WORLD RESOURCES INSTITUTE

Working Paper

AQUEDUCT METADATA DOCUMENT

ORANGE-SENQU RIVER BASIN STUDY

PAUL REIG, FRANCIS GASSERT, AND MATT LUCK

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 Orange-Senqu River Basin (ORB).

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 Orange-Senqu 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 sub-basin scale. The hydrological catchments used in the exercise are hydrozones developed by WRP Consulting Engineers for the Orange-Senqu River Commission (ORASECOM). Computation of the original datasets was completed by ISciences, L.L.C.

CONTENTS

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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the total amount of water abstracted from freshwater sources for human use, and consumptive use, the portion of withdrawn water that evaporates or is incorporated into a product thus is no longer available for further use.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 basin are courtesy of the South African Department of Water Affairs (DWA) and WRP Consulting Engineers. The withdrawal data was then georeferenced to the hydrological catchments.

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 were 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 was computed from runoff (R), the water available to flow across the landscape from a particular location and 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 the German Agency for International Cooperation (GIZ - Deutsche Gesellschaft für Internationale Zusammernarbeit) and ORASECOM, and computed by WRP Consulting Engineers. 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 observed records in the Orange-Senqu River Basin (ORB) over a common time period. Rainfall and the calibrated parameters were used to generate runoff values for 1920 to 2004.

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

TOTAL WITHDRAWAL

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

Calculation: Water withdrawals for the ORB were obtained from the South Africa Department of Water Affairs (DWA) Operating Analysis 2011/2012 and geo-referenced to hydrological catchments using schematic diagrams of the river infrastructure.

