

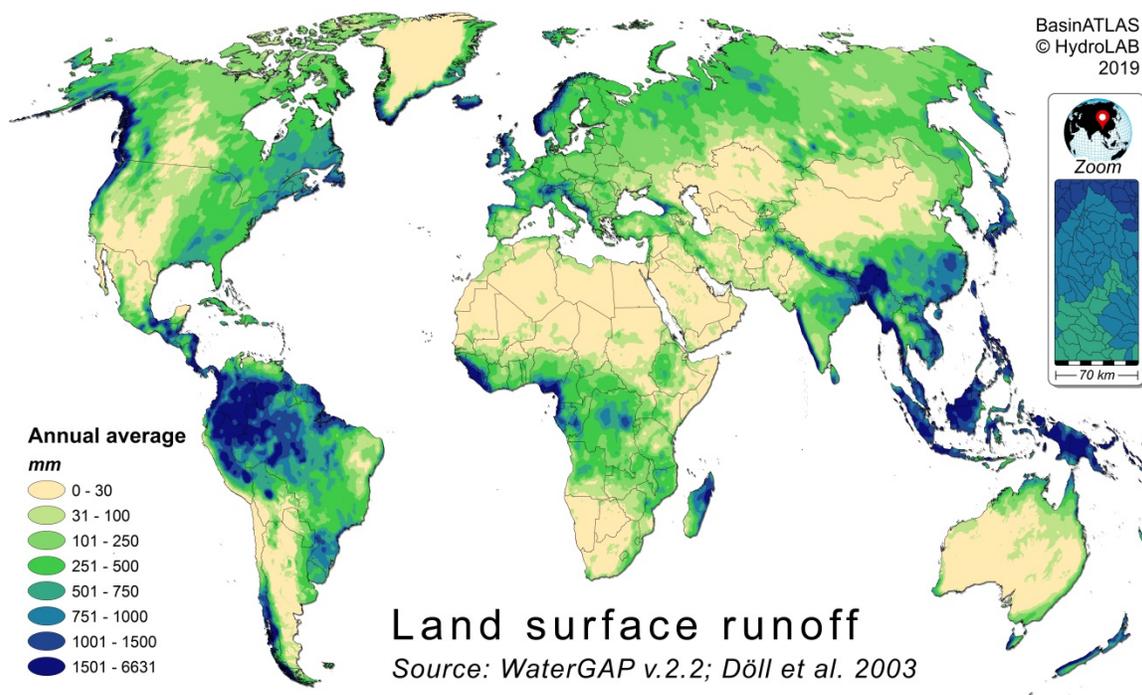
HydroATLAS

*A global compendium of hydro-environmental sub-basin and river reach characteristics
at 15 arc-second resolution*

Technical Documentation Version 0.6

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1. Background and introduction

The goal of HydroATLAS is to provide a broad user community with a standardized compendium of hydro-environmental attribute information for all watersheds and rivers of the world at high spatial resolution. Version 0.6 of HydroATLAS offers a set of 54 variables organized in six categories: hydrology; physiography; climate; land cover & use; soils & geology; and anthropogenic influences (Table 1 and Appendix 1). HydroATLAS derives the hydro-environmental attributes by reformatting original data from well-established global digital maps. The attributes are then linked

to hierarchically nested sub-basins at multiple scales, as well as to individual river reaches, both extracted from the global HydroSHEDS database at 15 arc-second (~500 m) resolution. The sub-basin and river reach information is offered in two companion datasets: BasinATLAS and RiverATLAS. The standardized format of HydroATLAS ensures easy applicability while the inherent topological information supports basic network functionality such as identifying up- and downstream connections. HydroATLAS is fully compatible with other products of the overarching HydroSHEDS project enabling versatile hydro-ecological assessments. Updates of HydroATLAS are envisioned as new data become available.

