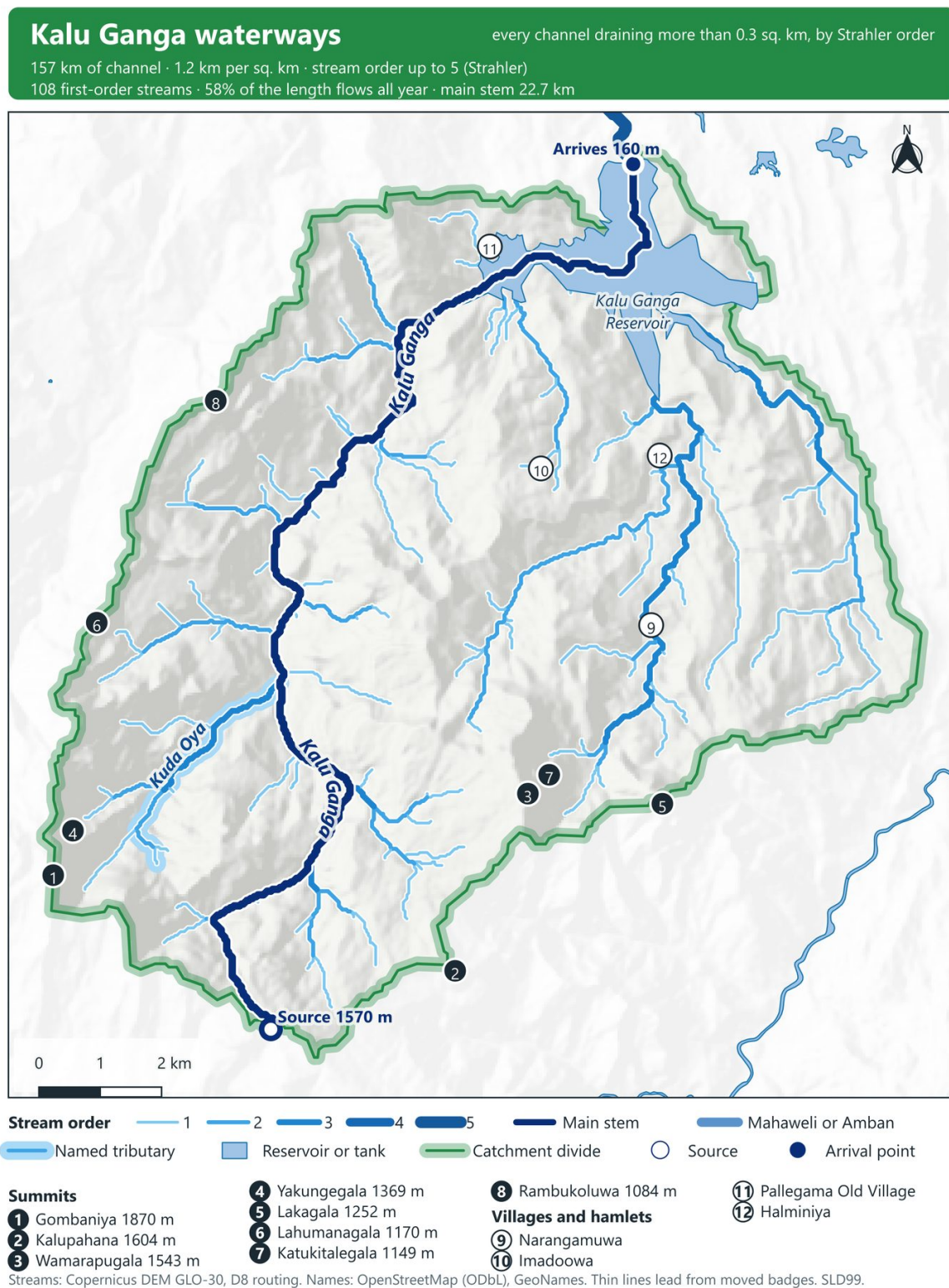


Figure 25. Kalu Ganga waterways, as in Figure 12.

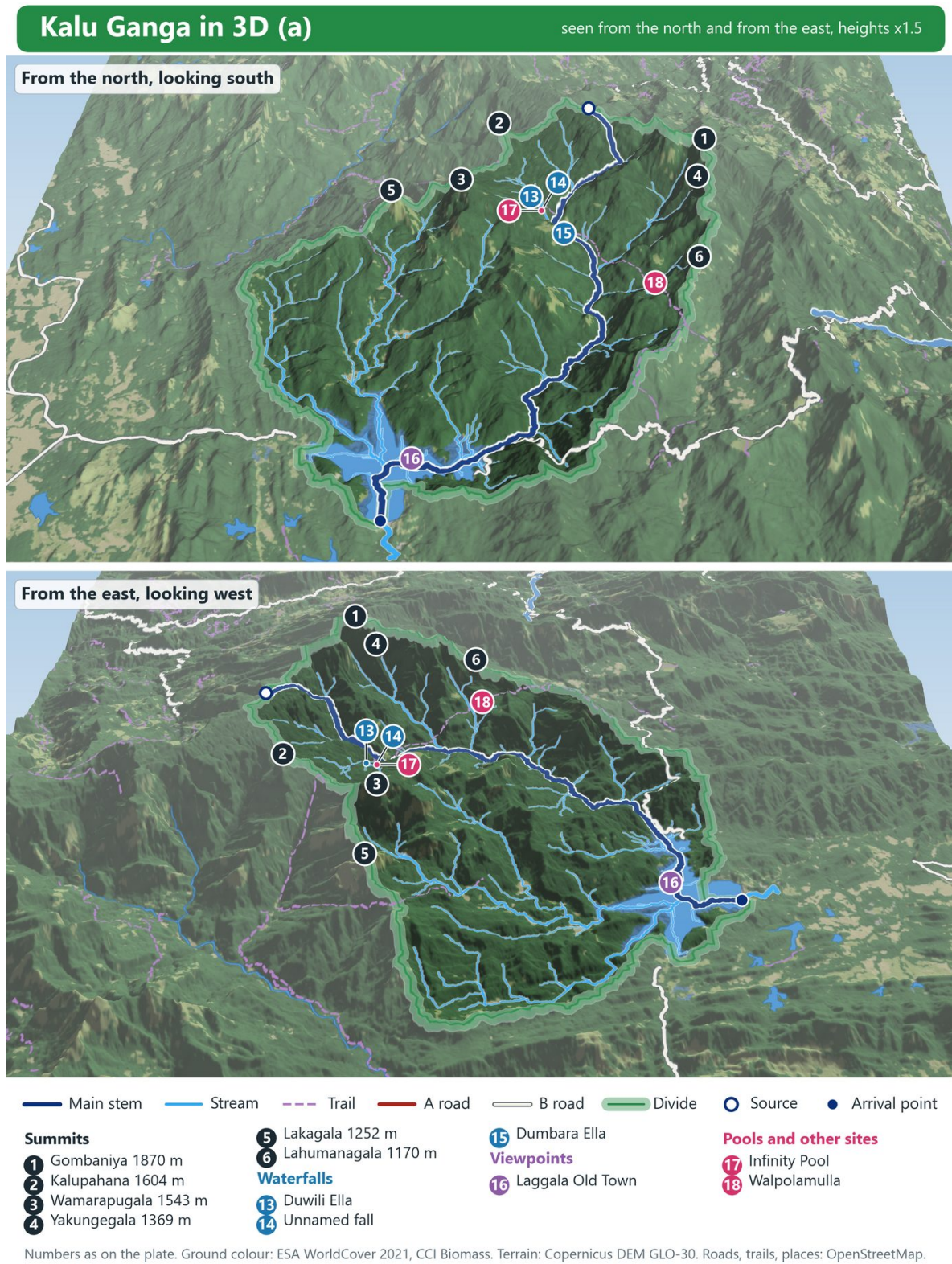


Figure 26. Kalu Ganga in three dimensions, seen from the north (top) and from the east (bottom), as in Figure 13.

