WORLD RESOURCES INSTITUTE

Working Paper

AQUEDUCT METADATA DOCUMENT

MEKONG RIVER BASIN STUDY

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EXECUTIVE SUMMARY

Prior to the creation of the global Aqueduct Water Risk Atlas, indicators (Table 1) were developed and tested in a number of river basins worldwide. The results of these Basin Studies helped inform and shape the global Aqueduct Water Risk Framework. Complete guidelines and processes for indicator selection, data collection, calculations, and mapping techniques are described fully in the Aqueduct Water Risk Framework.[1] This study focuses on the specific characteristics of the indicator data and calculation in the Mekong River Basin (MRB).

Table 1 | **Aqueduct Indicators**

Baseline water stress	Drought severity	Upstream protected land
Inter-annual variability	Upstream storage	Media coverage
Seasonal variability	Return flow ratio	Access to water
Flood occurrence	Water quality (3 indicators)	Threatened amphibians

The data selection and validation process for the Mekong River Basin Study involved three steps: (1) a literature review, (2) identification of data sources in the public domain, and (3) the compilation and expert review of selected data sources. Calculation of 6 of the 14 indicators required the creation of original datasets to estimate water availability and use at a subbasin scale.

CONTENTS

Suggested Citation: Gassert, F., P. Rai, P. Reig, and M. Luck. 2012. "Mekong River Basin Study." Working Paper. Washington, DC: World Resources Institute. Available online at http://wri.org/publication/aqueduct-metadata-mekong-river-basin.

The hydrological catchments used in the exercise were extracted from the Global Drainage Basin Database developed by Masutomi et al.[2] Computation of the original datasets was completed by ISciences, L.L.C.

Two measures of water use were used in this study: total withdrawal, the total amount of water abstracted from freshwater sources for human use, and consumptive use, the portion of withdrawn water that evaporates or is incorporated into a product thus is no longer available for further use. Withdrawals for the Lower Mekong Basin (LMB) countries (Lao People's Democratic Republic, Thailand, Cambodia and Vietnam) are from the Mekong River Commission's (MRC) State of the Basin Report 2010. Withdrawals for the Upper Mekong Basin (UMB) (China and Myanmar) are extrapolated from the same data using a spatial regression based approach. Consumptive use is derived from total withdrawals based on consumptive use ratios by Shiklomanov and Rodda.[3] Both total withdrawal and consumptive use were coded at the hydrological catchment scale.

Two metrics of water supply were computed: total blue water and available blue water. Total blue water approximates natural river discharge and does not account for withdrawals or consumptive use. Available blue water is an estimate of surface water availability minus upstream consumptive use. Modeled estimates of water supply are calculated using a catchment-to-catchment flow accumulation approach developed by ISciences, L.L.C., which aggregates water by catchment and transports it to the next downstream catchment. Water supply is computed from runoff (R), the water available to flow across the landscape from a particular location, and is calculated as the remainder of precipitation (P) after evapotranspiration (ET) and change in soil moisture storage (ΔS) are accounted for (i.e., $R = P - ET - \Delta S$). The runoff data is courtesy of Sonessa et al.[4] Runoff is the output from a rainfall-runoff calibration model, using observed rainfall, stream flow, and land use to calibrate parameters and simulate runoff records similar to the observed record in the MRB over a common time period. Rainfall and the calibrated parameters are used to generate runoff values for 1951 to 2006.

The remainder of this document contains definitions, formulas, and data sources for the Mekong River Basin Study.

TOTAL WATER WITHDRAWAL

Description: *Total withdrawal* is the total amount of water removed from freshwater sources for human use.

Calculation: Water withdrawal data by country for the Lower Mekong River Basin were spatially disaggregated by sector based on regressions with spatial datasets selected to maximize the correlation with the reported withdrawals (irrigated areas for agricultural, nighttime lights for industrial, and population for domestic withdrawals). Withdrawals for the upper Mekong River Basin (i.e., for China and Myanmar) were extrapolated based on applying the spatial regression model used in the four Lower Mekong Basin countries to the Upper Mekong Basin.

Data Sources

VARIABLE	BASIN DELINEATIONS
Authors	Yuji Masutomi, Yusuke Inui, Kiyoshi Takahashi, and Yuzuru Matsuoka
Title	Development of Highly Accurate Global Polygonal Drainage Basin Data
Year of publication	2009
URL	http://www.cger.nies.go.jp/db/gdbd/gdbd_index_e.html
Resolution	1 sq.km.
Comments	The Mekong River Basin hydrological catchments are extracted from the Global Drainage Basin Database.

VARIABLE	GRIDDED POPULATION
Authors	Center for International Earth Science Information Network (CIESIN)/Columbia University, United Nations Food and Agriculture Programme (FAO), and Centro Internacional de Agricultura Tropical (CIAT)
Title	Gridded Population of the World Version 3 (GPWv3): Population Count Grid, Future Estimates
Year of publication	2005
Time covered in analysis	2007
URL	http://sedac.ciesin.columbia.edu/gpw
Resolution	2.5 arc minute raster

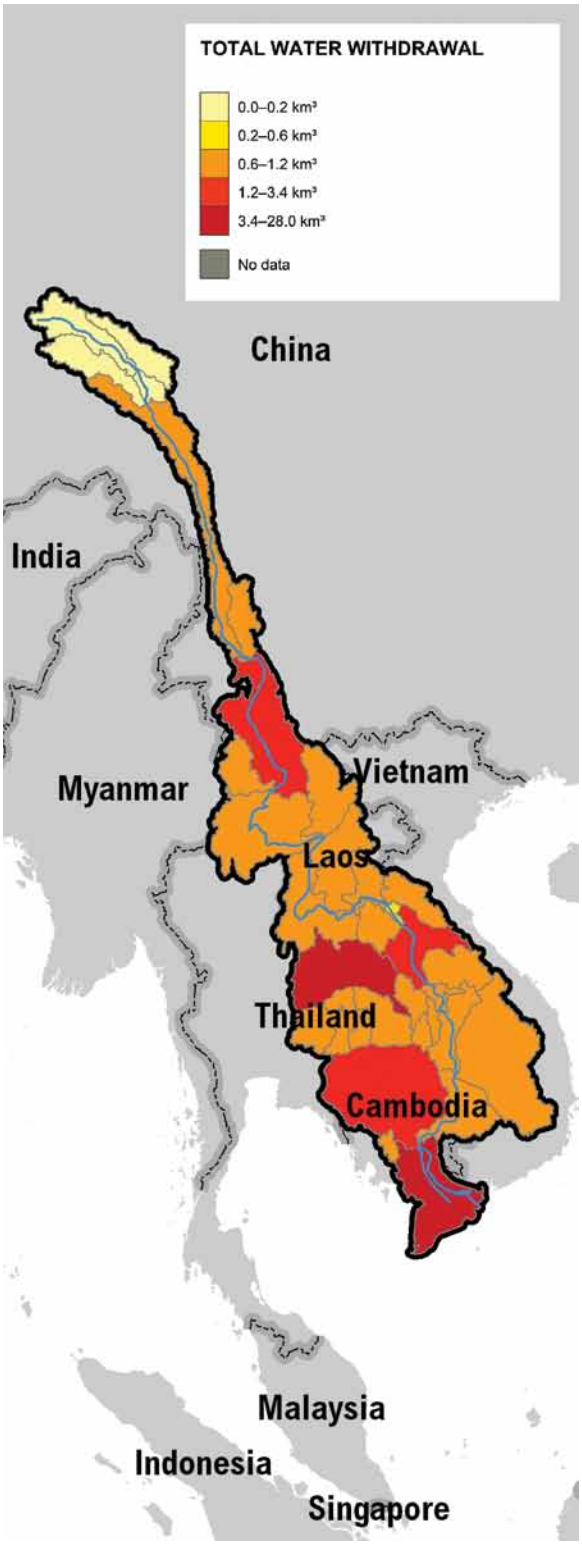
Data Sources

VARIABLE	NIGHTTIME LIGHTS
Author	NOAA National Geophysical Data Center (NGDC)
Title	Version 4 DMSP-OLS Nighttime Lights Time Series
Year of publication	2010
Time covered in analysis	2007
URL	http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html
Resolution	30 arc second raster

VARIABLE	GLOBAL IRRIGATION AREAS
Authors	S. Siebert, P. Döll, S. Feick, J. Hoogeveen, and K. Frenken
Title	Global Map of Irrigation Areas Version 4.0.1
Year of publication	2007
Time covered in analysis	2000
URL	http://www.fao.org/nr/water/aquastat/irrigationmap/index60.stm
Resolution	5 arc minute raster

VARIABLE	WITHDRAWALS BY SECTOR
Author	Mekong River Commission
Title	State of the Basin Report 2010
Year of publication	2010
Time covered in analysis	2007
URL	http://ns1.mrcmekong.org/free_download/State-of-the-Basin-Report.htm
Resolution	Country

Total Water Withdrawal



CONSUMPTIVE AND NON-CONSUMPTIVE USE

Description: *Consumptive use* is the portion of all water withdrawn that is consumed through evaporation or incorporation into a product, thus is no longer available for reuse. *Non-consumptive use* is the remainder of withdrawals that are not consumed and return to ground or surface water bodies.