The HydroATLAS documentation is organized in two parts: Part 1 (this document) provides an overview of the database and general explanations. Part 2 is provided in two alternative files: 'BasinATLAS_Catalog' or 'RiverATLAS_Catalog'. Each catalog file first provides a summary table listing all hydro-environmental attributes and their basic characteristics. This is followed by detailed information on each individual attribute, including source data descriptions, units, conversion methodology, and citations. Each attribute is presented in the two catalogs on one standardized sheet which includes a map at global extent indicating the spatial distribution of values of the respective attribute. Note that the summary table and information sheets within each catalog are hyperlinked.

The development of HydroATLAS is fully described in Linke et al. (2019). For data citations and acknowledgements see section 4.4 below. General citations of HydroATLAS should refer to:

Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019): Global compendium of hydro-environmental characteristics at sub-basin and river reach scales. Under review.

Table1. Categories of hydro-environmental attributes presented in the HydroATLAS database

Identifier	Category	Description
H	Hydrology & hydrography	Hydrological and hydrographic characteristics related to quantity, quality, location and extent of terrestrial water <i>Examples: natural runoff and discharge, groundwater table depth, lake cover</i>
P	Physiography	Topographic characteristics related to terrain, relief or landscape position <i>Examples: elevation, slope</i>
C	Climate	Climatic characteristics <i>Examples: mean temperature, climate moisture index, global aridity</i>
L	Land cover & land use	Land cover and land use characteristics including biogeographic regions <i>Examples: land cover classes, permafrost extent, freshwater ecoregions</i>
S	Soils & Geology	Soil and geology related characteristics including substrate types and soil conditions <i>Examples: percentage clay in soil, soil water stress, lithography, karst</i>
A	Anthropogenic influences	Anthropogenic characteristics including demographic and socioeconomic aspects <i>Examples: population density, human footprint, GDP per capita</i>

2. Methods and data characteristics

The methods used to create HydroATLAS are fully described in Linke et al. (2019). All spatial units of HydroATLAS, i.e. either sub-basin polygons or river reach lines, were extracted from World Wildlife Fund's HydroSHEDS database (Lehner et al. 2008; Lehner and Grill 2013) at a grid resolution of 15 arc-seconds (approx. 500 m at the equator). For more information please refer to the Technical Documentations of HydroSHEDS at <http://www.hydrosheds.org>.

HydroATLAS consists of two complementary parts: BasinATLAS and RiverATLAS. BasinATLAS provides hydro-environmental attributes for sub-basins (polygons). RiverATLAS provides hydro-environmental attributes for stream and river reaches (line segments).

Basin and sub-basin delineations have been pre-processed as a customized derivative of HydroSHEDS at 15 arc-second resolution and are available as a stand-alone product termed HydroBASINS (Lehner and Grill 2013). HydroBASINS offer a suite of 12 layers, each containing nested sub-basins that were subdivided and coded using the topological concept of the Pfafstetter system, which provides a methodology for the breakdown of sub-basins at different scales in a hierarchical and systematic manner (Figure 1a).

A global river network delineation has been extracted from HydroSHEDS at 15 arc-second resolution and is available as a stand-alone product termed HydroRIVERS (available at <http://www.hydrosheds.org>). For this network, rivers have been defined to start at all pixels where the accumulated upstream catchment area exceeds 10 km², or where the long-term average natural discharge exceeds 0.1 cubic meters per second, resulting in a line network consisting of individual stream and river reaches (Figure 1b).

It should be noted that the quality of HydroSHEDS data is significantly inferior for regions above 60 degrees northern latitude as there is no underlying SRTM elevation data available and thus a coarser scale DEM has been inserted (HYDRO1k provided by USGS).