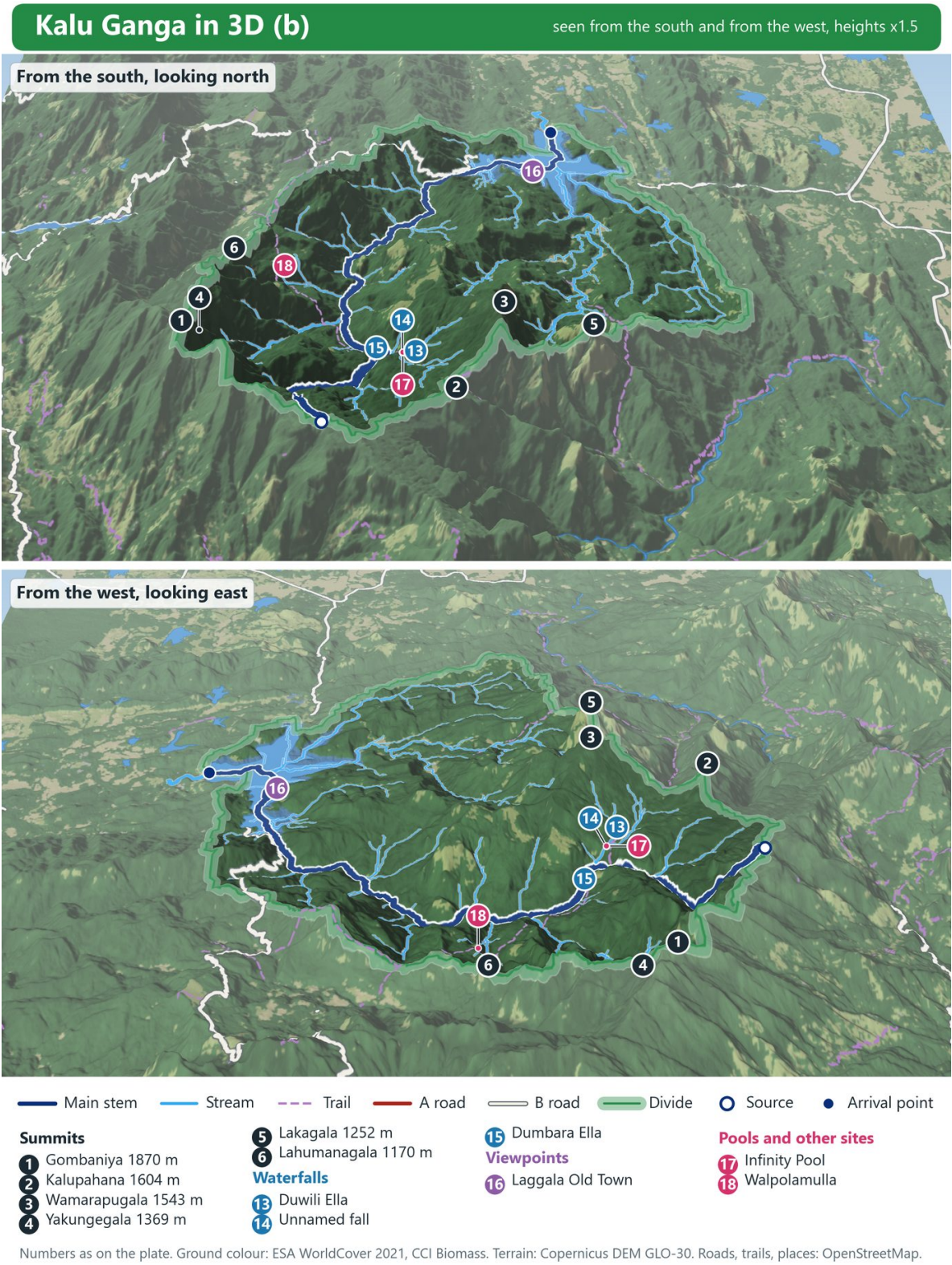
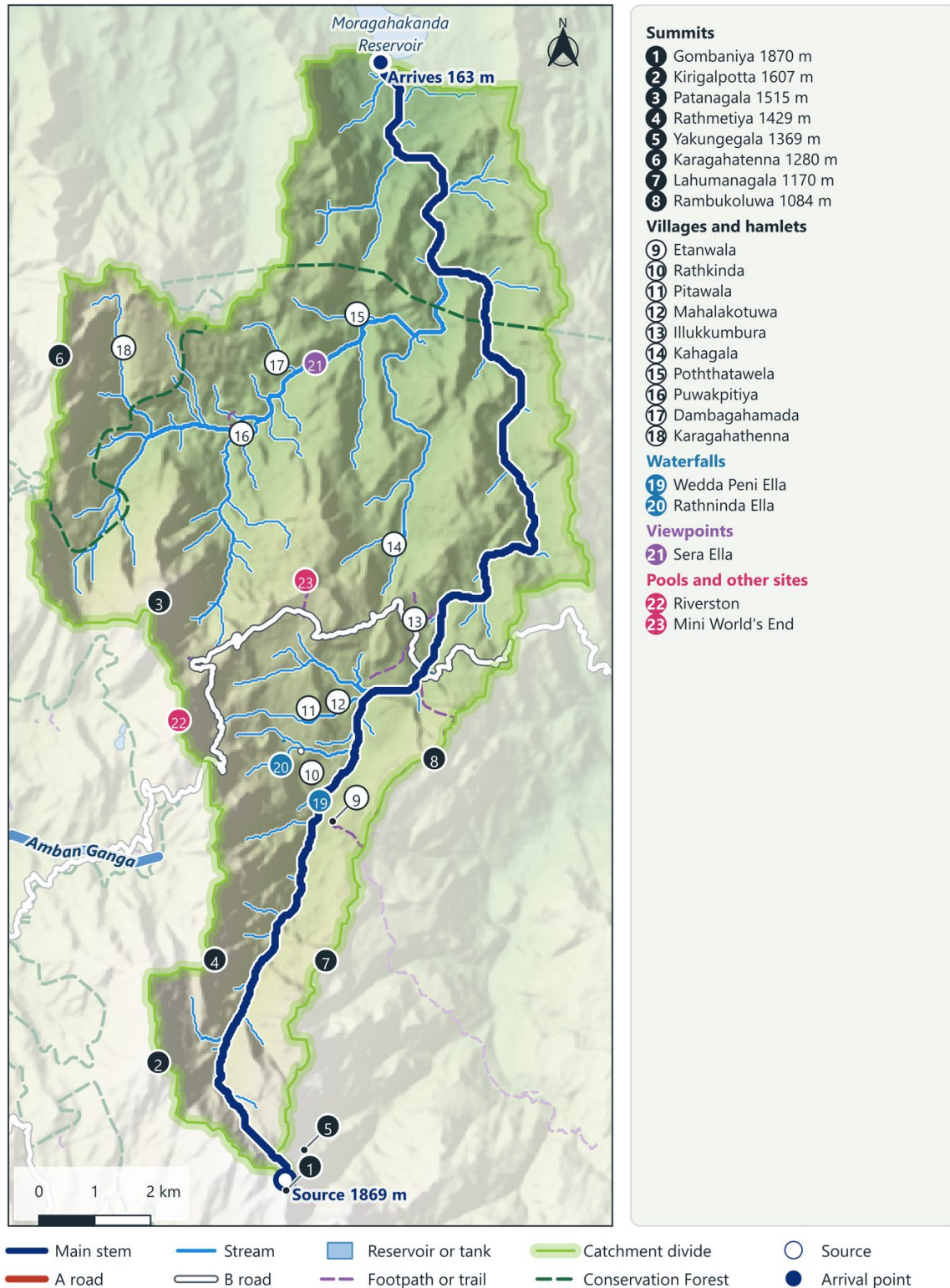