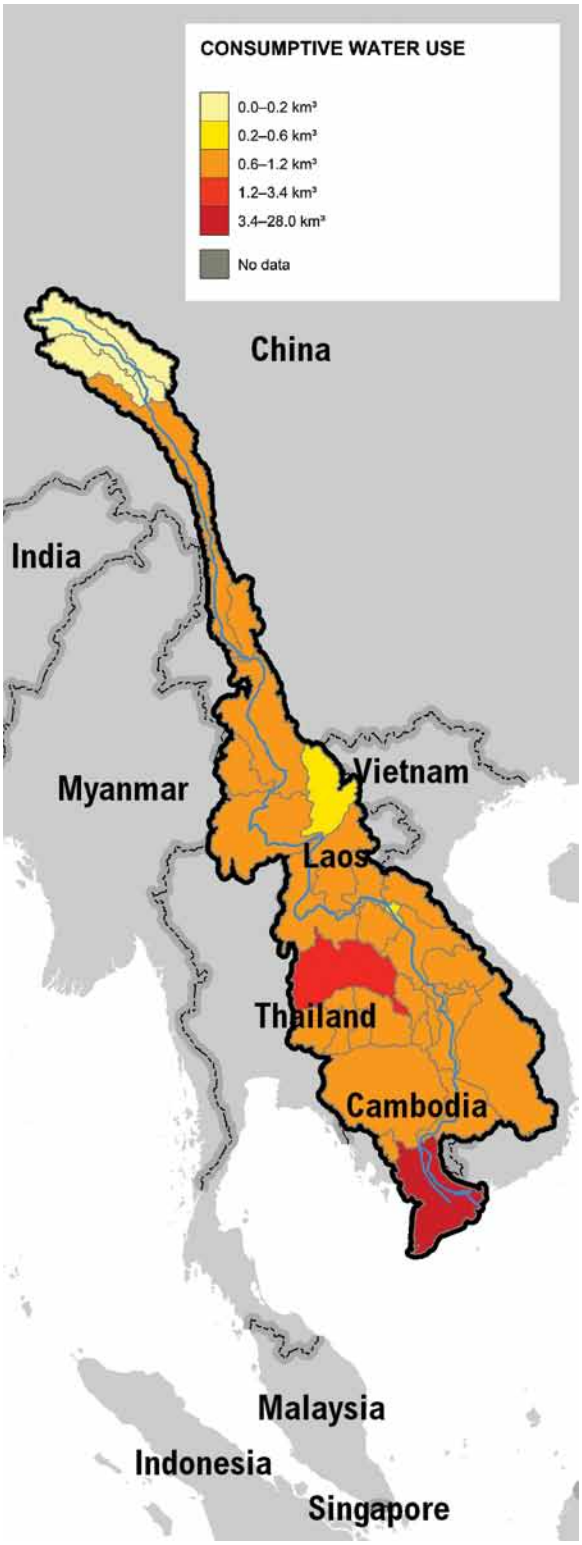
Calculation: Consumptive use by sector is estimated from total withdrawal using consumptive-use ratios developed by Shiklomanov and Rodda.

Data Sources

VARIABLE	WITHDRAWALS
Comments	See Total Withdrawal

VARIABLE	CONSUMPTIVE-USE RATIOS
Authors	I.A. Shiklomanov and John C. Rodda
Title	*World Water Resources at the Beginning of the Twenty-First Century* Cambridge University Press
Year of publication	2004
Resolution	Major regions

Consumptive Water Use



TOTAL BLUE WATER (BT)

Description: *Total blue water (Bt)* for each catchment is the accumulated runoff upstream of the catchment plus the runoff in the catchment.

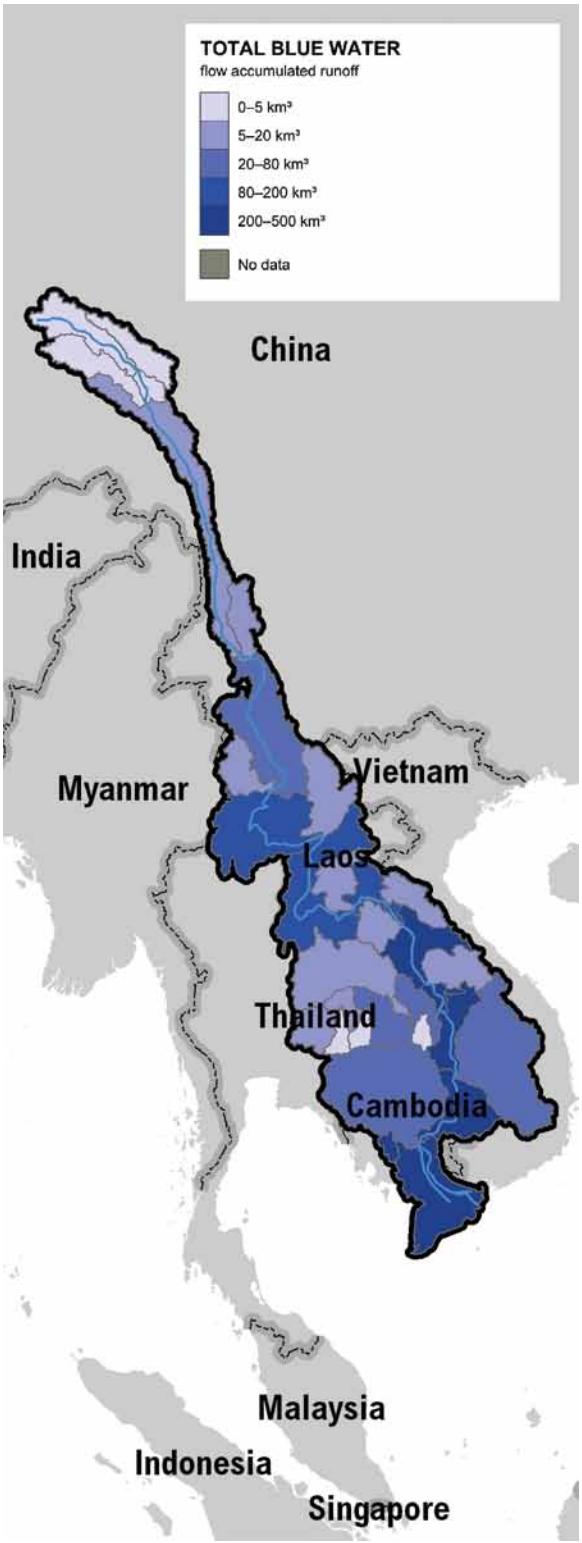
Calculation: Bt(i) = Rup(i) + R(i) where Rup(i) = ∑ Bt(iup), iup is the set of catchments immediately upstream of catchment i that flow into catchment i, and Rup(i) is the summed runoff in all upstream catchments. For first-order catchments (those without upstream catchments, e.g., headwater catchments), Rup(i) is zero, and total blue water is simply the volume of runoff in the catchment.

Data Sources

VARIABLE	BASIN DELINEATIONS
Comments	See Total Withdrawal

VARIABLE	RUNOFF
Authors	M.Y. Sonessa, J.E. Richey, and D.P. Lettenmaier
Title	*Evaluation of Water Balance Terms of the SEA with a Land Surface Model and ERA Interim Reanalysis*
Year of publication	(In prep)
Time covered in analysis	1951–2006
Resolution	¼ degree raster

Total Blue Water (BT)



AVAILABLE BLUE WATER (BA)

Description: *Available blue water (Ba)* is the total amount of water available to a catchment before any uses are satisfied. It is calculated as all water flowing into the catchment from upstream catchments minus upstream consumptive use plus the runoff in the catchment.