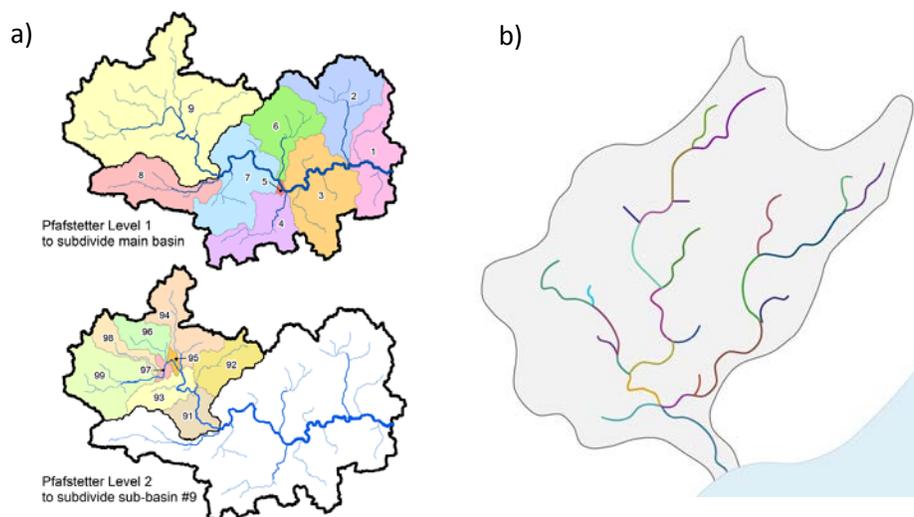


Figure 1: Overview of Pfafstetter sub-basin coding scheme used in BasinATLAS (a); and river reach concept used in RiverATLAS (b). Sub-basins are nested within 12 hierarchical levels. A river reach is defined as a stretch between two tributaries, or between the start/end of the network and a tributary.

3. Data format and distribution

a) Data format and projection

HydroATLAS is publicly available for download at <http://www.hydrosheds.org/page/hydroatlas>. All map data layers, including attribute tables, are provided in ESRI© Geodatabase and Shapefile formats. The data is projected in a Geographic Coordinate System using the World Geodetic System 1984 (GCS_WGS_1984). The attribute table can also be accessed as a stand-alone file in dBASE format which is included in the Shapefile format.

HydroATLAS data is available electronically in compressed zip file format. To use the data files, the zip files must first be decompressed. Each zip file includes a copy of the HydroATLAS Technical Documentation.

b) Available columns and column name syntax

The attribute tables of HydroATLAS contain the pre-existing columns of HydroBASINS and HydroRIVERS, respectively. The hydro-environmental attributes are then appended in a series of additional columns. This section provides information on the column name syntax used for the identification of each sub-basin or river reach attribute provided in the HydroATLAS database. All existing attributes and their associated column names are summarized in Appendix 1 and at the beginning of the individual documents BasinATLAS_Catalog or RiverATLAS_Catalog.

Each hydro-environmental attribute column name has 10 digits (for example 'dis_m3_s01') and its syntax is as follows:

<Layer name key>_<Unit key>_<Spatial key><Aggregation key>

Layer name key:

Three digits that describe the name of the attribute. The layer name key is unique to the attribute it represents. *Example: 'dis' for discharge.*

Unit key:

Two digits that describe the value units of the attribute. See Table 2 for possible keys.

Spatial key:

One digit that describes the spatial extent of the attribute. See Table 3 for possible keys.

Aggregation key:

Two digits that describe the type or dimension of aggregation of the attribute. The aggregation key can refer to a temporal dimension, spatial dimension, or statistical dimension. See Table 4 for possible keys.