Figure 27. Kalu Ganga in three dimensions, seen from the south (top) and from the west (bottom), as in Figure 13.

Thelgamu Oya

101.8 sq. km · main stem 27.8 km, falling 1706 m · source 1869 m at 7.4560 N 80.7503 E
arrives at Moragahakanda Reservoir, 163 m · highest summit Gombaniya 1870 m · 94% tree cover, 110 Mg/ha



Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap (ODbL). A thin line leads from a moved badge to its place. SLD99.

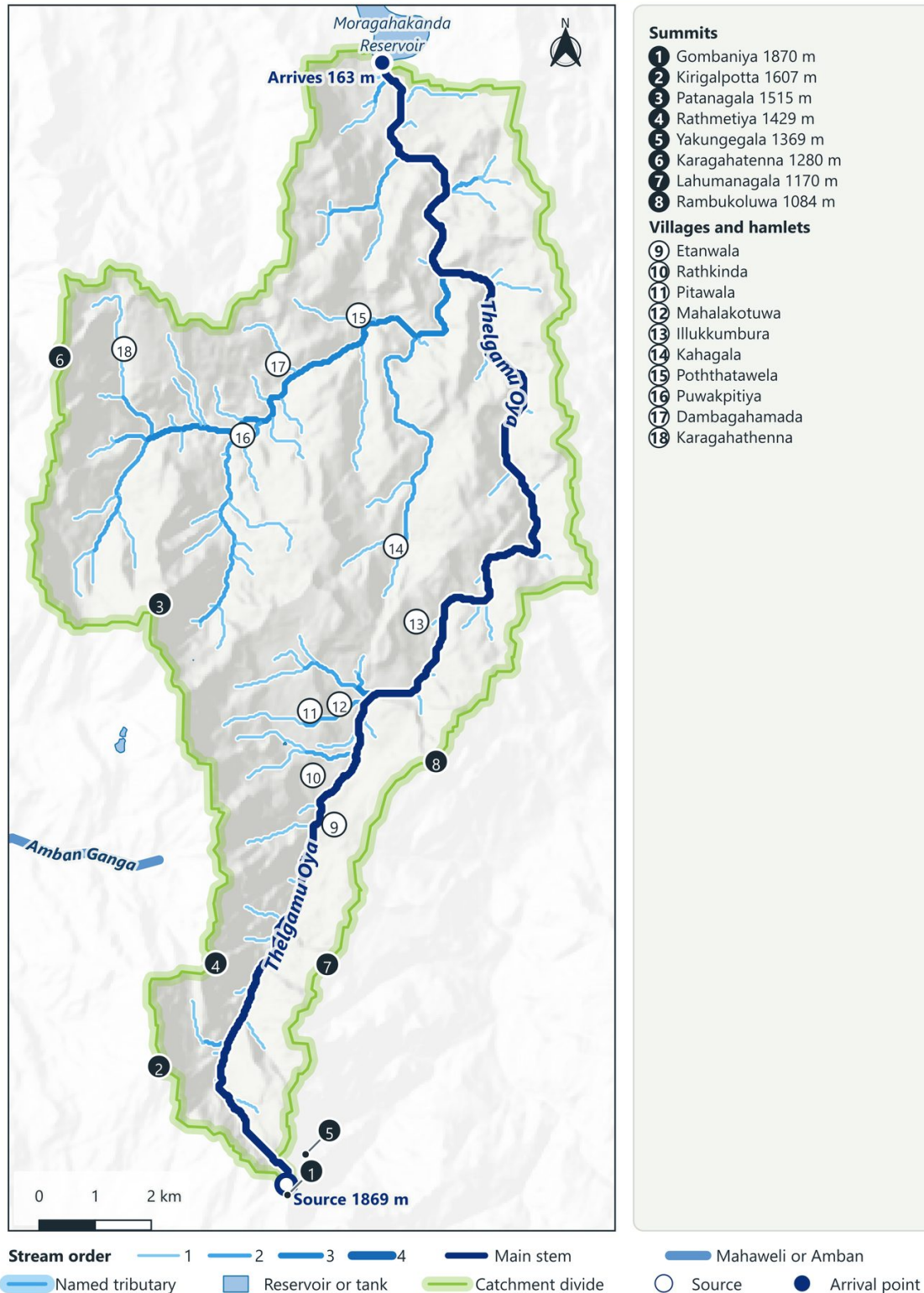
Figure 28. Thelgamu Oya, as in Figure 11. The stream ends in Moragahakanda Reservoir.