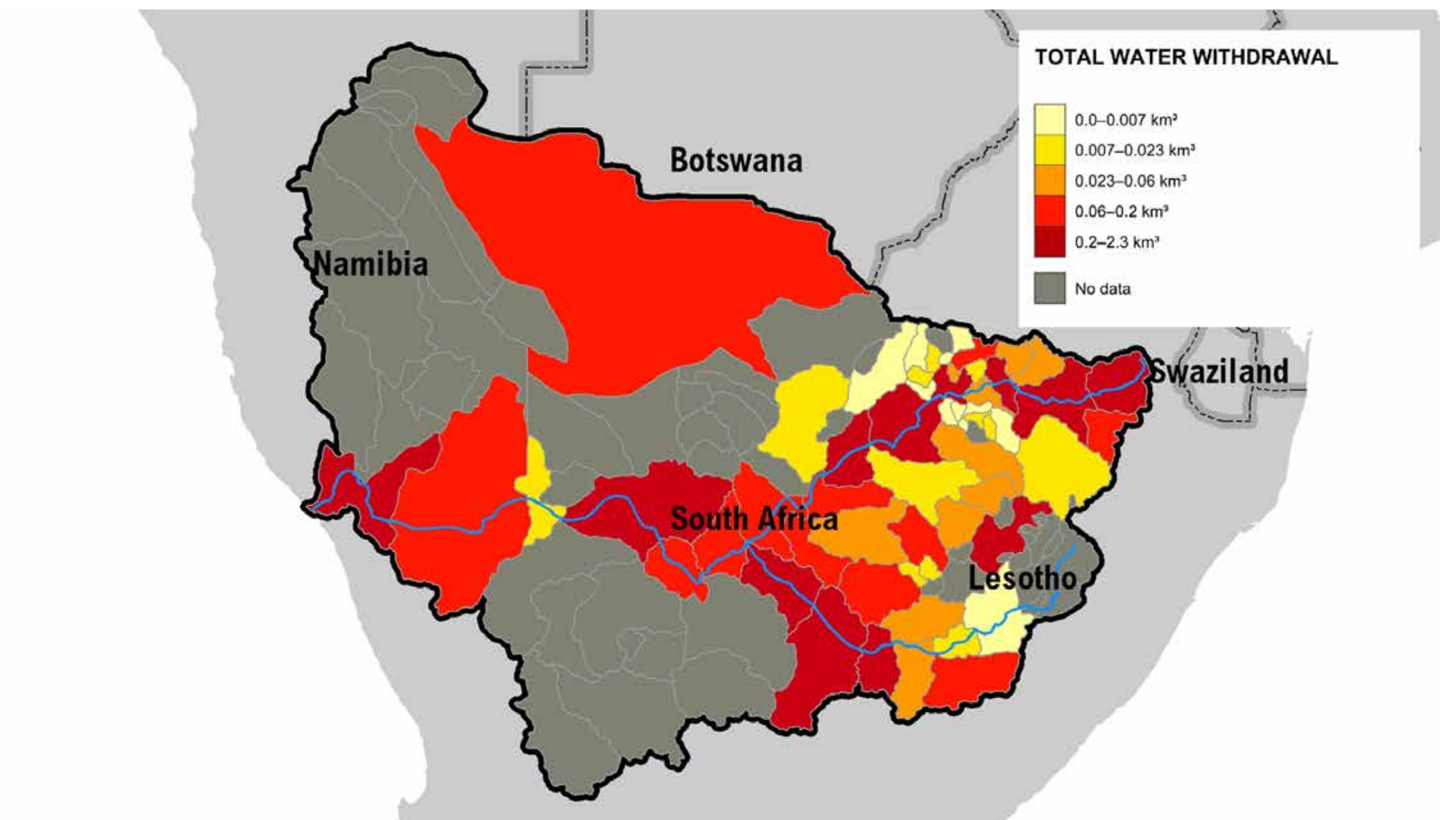
Data Sources

VARIABLE	BASIN DELINEATIONS
Authors	ORASECOM, GIZ, and WRP Consulting Engineers
Title	Orange-Senqu River Basin Hydrozones
Resolution	Sub-basin

Data Sources

VARIABLE	WATER WITHDRAWALS
Author	South African Department of Water Affairs and WRP Consulting Engineers
Title	South African Department of Water Affairs Operating Analysis 2011/2012
Date Accessed	September 10, 2011
Resolution	Point (demand locations)

Total Withdrawal



CONSUMPTIVE AND NON-CONSUMPTIVE USE

Description: *Consumptive use* is the portion of all water that evaporates or is incorporated into a product, thus is no longer available for reuse. *Non-consumptive use* is the remainder of withdrawals that is not consumed and instead returns to ground or surface water bodies.

Calculation: Consumptive use by catchment was calculated by subtracting the total amount of return flows from the total withdrawals supplied to each catchment. Return flows for urban centers without reported return flows were estimated at a rate of 61%. The Department of Water Affairs demand projection for 2011 was used in this study.