Table 2: Unit keys

Key	Unit of values
cl	Classes
dc	Degrees Celsius (°C)
dg	Degrees
ha	Hectares
id	ID number
ix	Index value
km	Kilometers
m3	Cubic meters per second (m ³ /s)
mc	Million cubic meters (mcm)
mm	Millimeters
mt	Meters <i>or</i> Meters above sea level (m.a.s.l.)
pc	Percent <i>or</i> Percent cover
pd	Population density (people per km ²)
pp	People count
sk	Square kilometers
th	Tonnes per hectare
ud	US dollars

Table 3: Spatial keys

Key	Spatial representation
c	In reach catchment <i>or</i> Mean of reach catchment
p	At sub-basin pour point <i>or</i> At reach pour point
r	Along reach segment
s	In sub-basin <i>or</i> Mean of sub-basin
u	In total watershed upstream of sub-basin pour point <i>or</i> Mean of total watershed upstream of sub-basin pour point <i>or</i> In total watershed upstream of reach pour point <i>or</i> Mean of total watershed upstream of reach pour point

Table 4: Aggregation keys

Key	Temporal, Spatial, or Statistical Dimension
01-12	Monthly average (number represents calendar month January to December)
01-99	Spatial extent (%) by class
av	Average
g1-g9	Spatial extent (%) by class grouping
lt	Long-term maximum
mj	Majority (dominant value)
mn	Minimum <i>or</i> Annual minimum
mx	Maximum <i>or</i> Annual maximum
se	Spatial extent (%)
su	Sum
va	Value
yr	Annual average

4. License, disclaimer and acknowledgement

4.1 License agreement



All attribute columns of HydroATLAS (version 1.0) are licensed under either a Creative Commons Attribution 4.0 International License (CC-BY 4.0; <http://creativecommons.org/licenses/by/4.0/>) or an Open Data Commons Open Database License (ODbL 1.0; <https://opendatacommons.org/licenses/odbl/1-0/index.html>), both permitting reuse of the data for any purpose including commercial. Note that the original licenses of the underpinning source datasets are not affected or altered by these licenses. In cases where original licenses differ from CC-BY 4.0 or ODbL 1.0, special permission was obtained from the original author(s) to release the derivatives of their works as provided in HydroATLAS under a CC-BY 4.0 or ODbL 1.0 license. Detailed information regarding the specific license that applies to each attribute column is provided in the respective data sheet of the BasinATLAS or RiverATLAS catalog, respectively.

By downloading and using the data the user agrees to the terms and conditions of these licenses.

4.2 Disclaimer of warranty

The HydroATLAS database and any related materials contained therein are provided “as is,” without warranty of any kind, either express or implied, including, but not limited to, the implied warranties of merchantability, fitness for a particular purpose, noninterference, system integration, or noninfringement. The entire risk of use of the data shall be with the user. The user expressly acknowledges that the data may contain some nonconformities, defects, or errors. The authors do not warrant that the data will meet the user's needs or expectations, that the use of the data will be uninterrupted, or that all nonconformities, defects, or errors can or will be corrected. The authors are not inviting reliance on these data, and the user should always verify actual data.

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In no event shall the authors be liable for costs of procurement of substitute goods or services, lost profits, lost sales or business expenditures, investments, or commitments in connection with any business, loss of any goodwill, or for any direct, indirect, special, incidental, exemplary, or consequential damages arising out of the use of the HydroATLAS database and any related materials, however caused, on any theory of liability, and whether or not the authors have been advised of the possibility of such damage. These limitations shall apply notwithstanding any failure of essential purpose of any exclusive remedy.

4.4 Data citations and acknowledgements

When using an attribute contained in HydroATLAS, citations and acknowledgements should be made to both the original data source and the HydroATLAS compendium. For example, the following template illustrates a reference to precipitation data sourced from HydroATLAS:

“Precipitation data from the WorldClim v1.4 database (Hijmans et al. 2005) has been used in the spatial format as provided by HydroATLAS v1.0 (Linke et al. 2019).”

Information regarding the reference(s) for each hydro-environmental attribute is provided on the individual attribute sheets in BasinATLAS_Catalog and RiverATLAS_Catalog. In addition, every data source may have individual requests for acknowledgements, and users of HydroATLAS are asked to honor those requests when using the respective attributes.