Thelgamu Oya waterways

every channel draining more than 0.3 sq. km, by Strahler order

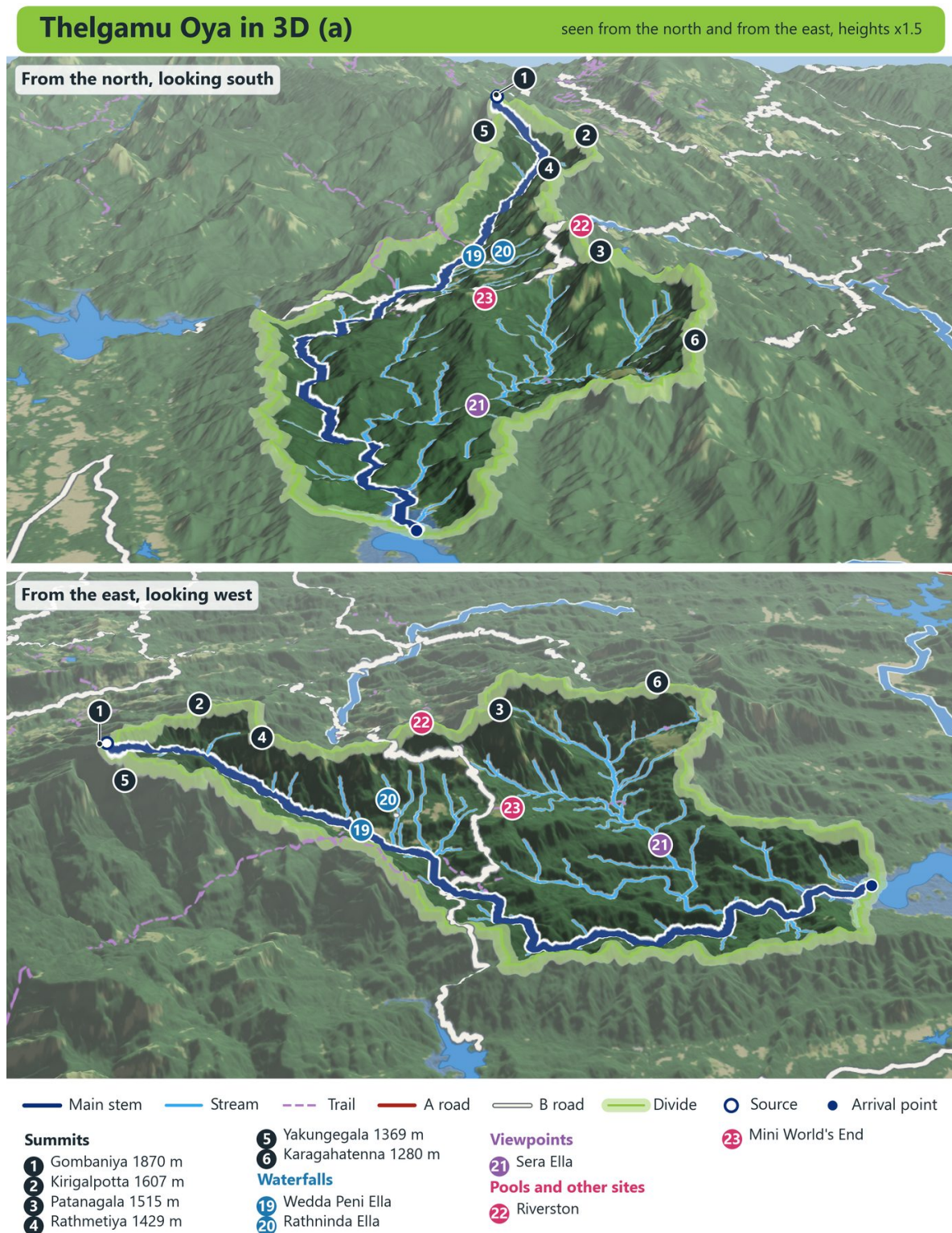
122 km of channel · 1.2 km per sq. km · stream order up to 4 (Strahler)

96 first-order streams · 63% of the length flows all year · main stem 27.8 km



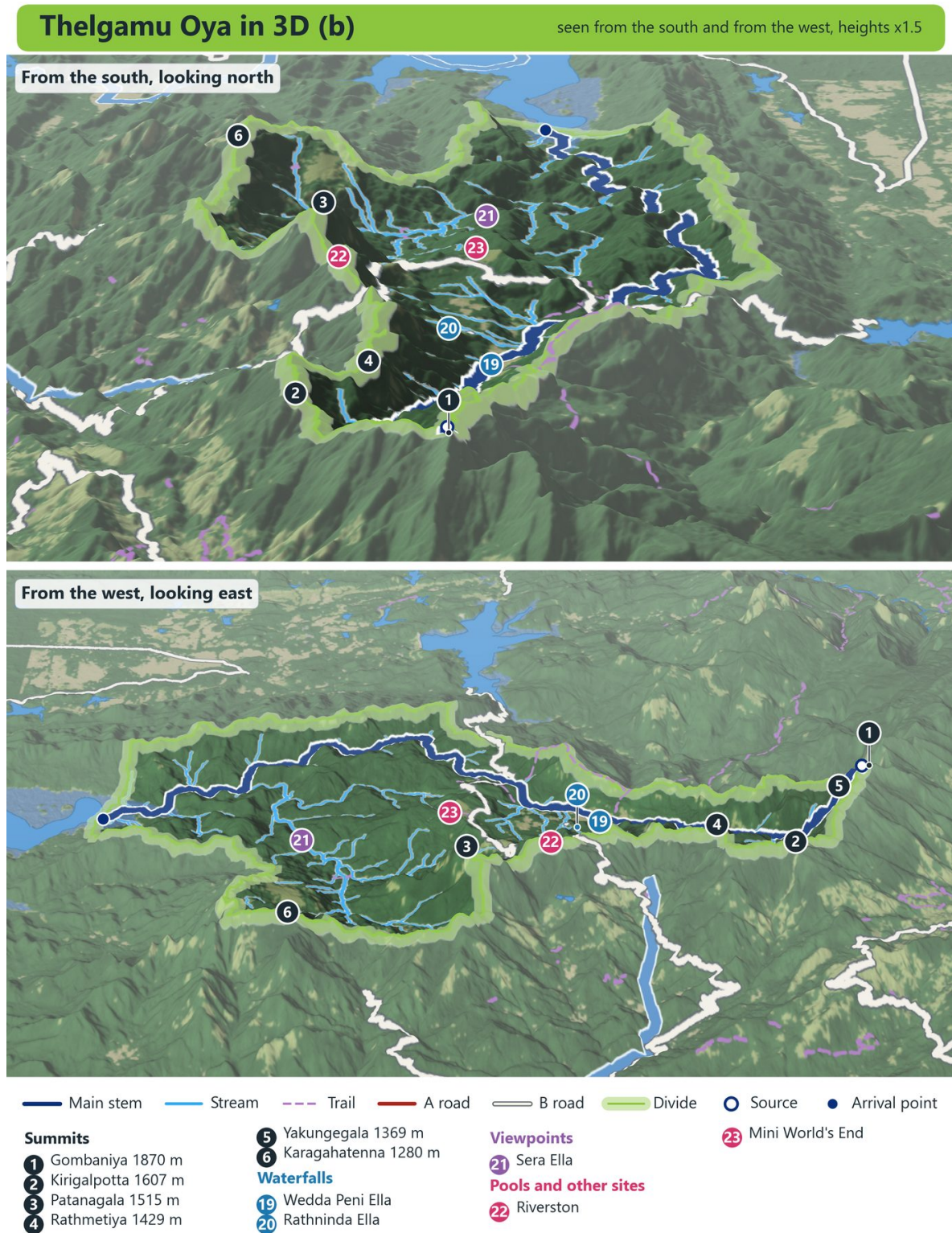
Streams: Copernicus DEM GLO-30, D8 routing. Names: OpenStreetMap (ODbL), GeoNames. Thin lines lead from moved badges. SLD99.