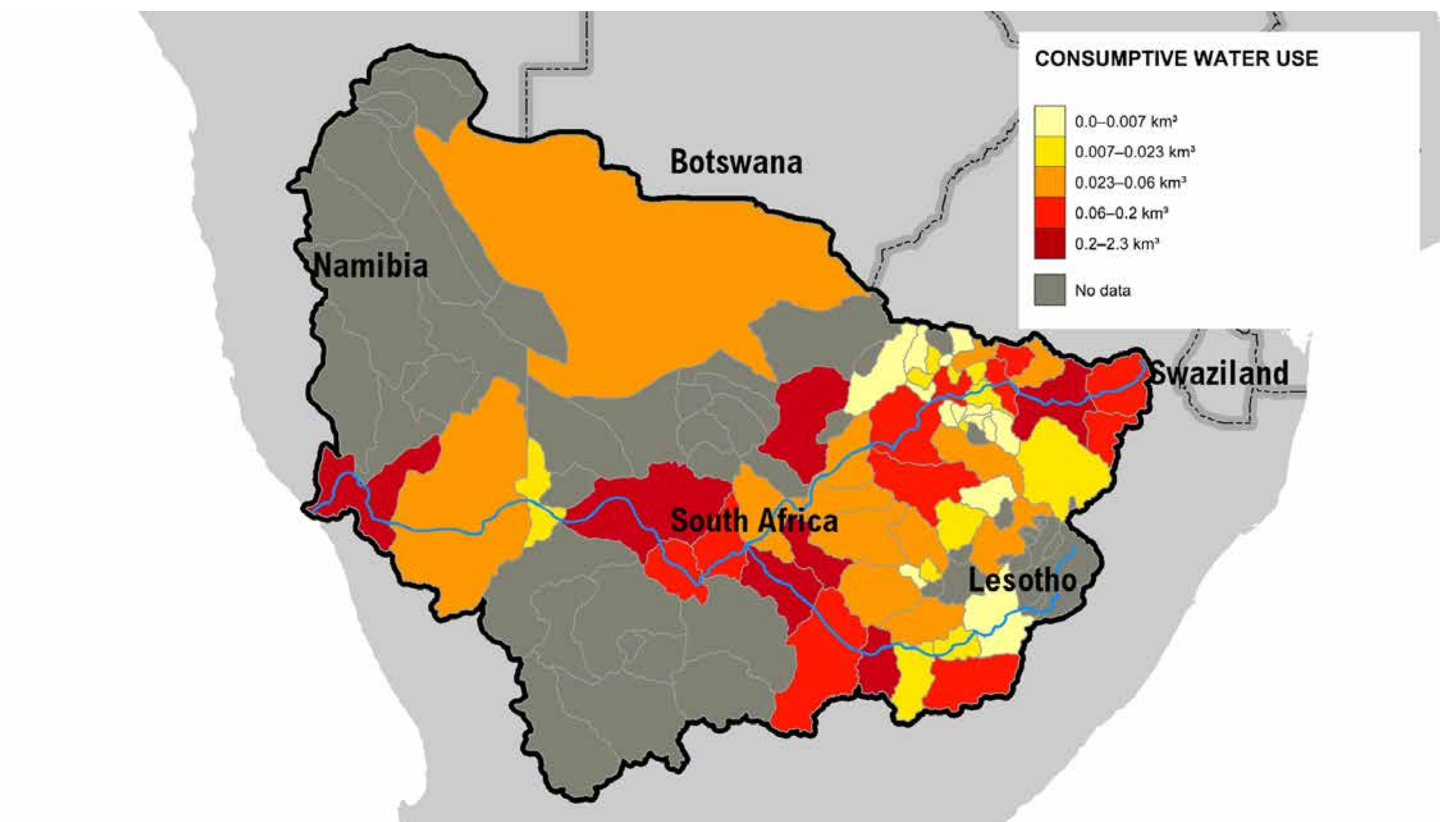
Data Sources

VARIABLE	WITHDRAWALS
Comments	See Total Withdrawal

Data Sources

VARIABLE	RETURN FLOWS, TRANSFERS, OPERATING LOSSES, AND ENVIRONMENTAL REQUIREMENTS
Authors	South African Department of Water Affairs and WRP Consulting Engineers
Title	South African Department of Water Affairs Operating Analysis 2011/2012
Date Accessed	September 10, 2011
Resolution	Point (demand locations)

Consumptive and Non-Consumptive 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: $Bt(i) = R_{up}(i) + R(i)$ where $R_{up}(i) = \sum Bt(i_{up})$, *iup* is the set of catchments immediately upstream of catchment *i* that flow into catchment *i*, and $R_{up}(i)$ is the summed runoff in all upstream catchments. For first-order catchments (those without upstream catchments, e.g., headwater catchments), $R_{up}(i)$ is zero, and total blue water is simply the volume of runoff in the catchment.