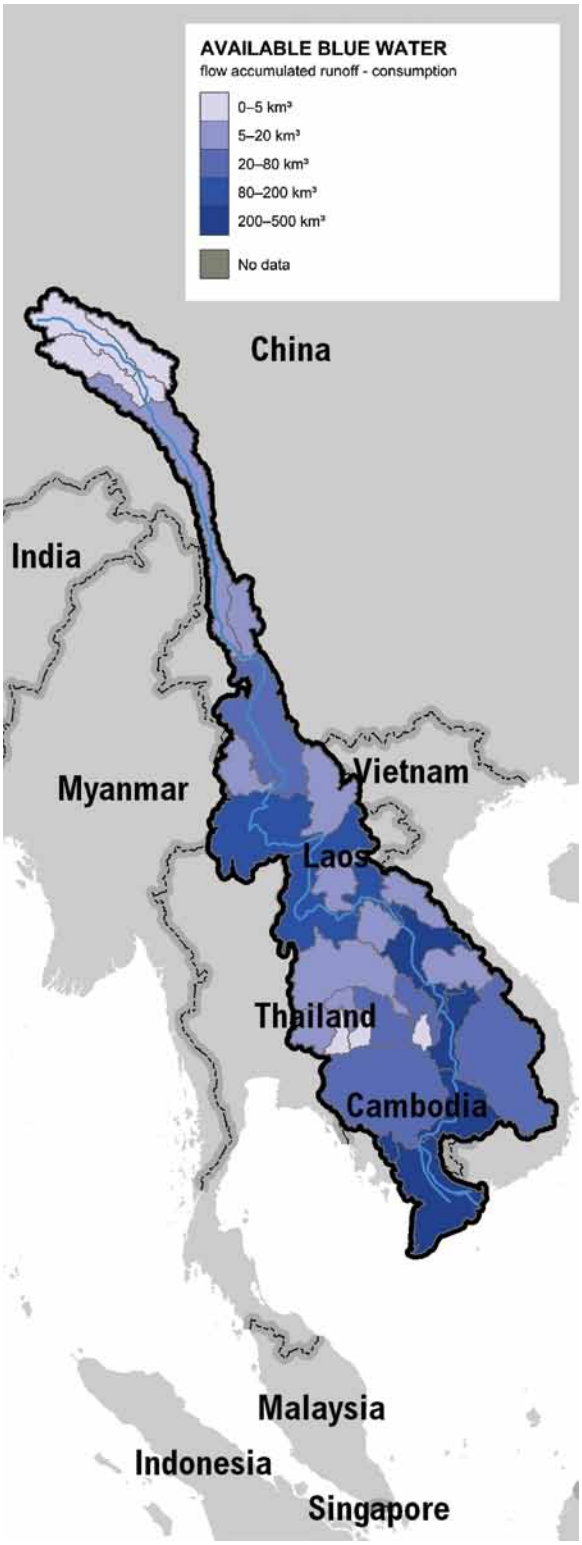
Calculation: Ba(i) = R(i) + ∑ Qout(iup) where Qout is defined as the volume of water exiting a catchment to its downstream neighbor: Qout(i) = max(0, Ba(i) – Uc(i)), Uc(i) are the consumptive uses in from catchment i. Negative values of Qout are set to zero. In first-order catchments ∑Qout(j) is zero, so available blue water is runoff plus imports.

Data Sources

VARIABLE	RUNOFF
Comments	See Total Blue Water

VARIABLE	CONSUMPTIVE USE
Comments	See Consumptive and Non-consumptive Use

Available Blue Water



BASELINE WATER STRESS

Description: *Baseline water stress* measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percentage of the total annual available blue water. Higher values indicate more competition among users.

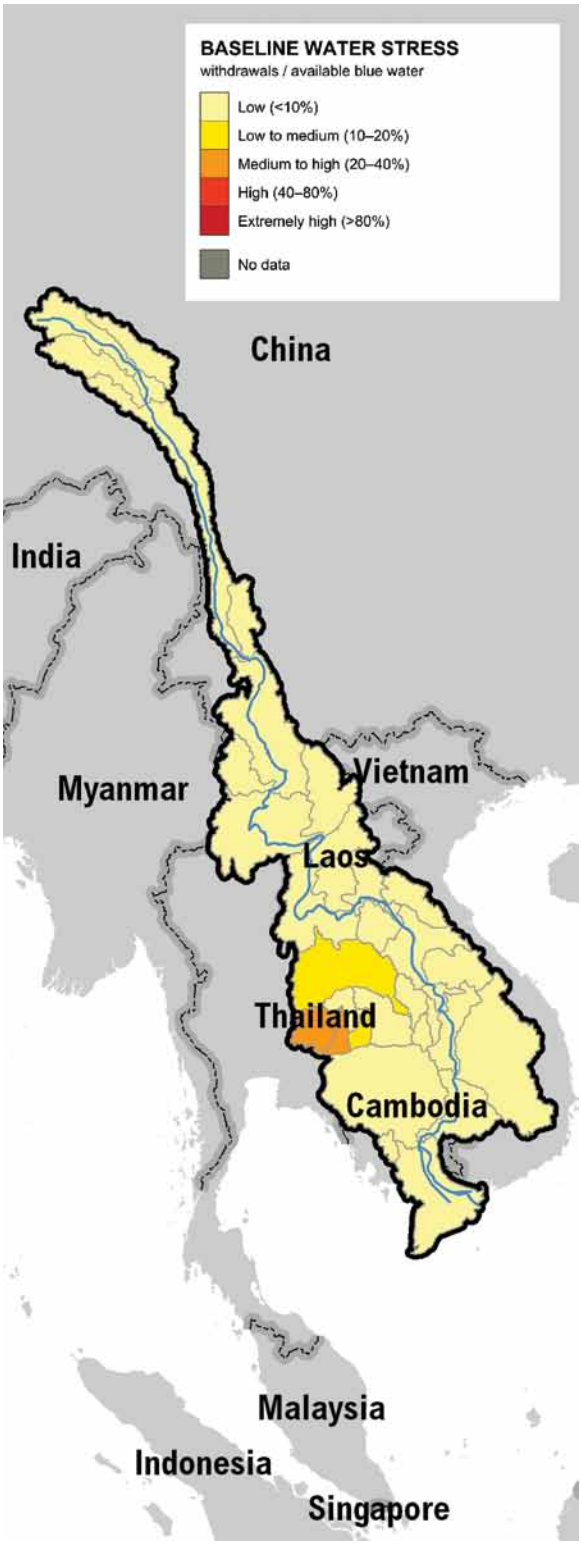
Calculation: Annual water withdrawals divided by the mean of available blue water (1951–2006). Areas with available blue water and water withdrawal equal to zero are coded as missing data.

Data Sources

VARIABLE	WITHDRAWALS
Comments	See Total Withdrawal

VARIABLE	AVAILABLE BLUE WATER
Comments	See Available Blue Water

Baseline Water Stress



INTER-ANNUAL VARIABILITY

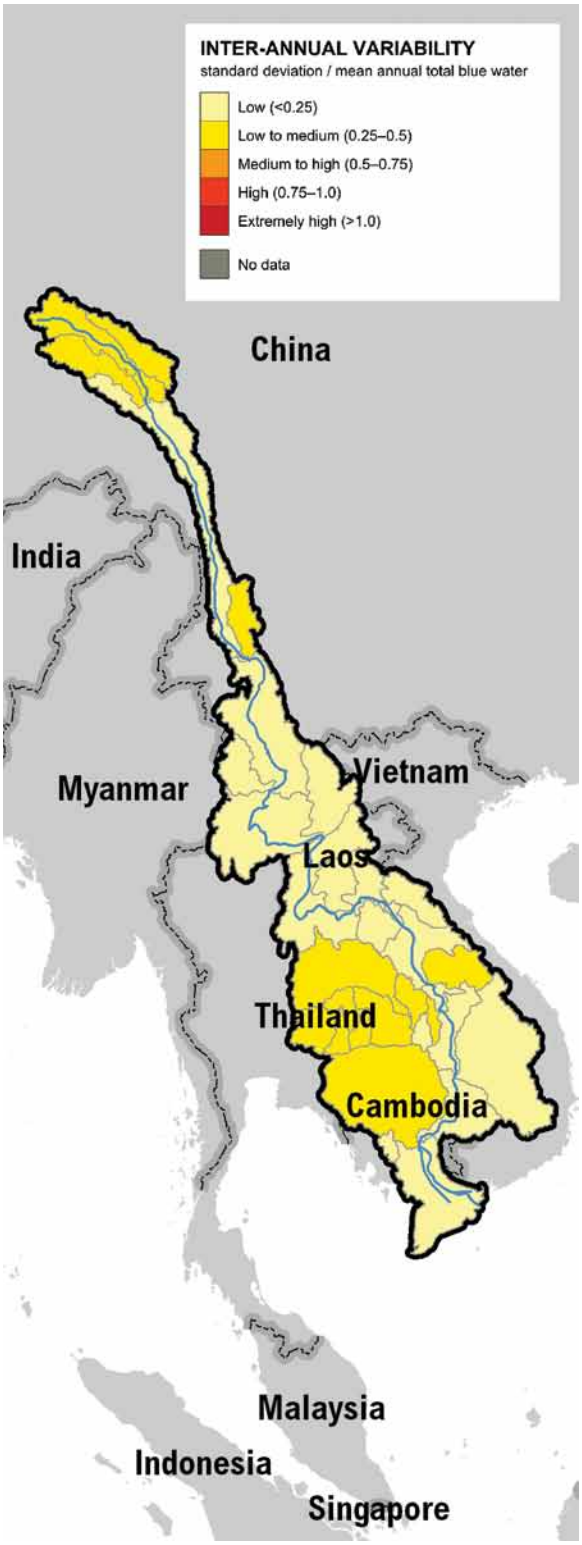
Description: *Inter-annual variability* measures the variation in water supply between years.