Figure 29. Thelgamu Oya waterways, as in Figure 12.



Numbers as on the plate. Ground colour: ESA WorldCover 2021, CCI Biomass. Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap.

Figure 30. Thelgamu Oya in three dimensions, seen from the north (top) and from the east (bottom), as in Figure 13.

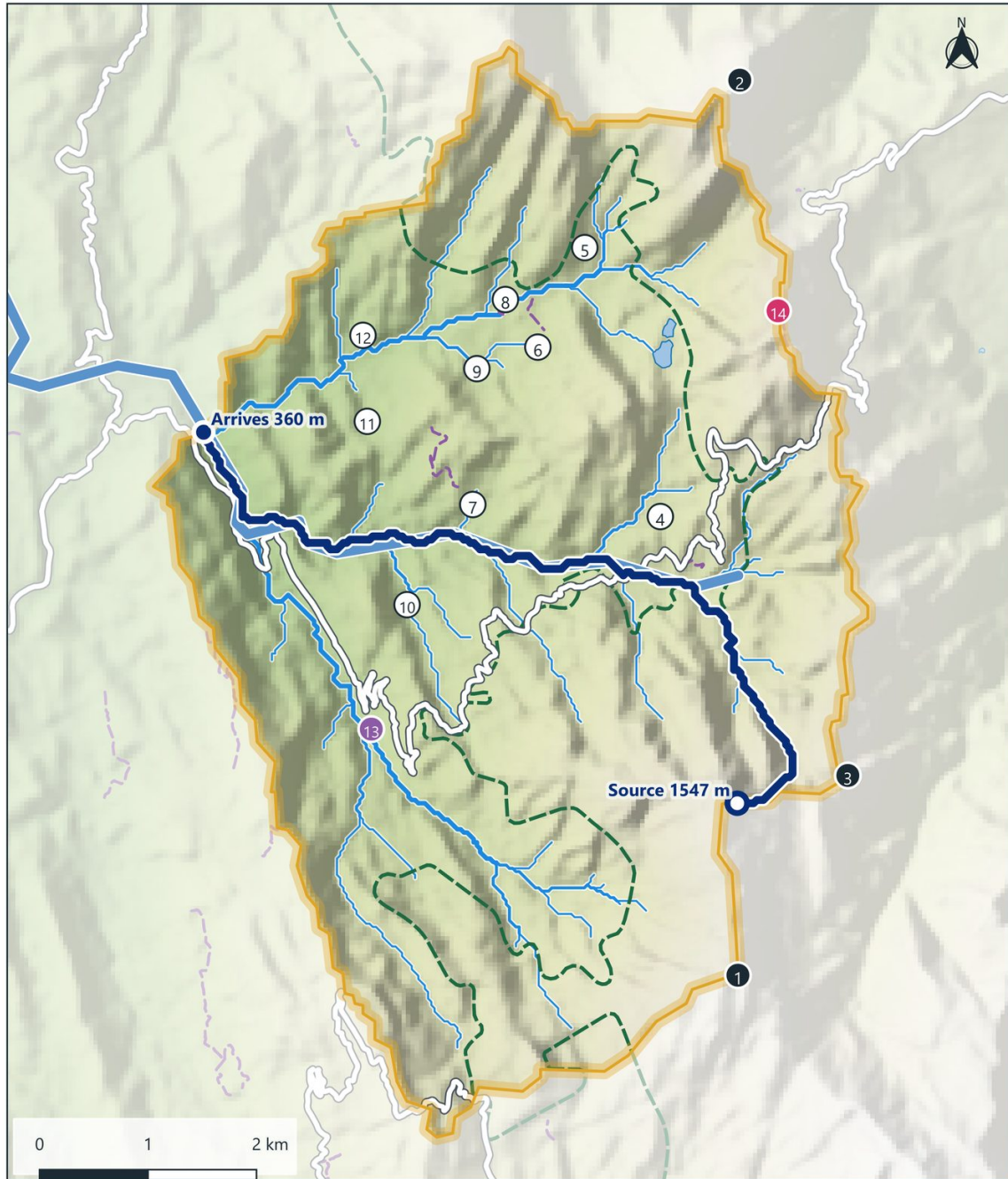


Numbers as on the plate. Ground colour: ESA WorldCover 2021, CCI Biomass. Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap.

Figure 31. Thelgamu Oya in three dimensions, seen from the south (top) and from the west (bottom), as in Figure 13.

Dankanda Oya

41.3 sq. km · main stem 8.6 km, falling 1187 m · source 1547 m at 7.4893 N 80.7297 E
arrives at Amban Ganga, 360 m · highest summit Kirigalpotta 1607 m · 91% tree cover, 131 Mg/ha



Main stem Stream Reservoir or tank Catchment divide Source
 A road B road Footpath or trail Conservation Forest Arrival point

Summits

- 1 Kirigalpotta 1607 m
- 2 Patanagala 1515 m
- 3 Rathmetiya 1429 m

Villages and hamlets

- 4 Midlands
- 5 Springmount Estate
- 6 Dankanda Estate
- 7 Weralugasthenna

- 8 Cattaratenne
- 9 Dambagolla
- 10 Madakumbura
- 11 Dankanda
- 12 Kirimetiya

Viewpoints

- 13 Bambarakiri Ella

Pools and other sites

- 14 Riverston

Terrain: Copernicus DEM GLO-30. Roads, trails, places: OpenStreetMap (ODbL). A thin line leads from a moved badge to its place. SLD99.

Figure 32. Dankanda Oya, as in Figure 11. The Dankanda Oya is the upper course of the Amban Ganga.