Data Sources

VARIABLE	BASIN DELINEATIONS
Comments	See Total Withdrawal

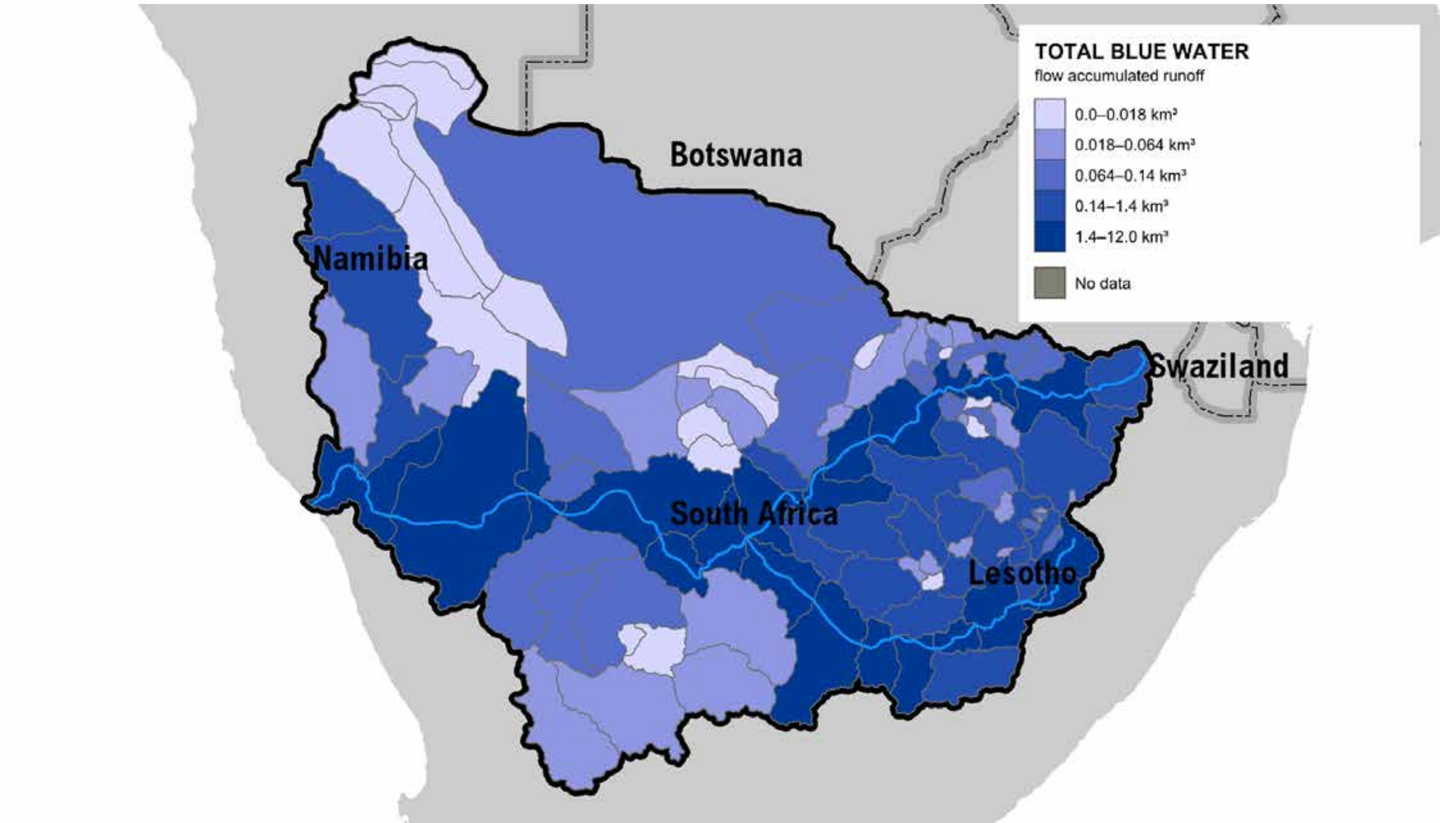
VARIABLE	RUNOFF
Authors	ORASECOM, GIZ, and WRP Consulting Engineers
Title	Hydrology Files
Time covered in analysis	1920–2004
Date Accessed	November 5, 2011
Resolution	Hydrozones

Data Sources

VARIABLE	RIVER FLOW GAUGES
Author	South African Department of Water Affairs
Title	Resource Quality Services – Water Management Systems
Time covered in analysis	1970–2010
URL	http://www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp
Date Accessed	October 26, 2011
Resolution	Flow monitoring site (point)

TOTAL BLUE WATER, CONTINUED

Total Blue Water



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.