Calculation: Standard deviation divided by the mean of annual total blue water (1951–2006).

Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Inter-annual Variability



SEASONAL VARIABILITY

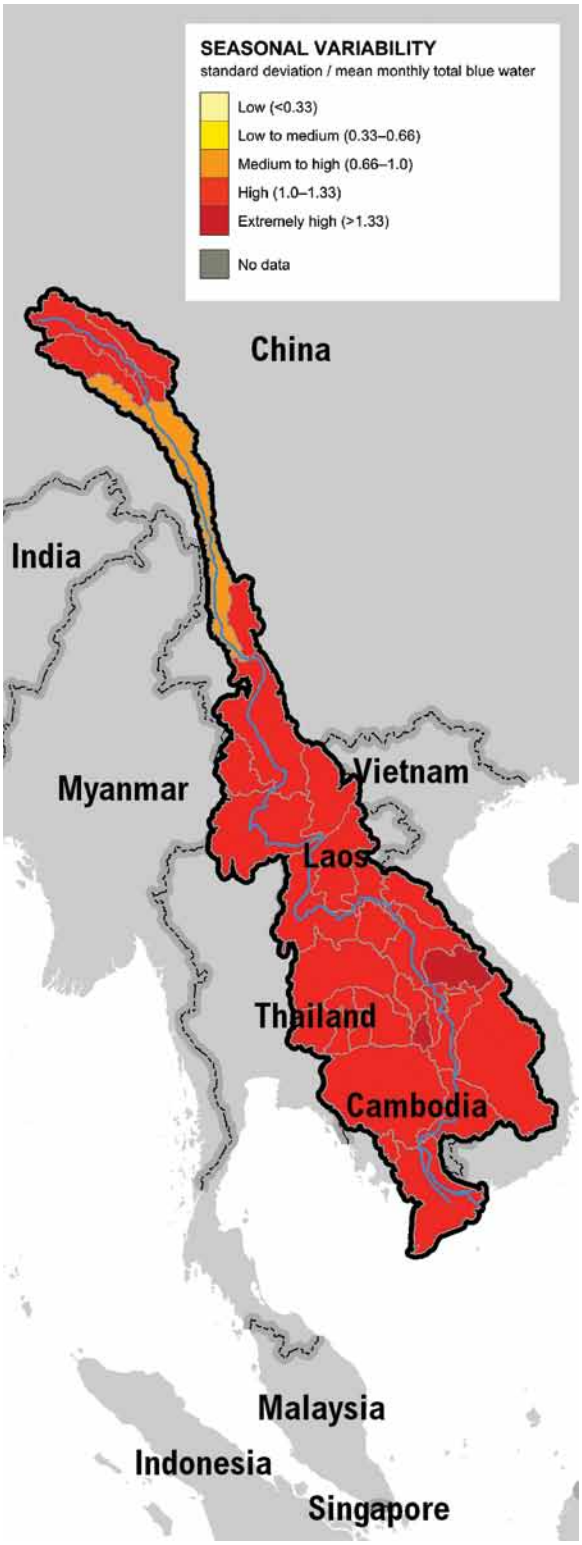
Description: *Seasonal variability* measures variation in water supply between months of the year.

Calculation: Standard deviation divided by the mean of monthly total blue water (1951–2006). The mean of monthly total blue water of each of the 12 months of the year is first calculated, then the variance is estimated between the mean monthly values.

Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Seasonal Variability



FLOOD OCCURRENCE

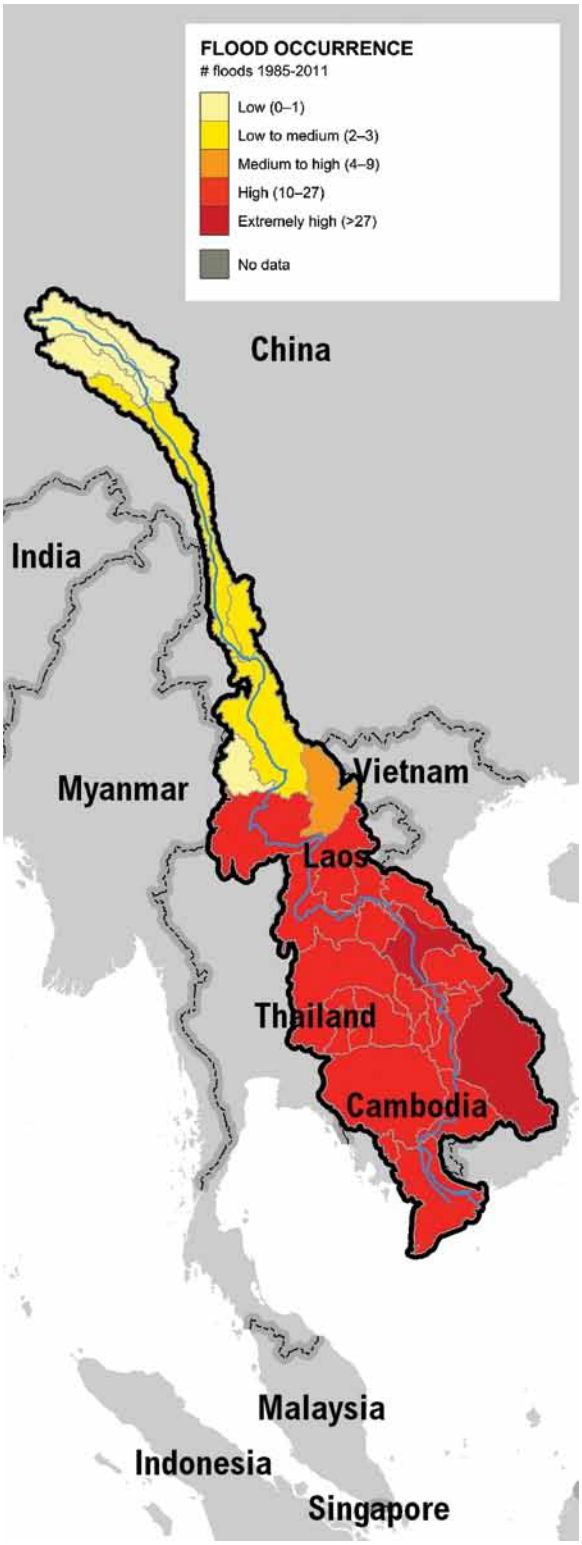
Description: *Flood occurrence* is the number of floods recorded from 1985 to 2011.

Calculation: Number of flood occurrences (1985–2011). Flood counts are calculated by intersecting hydrological units with estimated flood extent polygons. Only floods whose extent polygons' centroids lie within the Mekong River Basin are counted.

Data Sources

VARIABLE	FLOOD EVENTS
Authors	G.R. Brakenridge, Dartmouth Flood Observatory, University of Colorado
Title	Global Active Archive of Large Flood Events
Time covered in analysis	1985 – October 2011
URL	http://floodobservatory.colorado.edu/Archives/index.html
Date Accessed	October 15, 2011
Resolution	Flood extent polygons (multiple scales)
Comments	The Global Archive of Major Flood Events aggregates flood events from news, governmental, instrumental, and remote sensing sources and estimates the extent of flooding based on reports of affected regions.

Flood Occurrence



DROUGHT SEVERITY

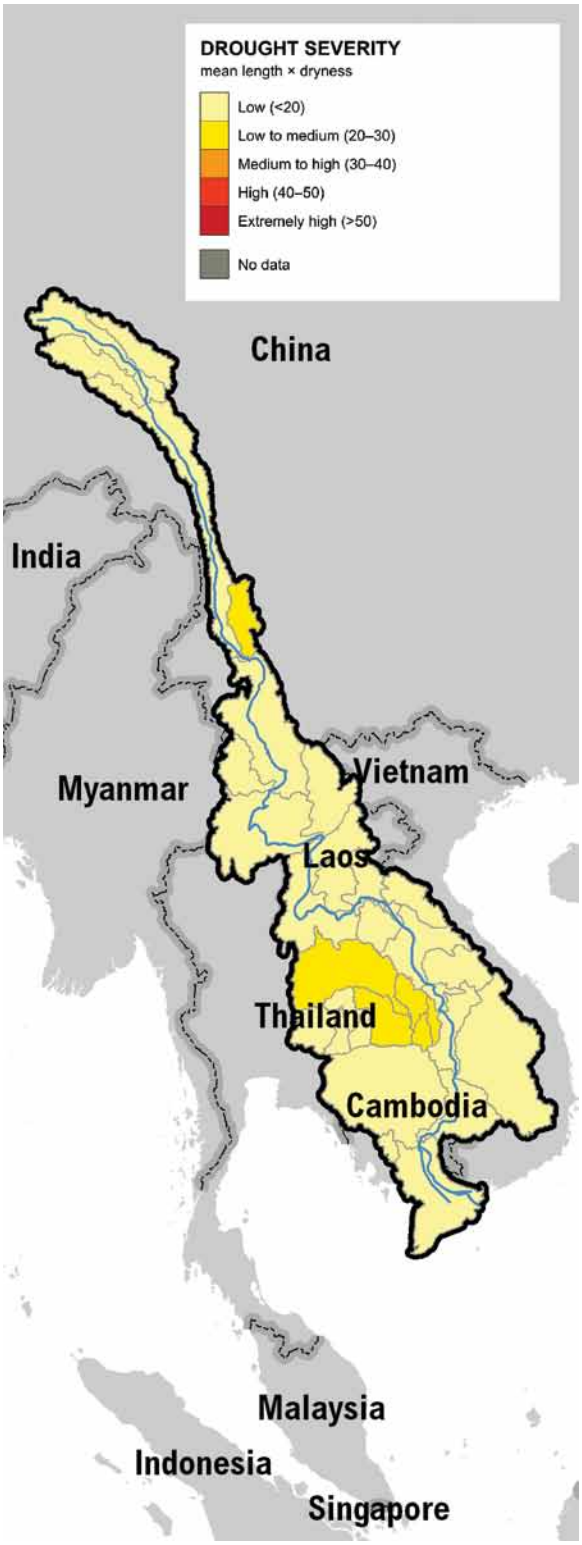
Description: *Drought severity* measures the average length of droughts times the dryness of the droughts from 1901 to 2008.