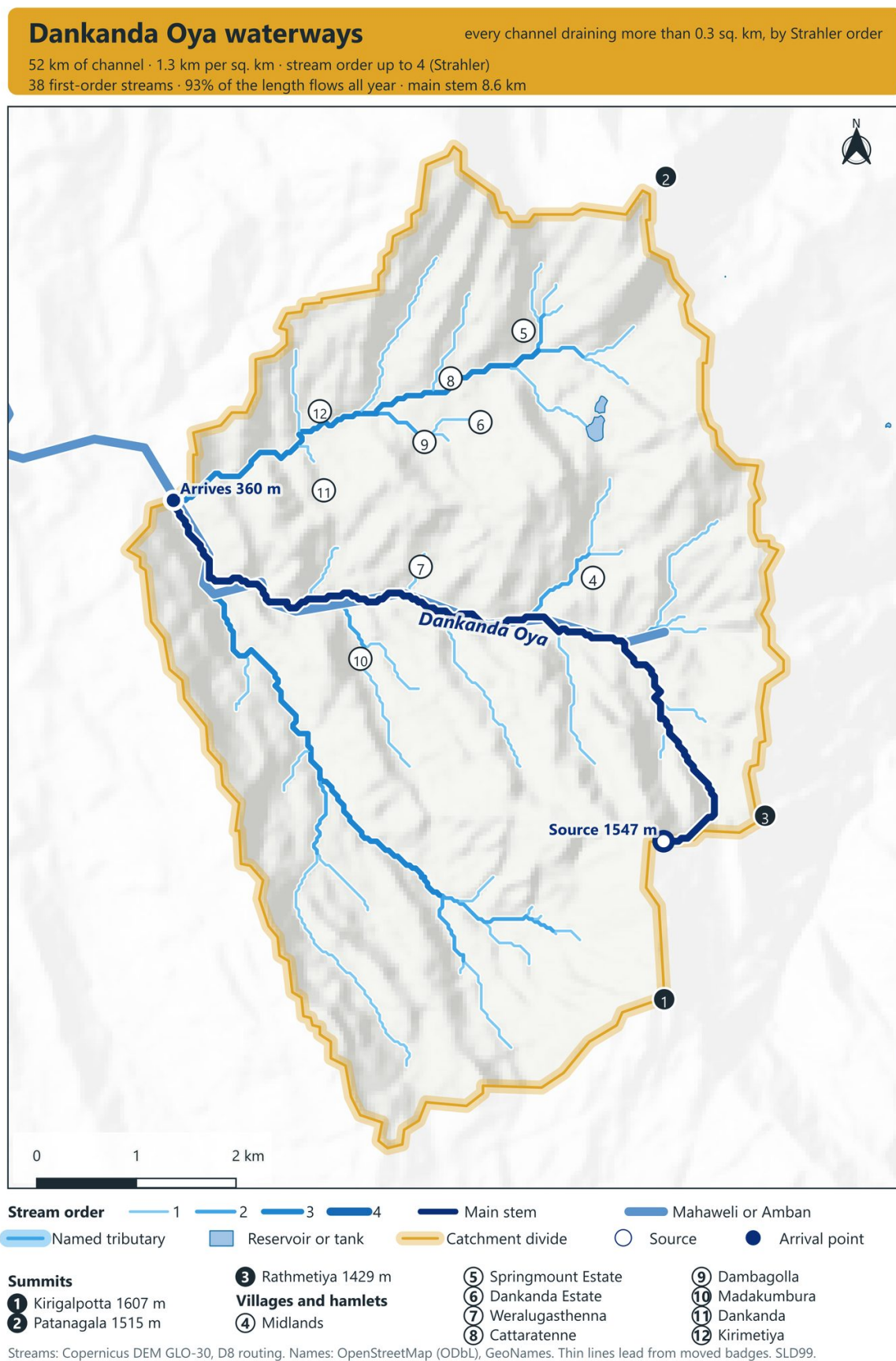


Figure 33. Dankanda Oya waterways, as in Figure 12.

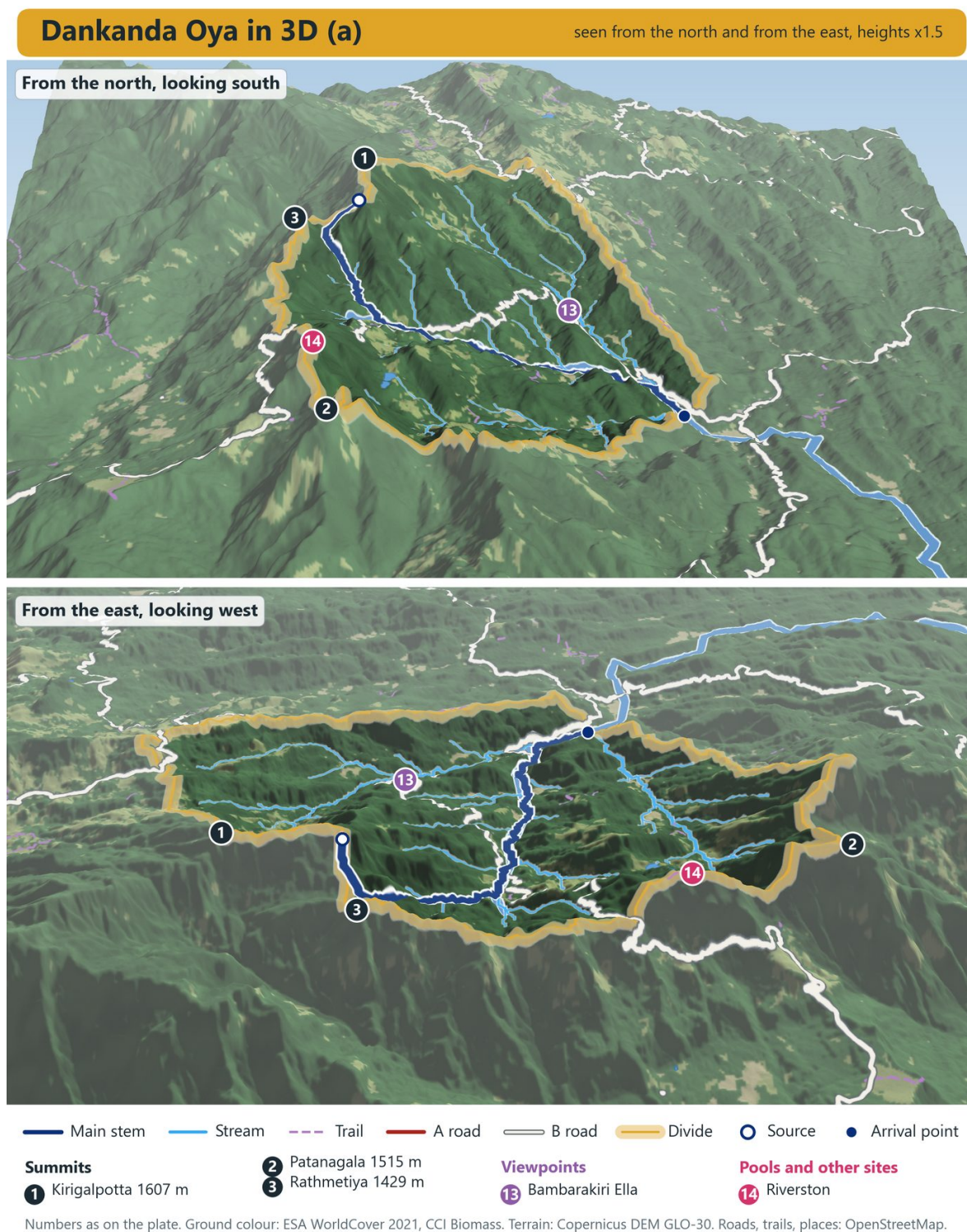


Figure 34. Dankanda Oya in three dimensions, seen from the north (top) and from the east (bottom), as in Figure 13.