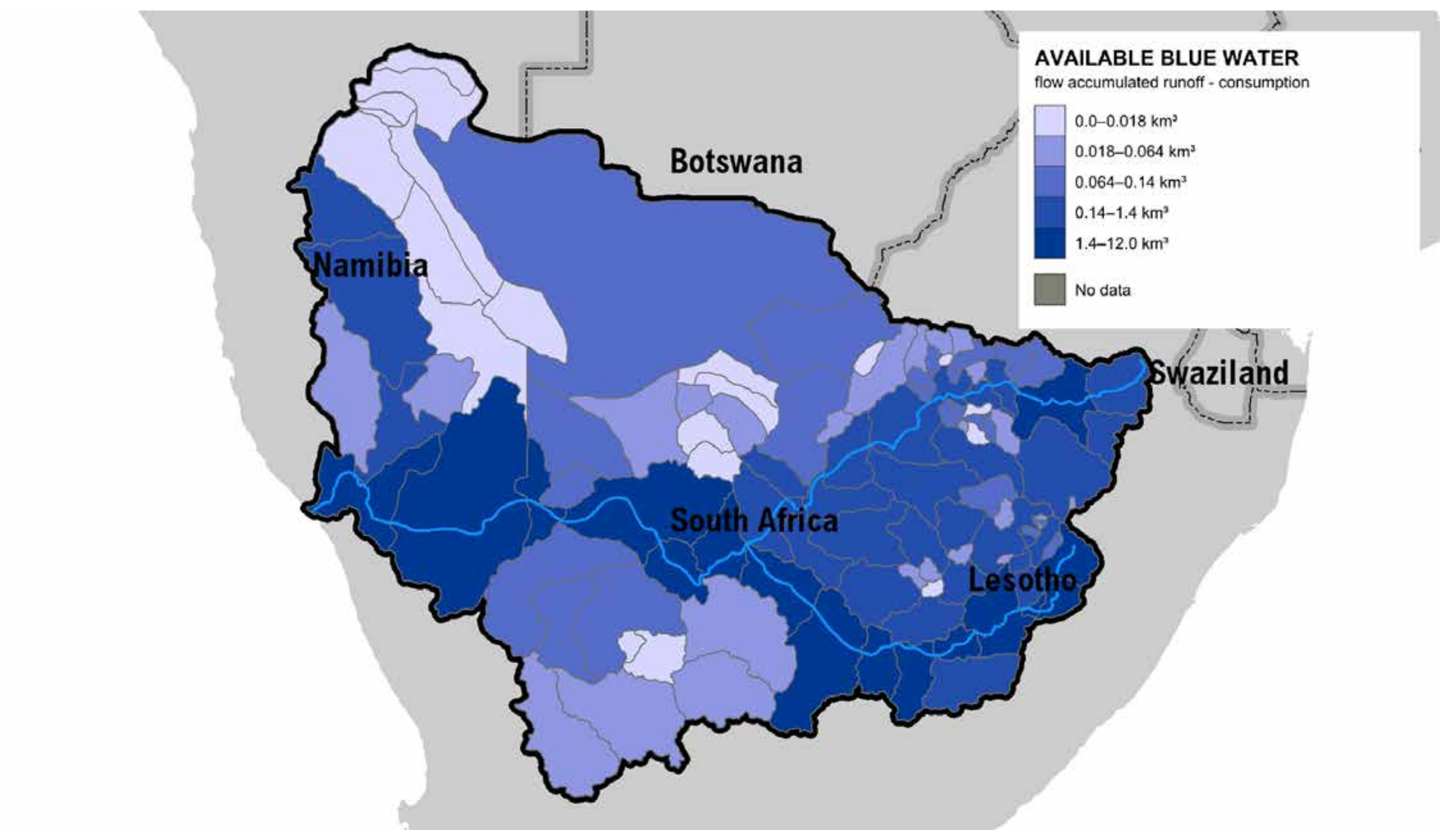
Calculation: $Ba(i) = R(i) + Eim(i) + \sum Q_{out}(i_{up})$ where *Qout* is defined as the volume of water exiting a catchment to its downstream neighbor: $Q_{out}(i) = \max(0, Ba(i) - Uc(i) - L(i) - Ex(i))$, $Uc(i)$ are the consumptive uses, $L(i)$ are the in-stream losses due to reservoirs and other infrastructure, and $Ex(i)$ are the exports of water from catchment *i*. Negative values of Q_{out} are set to zero. In first-order catchments, $\sum Q_{out}(j)$ 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.