Calculation: Drought severity is the mean of the lengths times the dryness of all droughts occurring in an area. Drought is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in months and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. Drought data is resampled from original raster form into hydrological catchments.

Data Sources

VARIABLE	DROUGHT SEVERITY
Authors	J. Sheffield and E.F. Wood
Title	Projected Changes in Drought Occurrence under Future Global Warming from Multi-Model, Multi-Scenario, IPCC AR4 Simulations
Year of publication	2007
Time covered in analysis	1901–2008
URL	http://ruby.fgcu.edu/courses/twimberley/EnviroPhilo/Drought.pdf
Resolution	1 degree raster
Comments	Sheffield and Wood's drought dataset combines a suite of global observation-based datasets with the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP-NCAR) reanalysis, and creates a global drought event occurrence dataset with a spatial resolution of 1 degree.

Drought Severity



UPSTREAM STORAGE

Description: *Upstream storage* measures the water-storage capacity available upstream of a location relative to the total water supply at that location. Higher values indicate areas more capable of buffering variations in water supply (i.e., droughts and floods) because they have more water storage capacity upstream.

Calculation: Upstream storage capacity divided by the mean total blue water (1951–2006). Multiple dam datasets were combined for more complete coverage.

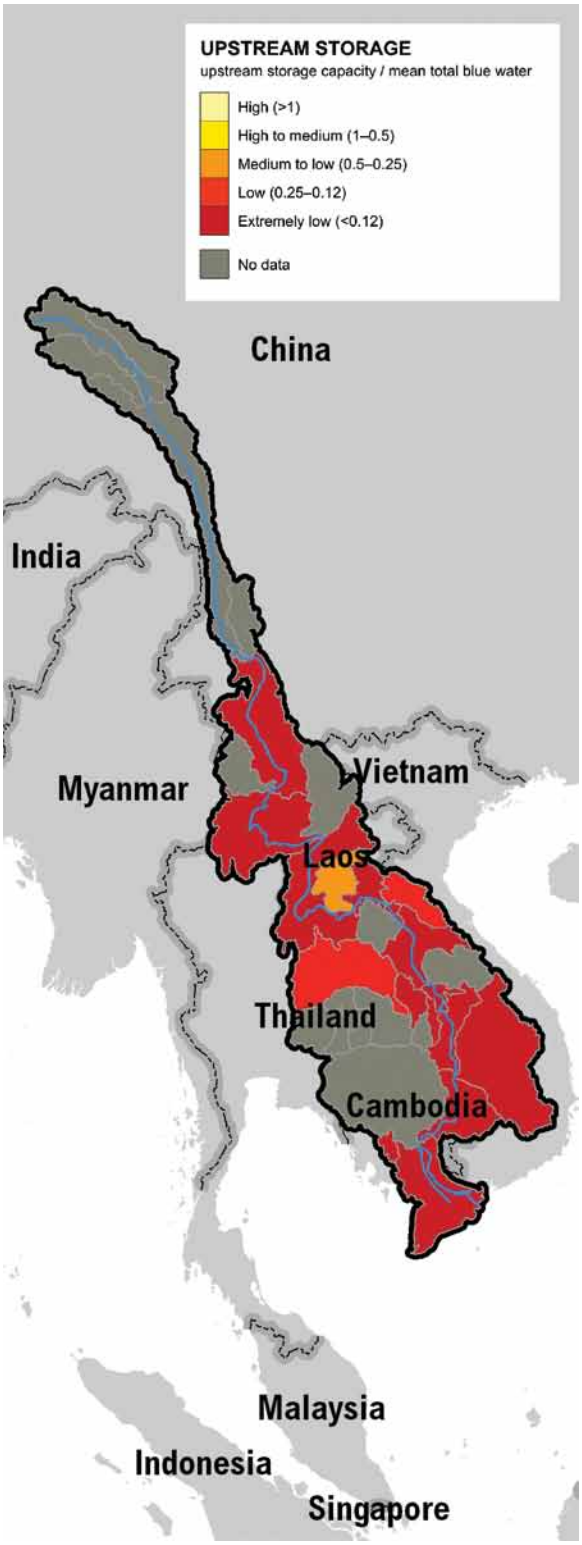
Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

VARIABLE	MAJOR DAMS AND RESERVOIRS
Authors	B. Lehner, C. R-Liermann, C. Revenga, C. Vörösmarty, B. Fekete, P. Crouzet, P. Döll, et al.
Title	Global Reservoir and Dam (GRanD) Database Version 1.1
Year of publication	2011
Time covered in analysis	2010
URL	http://atlas.gwsp.org/index.hp?option=com_content
Resolution	Dams (point)
Comments	GRanD database includes reservoirs with a storage capacity of more than 0.1 cubic km although many smaller reservoirs were included.

VARIABLE	MAJOR DAMS IN LOWER MEKONG BASIN
Author	Mekong River Commission
Title	Lower Mekong Hydro Power Database (9506000003818_____E0100eij)
Year of publication	2009
Time covered in analysis	2009
URL	http://portal.mrcmekong.org/master-catalogue/search?gi ai=9506000003818_____E0100eij
Resolution	Dams (point)
Comments	The MRC dam data includes existing hydropower dams in the LMB over 10MW installed capacity.

Upstream Storage



RETURN FLOW RATIO

Description: *Return flow ratio* measures the percent of available water previously used and discharged upstream as wastewater. Higher values indicate higher dependency on treatment plants and potentially worse water quality in areas that lack sufficient treatment infrastructure and policies.

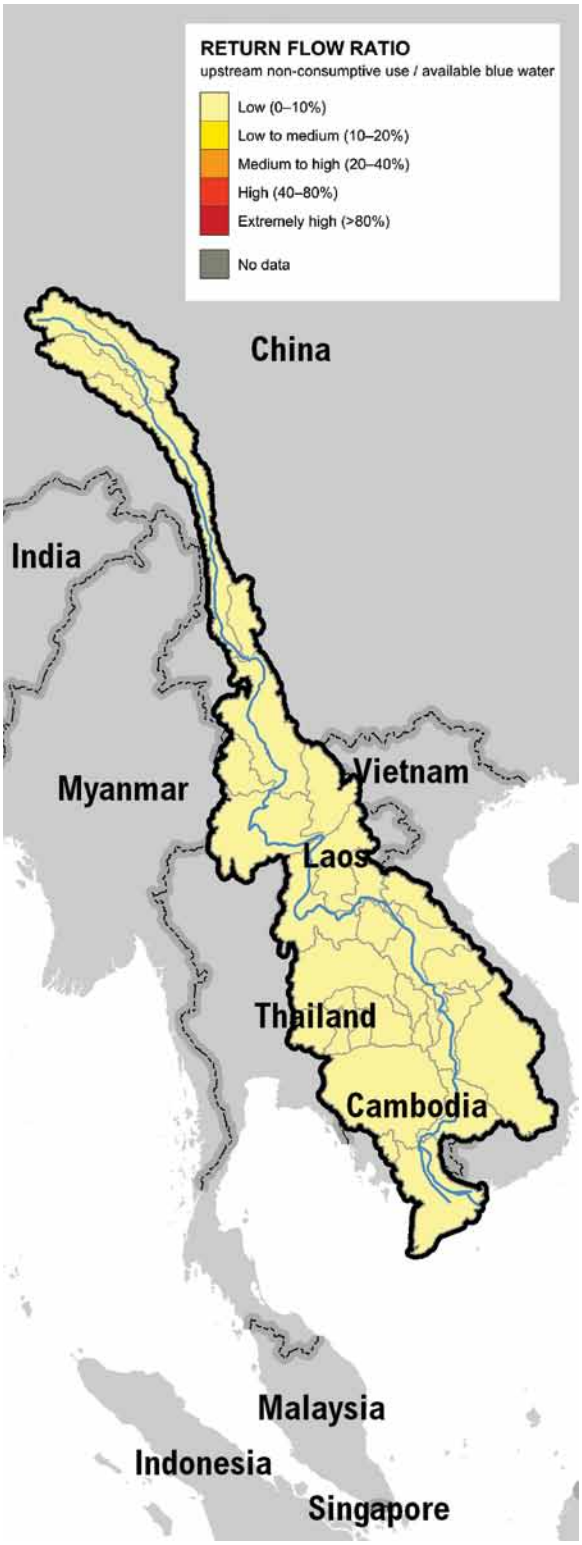
Calculation: Upstream non-consumptive use (2007) divided by the mean of available blue water (1951–2006).