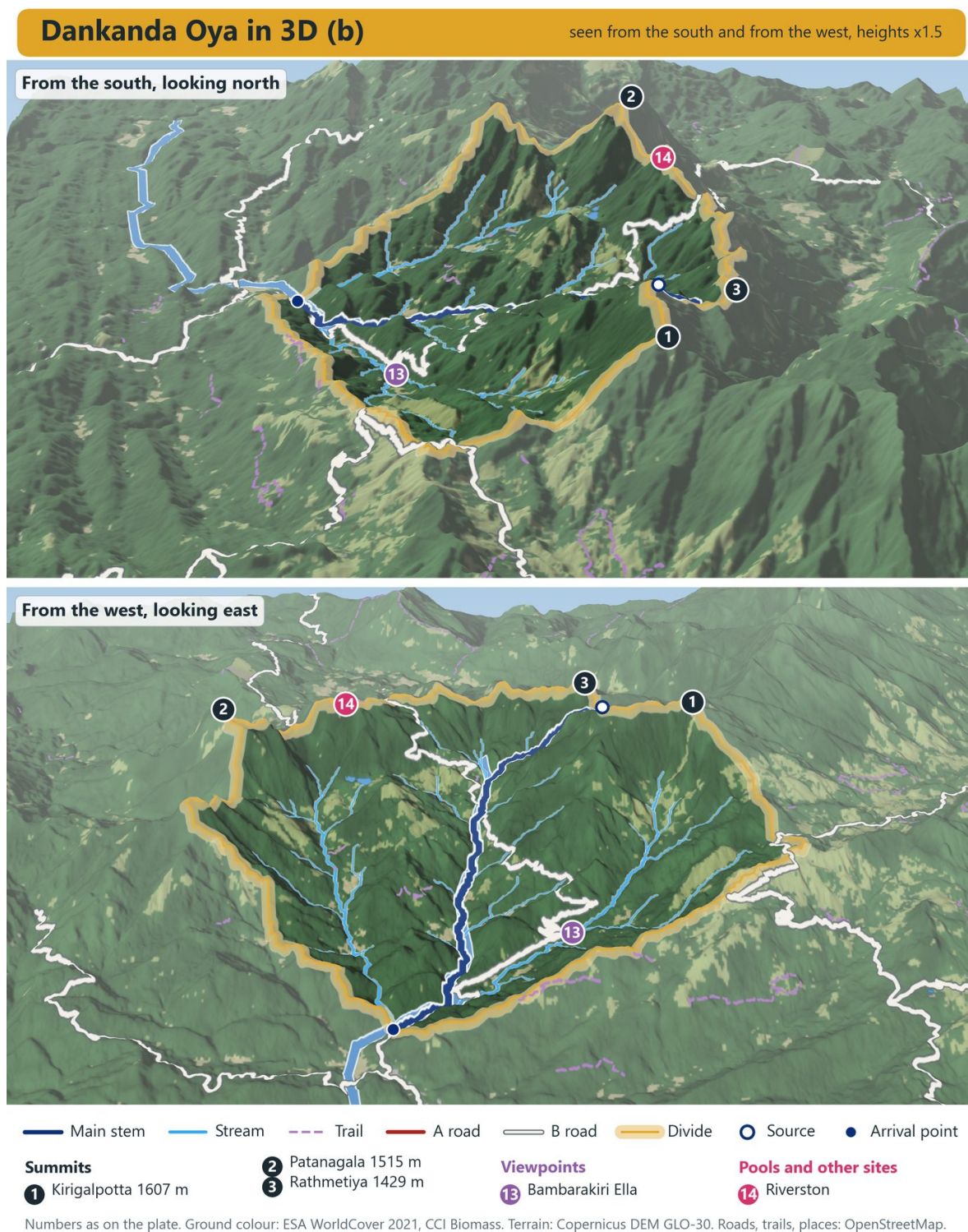


Figure 35. Dankanda Oya in three dimensions, seen from the south (top) and from the west (bottom), as in Figure 13.

Kehelpathdoruwegala appears 361 m below its published height, so its mapped point is probably not on the summit. Peak heights on the maps are therefore labelled as DEM summits and should not replace survey heights.

The channel threshold of 0.3 km² shows the streams a walker meets on the main valleys, but not every spring or seep. Order and drainage density depend on the threshold, so the values in Table 4 compare the six streams with each other, not with studies that used other thresholds. The sources are the heads of the longest flow paths on the DEM. They show where the longest thread of water begins, and on the ground the first trickle may be a few hundred metres away, or may flow only in the wet season. Bandarattillake's rule that streams rising above about 1067 m flow all year [3] applies to all six sources, which lie between 1547 and 1869 m.

The places along each stream come from OpenStreetMap, which is complete for some valleys and thin for others. The Hulu Ganga lists 28 villages and the Kalu Ganga two, which reflects real differences in settlement but also in mapping. Names in OpenStreetMap also vary in spelling, and the same waterfall is sometimes mapped twice. Duplicates were merged and obvious slips corrected (for example "Heen Gaga" to "Heen Ganga" and "Ratha Ella" to "Rathna Ella"), but local names should be checked on the ground.

8.2. *Why Delineate to the Arrival Point*

Catchments are often clipped to a forest or administrative boundary, which describes the land but not the water. Here each catchment runs to the point where its water arrives at a larger river or reservoir. A catchment defined this way answers a walker's question, where does this stream go, and a planner's question, what feeds this reservoir. It also gives a single, testable area for each stream. The agreement with independent delineations (within 1%), with the Teldeniya gauge and with the published share of Victoria's catchment supports the method.

The most error-prone step was finding the pour point. Two failures were instructive. Taking the cell of greatest flow accumulation near a confluence picks the larger river, not the tributary. A test for a jump in accumulation, which works at confluences, fails where a stream enters a reservoir, because a reservoir gives no such jump. Both were avoided by following each stream's own mapped course to its end, or by finding the cell where flow enters or leaves the reservoir. For one stream a plausible-looking result proved wrong when checked by overlap with an independent delineation, although its area alone looked right. Overlap with known geometry is a better test than area.

8.3. *The Forest as a Water Store*

Only 140 km², or 18%, of the six catchments lies above 1067 m, yet this is the ground that keeps 62% of the channel length flowing through the dry season (Figure 5). Most of it, 80%, lies inside the mapped conservation forest: all of it in the Heen Ganga and Kalu Ganga, and 88 to 97% in the Dankanda Oya, Thelgamu Oya and Hasalaka Oya. The exception is the Hulu Ganga. It has the largest area of high ground, 56 km² or a third of its catchment, and after the small Dankanda Oya the highest perennial share (77%), but only 55% of its high ground lies within the forest outline. The rest includes the estates and villages of its upper slopes, such as Kelebokka and Madulkelle. Bandarattillake [3] argued that protecting and enriching the forest of the source areas would raise dry-season flow, because more rain would soak into the soil instead of running off. The maps give that argument a geography. The forest that feeds the perennial streams is small and mostly protected already, and the largest unprotected part of it lies on the upper Hulu Ganga, which feeds Victoria. There, and wherever cardamom is grown under the forest canopy [10], the use of the land and the supply of water meet most closely.