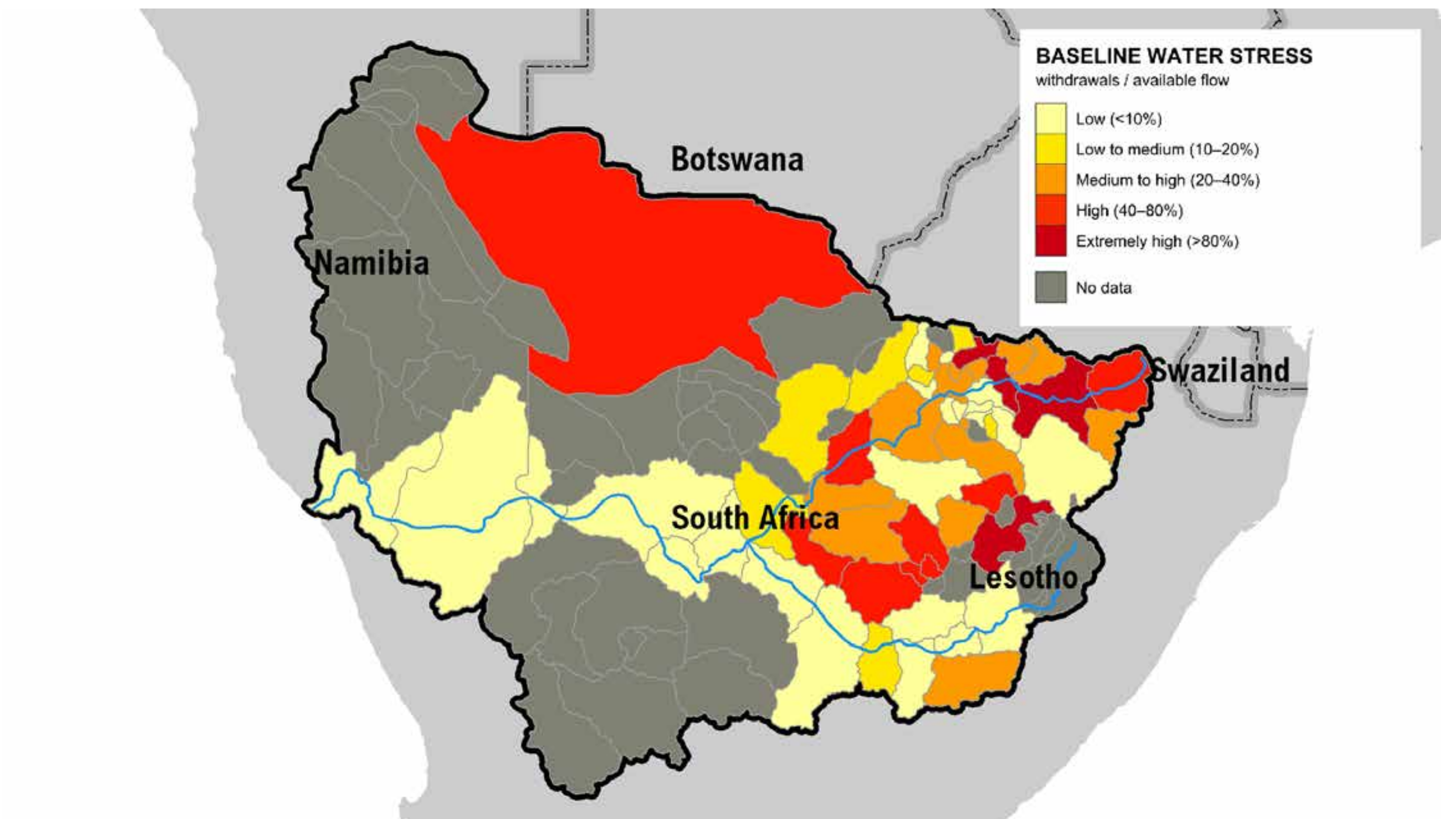
Calculation: Annual water withdrawals (2011) divided by the mean of available blue water (1920–2004). Water exports were counted as withdrawals for the purposes of calculating this indicator. Areas with available blue water and water withdrawals equal to zero were coded as missing data.