Data Sources

VARIABLE	NON-CONSUMPTIVE USE
Comments	See Consumptive and Non-consumptive Use

VARIABLE	AVAILABLE BLUE WATER
Comments	See Available Blue Water

Return Flow Ratio



WATER QUALITY - AMMONIA NITROGEN

Description: *Ammonia nitrogen (NH3-N)* is a measure of the level of nitrogen. Higher values, often driven by fertilizer use as well as by domestic and industrial discharges, may have a detrimental effect on water quality.

Calculation: NH3-N is reported using sampled data and averaged over a year. Catchments were assigned values equal to the average of all water-quality sample data within the polygon. Catchments that do not include sampled data for which a given parameter was measured were coded as missing data. The water-quality data for the Lower Mekong Basin were obtained from the Mekong River Commission and for the Upper Mekong Basin from the Ministry of Environment Projection of the People's Republic of China.

Data Sources

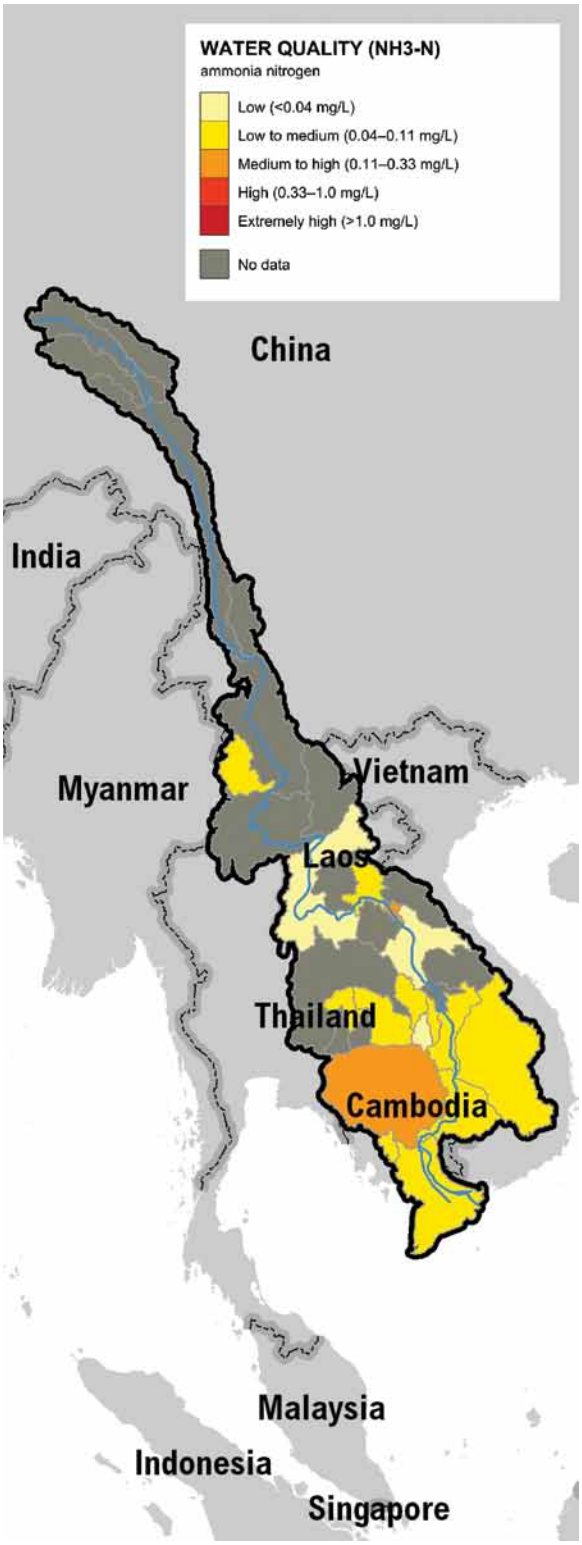
VARIABLE	AMMONIA NITROGEN (NH3-N) – LOWER MEKONG BASIN
Author	Mekong River Commission
Title	Water Quality Monitoring Data in the Lower Mekong Basin
Year of publication	2012
Time covered in analysis	2011
URL	http://portal.mrcmekong.org/master-catalogue/search?gi ai=9506000003818_____E0100eil
Resolution	Sites (point)

VARIABLE	AMMONIA NITROGEN (NH3-N) – UPPER MEKONG BASIN
Author	Ministry of Environmental Protection of the People's Republic of China
Title	2010. 52 weeks in Xishuangbanna Xiaoganlanba, Yunnan Section of Water (Record number: Beijing ICP 05009132)
Year of publication	2011
Time covered in analysis	2010 (52 weeks)
URL	http://datacenter.mep.gov.cn/report/water/report_52weeks_waterplace_new1.jsp?waterplace=%E4%BA%91%E5%8D%97%E8%A5%BF%E5%8F%8C%E7%89%88%E7%BA%B3%E6%A9%84%E6%A6%84%E5%9D%9D&year=2010&wissue=31
Resolution	Sites (point)

Data Sources

VARIABLE	LOCATIONS OF WATER-QUALITY
Author	Mekong River Commission
Title	Water Quality Stations within the Lower Mekong Basin
Year of publication	2003
URL	http://portal.mrcmekong.org/master-catalogue/search?giai=9506000003818___wqstatE01009r9
Resolution	Sites (point)

Water Quality – Ammonia Nitrogen



WATER QUALITY - ELECTRICAL CONDUCTIVITY (EC)

Description: *Electrical conductivity (EC)* measures how easily electricity passes through water and is a common proxy for salinity. In general, higher values reflect higher salinity, thus poorer water quality.

Calculation: EC is reported using empirical sample data and averaged over a year. Catchments are assigned values equal to the average of all water-quality sample data within the polygon. Catchments that do not include sampled data for which a given parameter is measured were coded as missing data.

Data Sources

VARIABLE	ELECTRICAL CONDUCTIVITY (EC)
Author	Mekong River Commission
Title	Water Quality Monitoring Data in the Lower Mekong Basin
Year of publication	2012
Time covered in analysis	2011
URL	http://portal.mrcmekong.org/master-catalogue/search?giai=9506000003818_____E0100eil
Resolution	Sites (point)

VARIABLE	LOCATIONS OF WATER QUALITY MONITORING SITES
Author	Mekong River Commission
Title	Water Quality Stations within the Lower Mekong Basin
Year of publication	2003
URL	http://portal.mrcmekong.org/master-catalogue/search?giai=9506000003818___wqstatE01009r9
Resolution	Sites (point)

Water Quality – Electrical Conductivity

Note: a higher number indicates poorer water quality.

UPSTREAM PROTECTED LAND

Description: *Upstream protected land* measures the percentage of total water supply that originates from protected ecosystems. Modified land use can affect the health of freshwater ecosystems and have severe downstream impacts on both water quality and quantity.