8.4. *Where the Water Is Going Next*

The water of the Knuckles is being drawn further north. The North Central Province Canal Program, of which the Mahaweli Water Security Investment Program is the first phase, will move about 1100 million m³ a year from the Mahaweli basin to the northern provinces when complete: about

1040 million m³ for 84,000 ha of irrigation and 160 million m³ for community water supply [1]. Its first works start at the reservoirs of this guide. The Upper Elahera Canal Project links the Kalu Ganga and Moragahakanda reservoirs by a 9 km transfer canal, 8 km of it in tunnel, and carries water from Moragahakanda along 82 km of canal, including a 26 km tunnel, to the Huruluwewa, Manankattiya, Eruwewa and Mahakanadarawa tanks [1]. By August 2024 the transfer canal was nearly complete, and about 12 km of the 28 km of tunnel on the northern canal had been bored [2]. The North Western Province Canal Project will take a further 130 million m³ a year from the Dambulu Oya, which receives water from Bowatenna downstream of the Dankanda Oya, and from the Nalanda and Wemedilla reservoirs [1]. Later stages were planned to bring in the eastern streams as well: a Randenigala to Kalu Ganga transfer canal with supplementary inflows from reservoirs on the Hasalaka Oya and the Heen Ganga, which were also proposed for small hydropower stations of 11 and 6 MW [31].

Read with this guide, these plans mean that the water of every one of the six streams is, or is planned to be, part of the supply of the northern dry zone. In the 1960s the three gauged streams alone carried about 830 million m³ a year (Table 5), more than the gross storage of Victoria and about three quarters of the volume that the canal program is to move north. The same assessment reports that the mean annual flow of the Mahaweli at Polgolla, upstream of the Knuckles streams, fell by about 20% between the 1940s and the 2000s [1]. Yet the only published flow records from the Knuckles end with the closure of the Kalu Ganga station in 1972 [3]. Gauges at or near the old stations at Teldeniya, Wellewala and Uduwelwala, where the 1960s records can serve as a baseline, would cost little beside the canal program. They would show how much water the range gives now, in which season, and how that changes with the forest and the climate.

8.5. Testing the 1067 m Rule

The perennial map rests on one field rule from the 1980s, and it can be tested by the people this guide is written for. A walker who crosses a stream between May and September can note the date, the place and whether the stream is flowing, standing in pools or dry. Every crossing on the trails of Figure 7 has a predicted state in Figure 5. A season of such notes, shared with the forest authorities or through an open map, would show where the rule holds, whether the boundary lies higher or lower than 1067 m on the wet western and the drier eastern slopes, and whether it moves as the rainfall changes. A dry stream that the map calls perennial is as useful a record as a flowing one.

8.6. For Those Who Walk the Streams

The Conservation Forest is protected, and entry needs permission from the forest authorities [13]. Many of the pools and falls in this guide lie inside it. Streams in these steep valleys rise quickly in heavy rain, so crossings that are easy in the dry months can become dangerous during the north-east monsoon from October to January. The damage left by Cyclone Ditwah in 2025 [6] is a reminder of how violent these waters can be. The streams also rise quickly (Table 7). By the two formulas of Section 3.10, rain on the upper slopes reaches the arrival point of the Dankanda Oya in about 1 to 2 hours, and that of the Heen Ganga in about 3 to 6 hours. At a pool or a crossing high in the valley it arrives sooner still. A storm on the ridge can therefore raise a stream that is calm under a clear sky, within the time of a walk. Walkers should leave stream beds and pools when rain falls upstream, even if none falls where they stand, and should not cross a stream that is rising or has turned muddy.

Table 7. Indicative time of concentration of each stream at its arrival point (Equation 4). The two formulas bracket the likely response; neither is a forecast.

Stream	Area (km ²)	Main stem (km)	Kirpich (h)	Giandotti (h)
Dankanda Oya	41.3	8.6	0.7	2.1
Kalu Ganga	125.8	22.7	2.1	4.4
Hasalaka Oya	128.4	24.5	2.3	4.4
Thelgamu Oya	101.8	27.8	2.5	4.5
Hulu Ganga	166.9	29.4	3.1	5.4
Heen Ganga	197.7	32.0	3.1	6.3

Walkers who keep to existing paths, carry out what they carry in and leave the stream banks as they found them help protect the water that a large part of the country uses.

9. Conclusions

Six streams rising in the Knuckles were mapped from source to arrival point, with hydrological methods that can be repeated and checked. The main findings are these.

1. The six catchments, each delineated to where its water arrives, cover 761.9 km² and drain 87% of the mapped conservation forest.
2. The main stems fall 1187 to 1706 m, most of it in their first few kilometres. Reaches of 10% or steeper make up 27% of the channel length but hold 7 of the 12 mapped waterfalls.
3. By Bandaratilake's rule, 62% of the channel length flows all year. It is fed from only 140 km² of ground above 1067 m, of which 80% lies inside the forest, but only 55% on the upper Hulu Ganga.
4. The streams respond to heavy rain within about 1 to 6 hours at their arrival points, and faster in their upper valleys.
5. Their water reaches the sea at Koddigar Bay after 162 to 229 km, or, more and more, the tanks and fields of the northern dry zone, through the canals built and being built from Bowatenna, the Kalu Ganga Reservoir and Moragahakanda.

Three steps would build on this guide: protecting the high ground above 1067 m, above all on the upper Hulu Ganga; restoring stream gauges at or near the stations of the 1960s; and asking walkers to record dry-season flow at the crossings they use, to test the perennial map. The same methods can be applied to the other streams of the range and to the other components of the Central Highlands.

For a walker, the guide turns a pool, a waterfall or a crossing into part of a whole stream: where its water began, how steeply it fell, whether it will still be flowing in August, and where it is going. The pools of the Heen Ganga, the falls of the Kalu Ganga and the long valley of the Thelgamu Oya are the first kilometres of a water supply on which a large part of the country depends. The three drops that fell together on Gombaniya may never meet again. One may turn the turbines at Victoria and reach the sea; the others may end in a tank near Huruluwewa. All three began within a few metres of each other, in forest that walkers know by its pools and its falls.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The GeoPackage of catchments, streams, main stems and places, the analysis scripts and the QGIS projects for every figure are available from the author on request. Copernicus DEM, ESA WorldCover, ESA CCI Biomass and OpenStreetMap data are openly available from their providers.

Acknowledgments: The author thanks the contributors to OpenStreetMap, whose mapping of roads, trails, villages and waterfalls makes the places in this guide findable. During the preparation of this manuscript the author used Claude (Anthropic), a generative AI tool, to assist with writing: drafting and editing the text. It was

also used to help write the analysis and mapping scripts. The author reviewed and edited all output and takes full responsibility for the content of this publication.

Conflicts of Interest: The author declares no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CCI	Climate Change Initiative (European Space Agency)
D8	eight-direction single flow routing
DEM	digital elevation model
ESA	European Space Agency
GLO-30	Copernicus global 30 m DEM
SLD99	Sri Lanka Datum 1999 (EPSG:5235)

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