General citations and acknowledgements of HydroATLAS should be made as follows:

Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019): Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific Data...

We kindly ask users to cite both source data and HydroATLAS in any published material produced using the data. If possible, online links to the HydroATLAS website should be provided (<http://www.hydrosheds.org/page/hydroatlas>).

5. References

Lehner, B., Grill G. (2013): Global river hydrography and network routing: baseline data and new approaches to study the world’s large river systems. *Hydrological Processes*, 27(15): 2171–2186.

Lehner, B., Verdin, K., Jarvis, A. (2008): New global hydrography derived from spaceborne elevation data. *Eos, Transactions, AGU*, 89(10): 93-94.

Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019): Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Under review. Data available at <http://www.hydrosheds.org/page/hydroatlas>.

Appendix 1: Attributes included in version 0.6 of HydroATLAS (for details see HydroATLAS catalogs)

HydroATLAS Attributes (version 0.6)						
ID	Category	Attribute	Source Data	Citation	Column(s)	#s
H01	Hydrology	Natural Discharge	WaterGAP v.2.2	Döll et al. 2003	dis_m3_---	x3
H02	Hydrology	Land Surface Runoff	WaterGAP v.2.2	Döll et al. 2003	run_mm_---	x1
H03	Hydrology	Inundation Extent	GIEMS-D15	Fluet-Chouinard et al. 2015	inu_pc_---	x6
H04	Hydrology	Limnicity (Percent Lake Area)	HydroLAKES	Messenger et al. 2016	lka_pc_---	x2
H05	Hydrology	Lake Volume	HydroLAKES	Messenger et al. 2016	lkv_mc_---	x1
H06	Hydrology	Reservoir Volume	GResD v.1.1	Lehner et al. 2011	rev_mc_---	x1
H07	Hydrology	Degree of Regulation	HydroSHEDS & GResD	Lehner et al. 2011	dor_pc_---	x1
H08	Hydrology	River Area	HydroSHEDS & WaterGAP	Lehner & Grill 2013	ria_sk_---	x2
H09	Hydrology	River Volume	HydroSHEDS & WaterGAP	Lehner & Grill 2013	riv_mc_---	x2
H10	Hydrology	Groundwater Table Depth	Global Groundwater Map	Fan et al. 2013	gwt_mt_---	x1
P01	Physiography	Elevation	EarthEnv-DEM90	Robinson et al. 2014	ele_mt_---	x4
P02	Physiography	Terrain Slope	EarthEnv-DEM90	Robinson et al. 2014	slp_dg_---	x2
P03	Physiography	Stream Gradient	EarthEnv-DEM90	Robinson et al. 2014	sgr_dg_---	x1
C01	Climate	Climate Zones	GENs	Metzger et al. 2013	clz_cl_---	x1
C02	Climate	Air Temperature	WorldClim v.1.4	Hijmans et al. 2005	tmp_dc_---	x16
C03	Climate	Precipitation	WorldClim v.1.4	Hijmans et al. 2005	pre_mm_---	x14
C04	Climate	Potential Evapotranspiration	Global-PET v.1	Zomer et al. 2008	pet_mm_---	x14
C05	Climate	Actual Evapotranspiration	Global Soil-Water Balance	Trabucco & Zomer 2010	aet_mm_---	x14
C06	Climate	Global Aridity Index	Global Aridity Index v.1	Zomer et al. 2008	ari_ix_---	x2
C07	Climate	Climate Moisture Index	WorldClim 1.4 & Global-PET	Hijmans et al. 2005	cmi_ix_---	x14