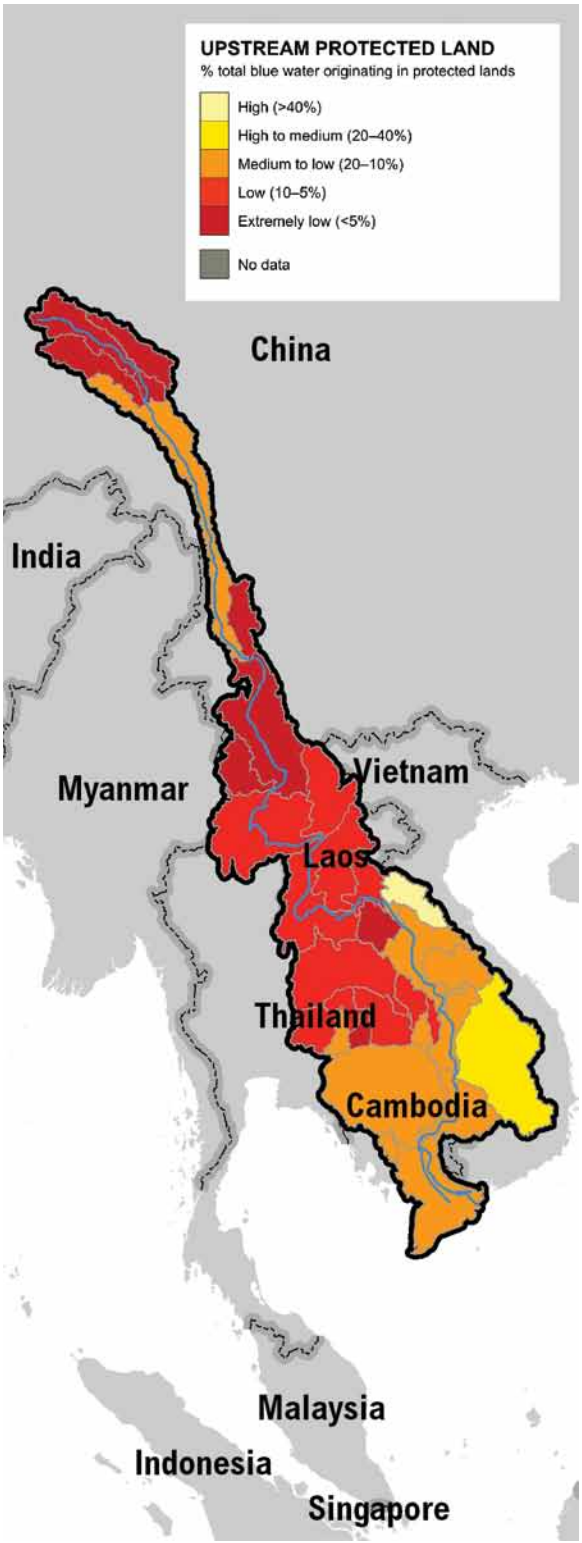
Calculation: Percentage of total blue water that originates in protected areas. IUCN category V protected lands, as well as a large number of unclassified proposed lands, breeding centers, municipal parks, cultural and historic sites, and exclusively marine areas are excluded.

Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

VARIABLE	PROTECTED AREAS
Authors	International Union for Conservation of Nature (IUCN) and United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC)
Title	The World Database on Protected Areas
URL	http://protectedplanet.net/
Date accessed	June 14, 2012
Resolution	Protected areas (multiple scales)

Upstream Protected Land



Note: a higher number indicates poorer water quality.

WATER QUALITY – CHEMICAL OXYGEN DEMAND (COD)

Description: *Chemical oxygen demand (COD)* measures the presence of organic pollutants in water. In general, higher values reflect poorer water quality.

Calculation: COD is reported using empirical sample data and averaged over a year. Catchments were assigned values equal to the average of all water-quality sample data within the polygon. Catchments that did not include sampled data for which a given parameter was measured were coded as missing data. The water quality data for the Lower Mekong Basin were obtained from the Mekong River Commission and for the Upper Mekong Basin from the Ministry of Environment Projection of the People's Republic of China.

Data Sources

VARIABLE	CHEMICAL OXYGEN DEMAND (COD) – LOWER MEKONG BASIN
Author	Mekong River Commission
Title	Water Quality Monitoring Data in the Lower Mekong Basin
Year of publication	2012
Time covered in analysis	2011
URL	http://portal.mrcmekong.org/master-catalogue/search?giai=9506000003818_____E0100eiI
Resolution	Sites (point)

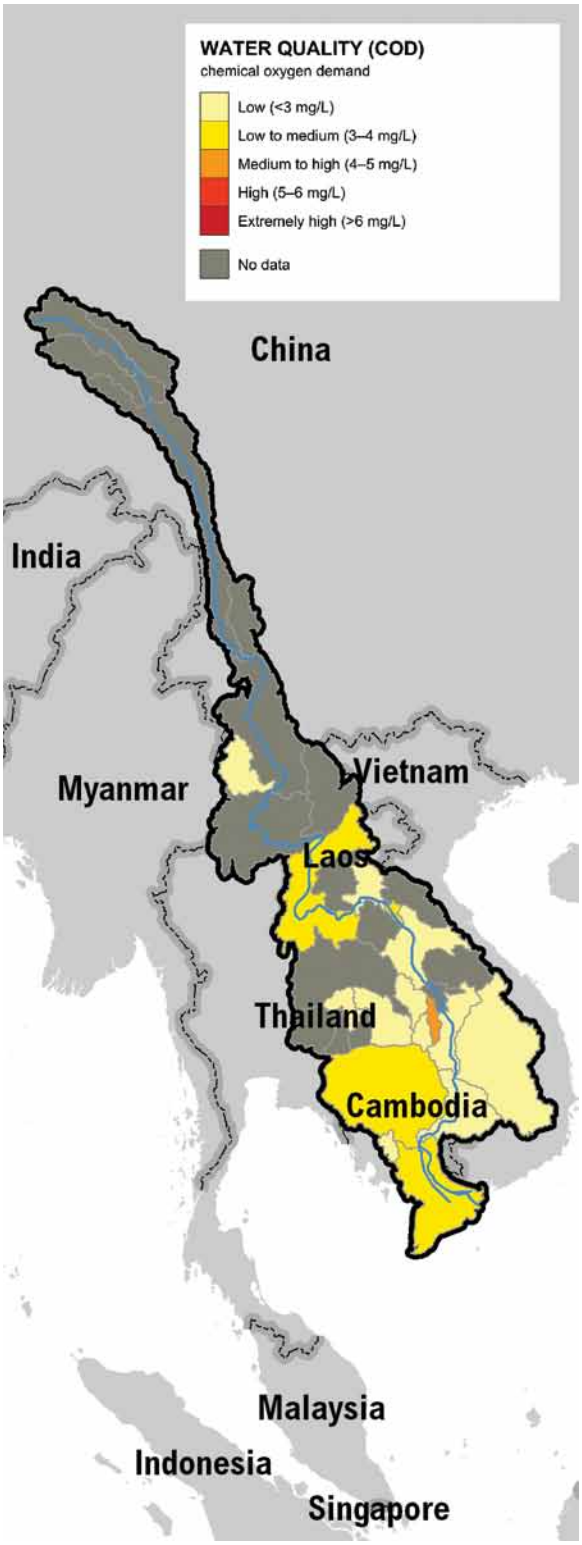
VARIABLE	CHEMICAL OXYGEN DEMAND (COD) – UPPER MEKONG BASIN
Author	Ministry of Environmental Protection of the People's Republic of China
Title	52 weeks in Xishuangbanna Xiaoganlanba, Yunnan Section of Water (Record number: Beijing ICP 05009132)
Year of publication	2011
Time covered in analysis	2010
URL	http://datacenter.mep.gov.cn/report/water/report_52weeks_waterplace_new1.jsp?waterplace=%E4%BA%91%E5%8D%97%E8%A5%BF%E5%8F%8C%E7%89%88%E7%BA%B3%E6%A9%84%E6%A6%84%E5%9D%9D&year=2010&wissue=31
Resolution	Sites (point)

VARIABLE	LOCATIONS OF WATER-QUALITY MONITORING SITES
Author	Mekong River Commission
Title	Water Quality Stations within the Lower Mekong Basin
Year of publication	2003
URL	http://portal.mrcmekong.org/master-catalogue/search?giai=9506000003818___wqstatE01009r9
Resolution	Sites (point)

Data Sources

VARIABLE	LOCATIONS OF WATER-QUALITY MONITORING SITES
Author	Mekong River Commission
Title	Water Quality Stations within the Lower Mekong Basin
Year of publication	2003
URL	http://portal.mrcmekong.org/master-catalogue/search?giai=9506000003818___wqstatE01009r9
Resolution	Sites (point)

Water Quality – Chemical Oxygen Demand



Note: A higher number indicates poorer water quality.

MEDIA COVERAGE

Description: *Media coverage* measures the percentage of media articles in an area on water-related issues. Higher values indicate areas with higher public awareness of water issues, and consequently higher reputational risks to those not sustainably managing water.

Calculation: Percentage of all media articles on water scarcity and/or pollution in an administrative unit. Google Archives was used to search a string of keywords including river name, "water shortage" or "water pollution," and administrative unit, e.g. "Mekong River+ water shortage + Cambodia." The time frame was limited to the past 10 years from January 1, 2002 to December 31, 2011. For each country, the total number of articles for both water shortage and water pollution was summed and divided by the total number of articles on any topic found in a search of the administrative unit.

Data Sources

VARIABLE	MEDIA COVERAGE
Author	Google
Title	Google News
Time covered in analysis	2002–2011
URL	http://news.google.com/news/advanced_news_search?as_drrb=a
Date accessed	September 26, 2012
Resolution	Country

Media Coverage

ACCESS TO WATER

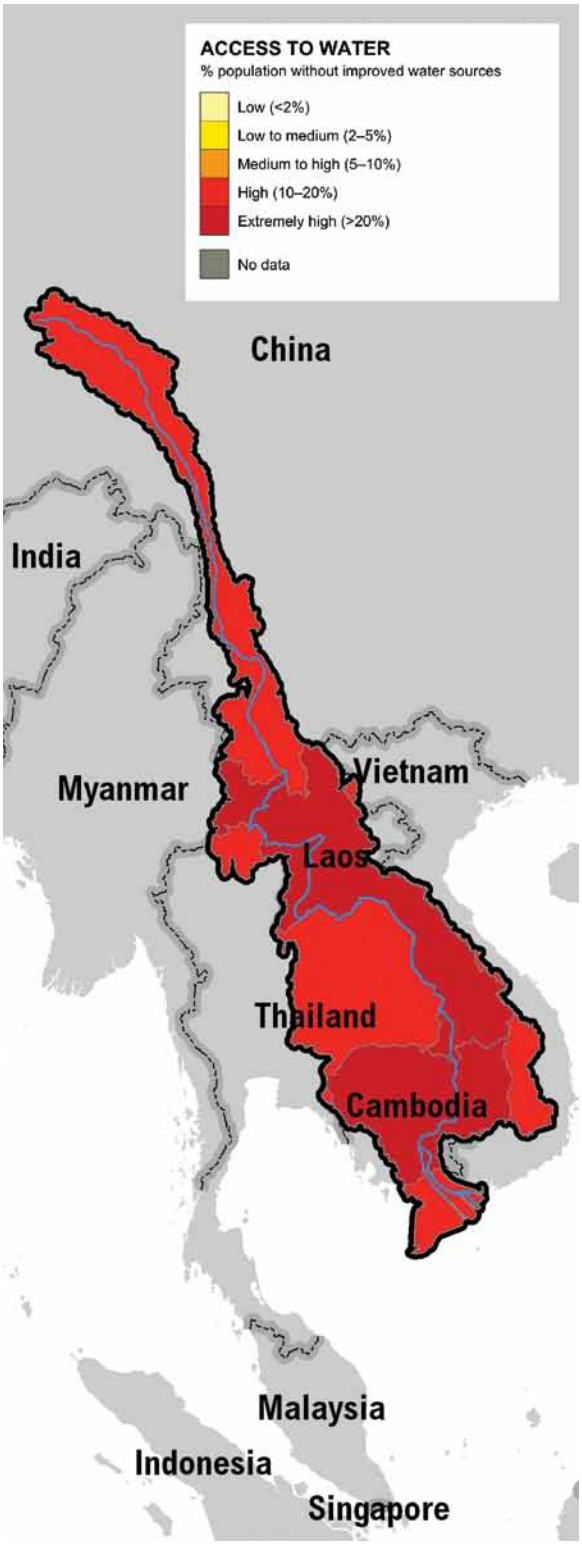
Description: *Access to water* measures the percentage of population without access to improved drinking water sources. Higher values indicate areas where people have less access to safe drinking water, and consequently high reputational risks to those not using water in an equitable way.

Calculation: Percentage of population without access to improved drinking water sources. An improved drinking water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter.

Data Sources

VARIABLE	ACCESS TO WATER
Authors	World Health Organizaiton (WHO) and the United Nations Children's Fund (UNICEF)
Title	WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation
Year of publication	2012
Time covered in analysis	2010
URL	http://www.wssinfo.org/data-estimates/table/
Resolution	Country

Access to Water



THREATENED AMPHIBIANS

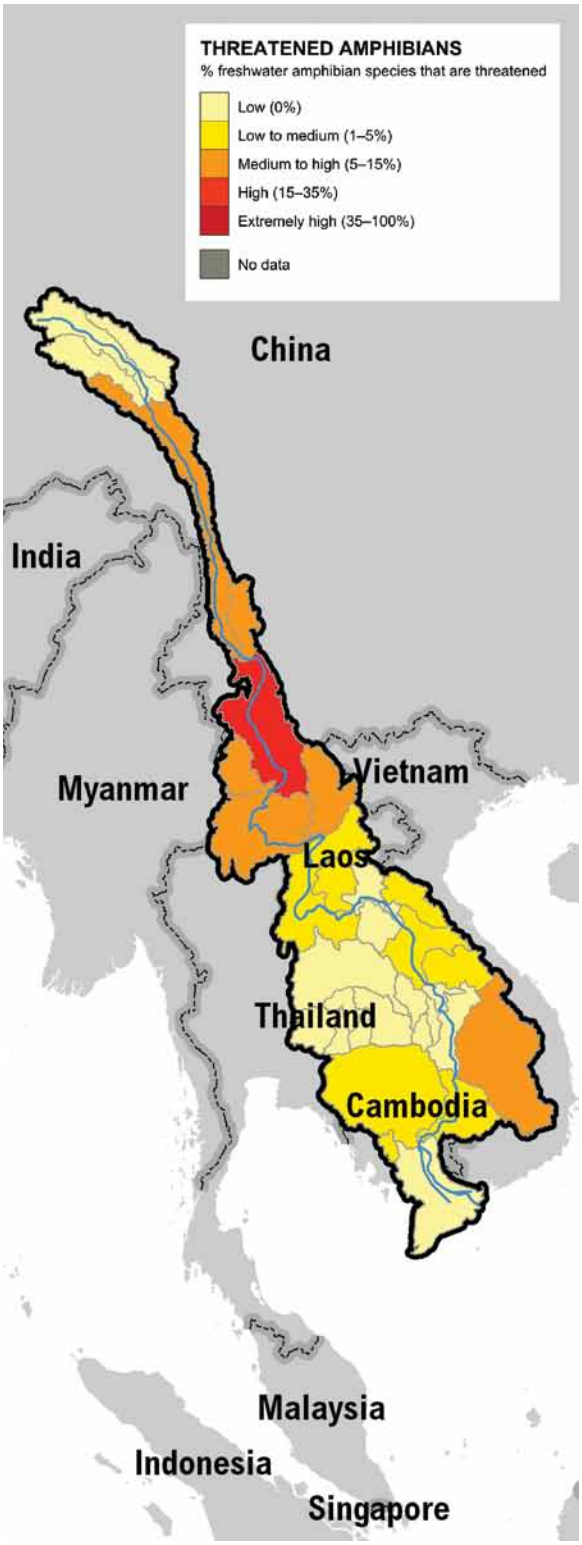
Description: *Threatened amphibians* measures the percentage of freshwater amphibian species classified by IUCN as threatened. Higher values indicate more fragile freshwater ecosystems and thus areas more likely to be subject to water withdrawal and discharge regulations.

Calculation: The percentage of amphibian species classified by IUCN as threatened in a particular area. For each catchment, the total number of threated freshwater amphibian species is counted and divided by the total number of species whose ranges overlap the catchment. Catchments with fewer than two amphibian species are excluded.

Data Sources

VARIABLE	THREATENED AMPHIBIANS
Author	International Union for Conservation of Nature (IUCN)
Title	The IUCN Red List of Threatened Species
Year of publication	October 2010
URL	http://www.iucnredlist.org/technical-documents/spatial-data#amphibians
Resolution	Ranges (multiple scales)
Comments	Amphibian species status database is joined to the known species range spatial data. Several name corrections were made in joining the data.

Threatened Amphibians



ENDNOTES

1. Paul Reig, Tien Shiao, and Francis Gassert. "Aqueduct Water Risk Framework," WRI Working Paper, Washington DC: World Resources Institute, forthcoming.

2. Yuji Masutomi, Yusuke Inui, Kiyoshi Takahashi, and Yuzuru Matsuoka. "Development of Highly Accurate Global Polygonal Drainage Basin Data," *Hydrological Processes* 23: 572-84, DOI: 10.1002/hyp.7186, 2009.

3. I.A. Shiklomanov and John C. Rodda, eds. "World Water Resources at the Beginning of the Twenty-First Century," International Hydrology Series, Cambridge University Press, 2004.

4. M.Y. Sonessa, J.E. Richey, and D.P. Lettenmaier. "Evaluation of Water Balance Terms of the SEA with a Land Surface Model and ERA Interim Reanalysis," River System Research Group, University of Washington (in prep).

ACKNOWLEDGMENTS

This publication was made possible thanks to the ongoing support of the World Resources Institute Markets and Enterprise Program and the Aqueduct Alliance. The authors would like to thank the following people for providing invaluable insight and assistance: Charles Iceland, Robert Kimball, Kirsty Jenkinson, Betsy Otto, Tien Shiao, Vansa Chatikavanij, Tianyi Luo, Nicole Grohoski, and Thomas Parris, as well as Nick Price and Hyacinth Billings for graphic support and final editing. For their extensive technical guidance and feedback during the development of the Mekong River Basin study, the authors would also like to thank:

- Mariza Costa-Cabral, Hydrology Futures, LLC
- Mac Kirby, CSIRO Land and Water
- Soukaseum Phichit, Mekong River Commission
- Mergia Sonessa, University of Washington
- Katsuhiko Yamauchi, Mekong River Commission

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WITH SUPPORT FROM

The Aqueduct Alliance:

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