C08	Climate	Snow Cover Extent	MODIS/Aqua	Hall & Riggs 2016	snw_pc_---	x15
L01	Landcover	Land Cover Classes	GLC2000	Bartholomé & Belward 2005	glc_cl_---	x1
L02	Landcover	Land Cover Extent	GLC2000	Bartholomé & Belward 2005	glc_pc_---	x44
L03	Landcover	Potential Natural Vegetation Classes	EarthStat	Ramankutty & Foley 1999	pnv_cl_---	x1
L04	Landcover	Potential Natural Vegetation Extent	EarthStat	Ramankutty & Foley 1999	pnv_pc_---	x30
L05	Landcover	Wetland Classes	GLWD	Lehner & Döll 2004	wet_cl_---	x1
L06	Landcover	Wetland Extent	GLWD	Lehner & Döll 2004	wet_pc_---	x22
L07	Landcover	Forest Cover Extent	GLC2000	Bartholomé & Belward 2005	for_pc_---	x2
L08	Landcover	Cropland Extent	EarthStat	Ramankutty et al. 2008	crp_pc_---	x2
L09	Landcover	Pasture Extent	EarthStat	Ramankutty et al. 2008	pst_pc_---	x2
L10	Landcover	Irrigated Area Extent	HID v.1.0	Siebert et al. 2015	ire_pc_---	x2
L11	Landcover	Glacier Extent	GLIMS	GLIMS & NSIDC 2012	gla_pc_---	x2
L12	Landcover	Permafrost Extent	PZI	Gruber 2012	prm_pc_---	x2
L13	Landcover	Protected Area Extent	WDPA	IUCN & UNEP-WCMC 2014	pac_pc_---	x2
L14	Landcover	Terrestrial Biomes	TEOW	Dinerstein et al. 2017	tbi_cl_---	x1
L15	Landcover	Terrestrial Ecoregions	TEOW	Dinerstein et al. 2017	tec_cl_---	x1
L16	Landcover	Freshwater Major Habitat Types	FEOW	Abell et al. 2008	fmh_cl_---	x1
L17	Landcover	Freshwater Ecoregions	FEOW	Abell et al. 2008	fec_cl_---	x1
S01	Soils & Geology	Clay Fraction in Soil	SoilGrids1km	Hengl et al. 2014	cly_pc_---	x2
S02	Soils & Geology	Sand Fraction in Soil	SoilGrids1km	Hengl et al. 2014	snd_pc_---	x2
S03	Soils & Geology	Silt Fraction in Soil	SoilGrids1km	Hengl et al. 2014	slt_pc_---	x2
S04	Soils & Geology	Organic Carbon Content in Soil	SoilGrids1km	Hengl et al. 2014	soc_th_---	x2
S05	Soils & Geology	Soil Water Content	Global Soil-Water Balance	Trabucco & Zomer 2010	swc_pc_---	x14
S06	Soils & Geology	Lithological Classes	GLiM	Hartmann & Moosdorf 2012	lit_cl_---	x1
S07	Soils & Geology	Karst Area Extent	Rock Outcrops v.3.0	Williams & Ford 2006	krst_pc_---	x2
A01	Anthropogenic	Population Count	GPW v.4	CIESIN 2016	gpw_pp_---	x2
A02	Anthropogenic	Population Density	GPW v.4	CIESIN 2016	gpw_pd_---	x2
A03	Anthropogenic	Urban Extent	GHS S-MOD v.2016	Pesaresi & Freire 2016	ubx_pc_---	x2
A04	Anthropogenic	Nighttime Lights	Nighttime Lights v.4	Doll 2008	nli_ix_---	x2
A05	Anthropogenic	Road Density	GRIP v.4	Meijer et al. 2018	rdd_pc_---	x2
A06	Anthropogenic	Human Footprint	Human Footprint v.2	Venter et al. 2016	hft_ix_---	x4
A07	Anthropogenic	Global Administrative Areas	GADM	University of Berkeley 2012	gad_id_---	x1
A08	Anthropogenic	Gross Domestic Product	GDP PPP v.2	Kummu et al. 2018	gdp_ud_---	x3
A09	Anthropogenic	Human Development Index	HDI v.2	Kummu et al. 2018	gni_ix_---	x1