Data Sources

VARIABLE	WITHDRAWALS
Comments	See Total Withdrawal

VARIABLE	AVAILABLE BLUE WATER
Comments	See Available Blue Water

Baseline Water Stress



INTER-ANNUAL VARIABILITY

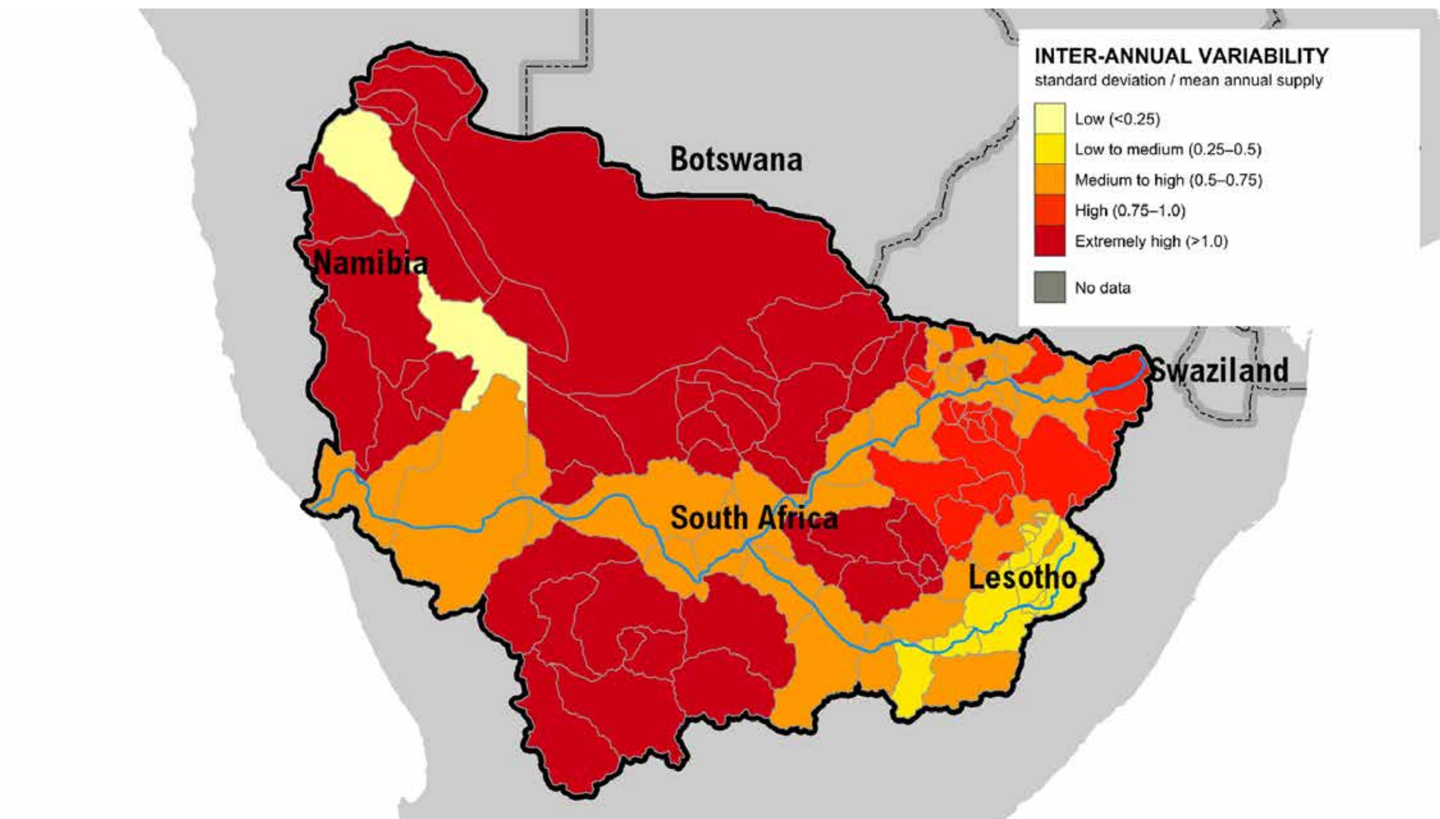
Description: *Inter-annual variability* measures the variation in water supply between years.

Calculation: Standard deviation divided by the mean of annual total blue water (1920–2004).

Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Inter-annual Variability



SEASONAL VARIABILITY

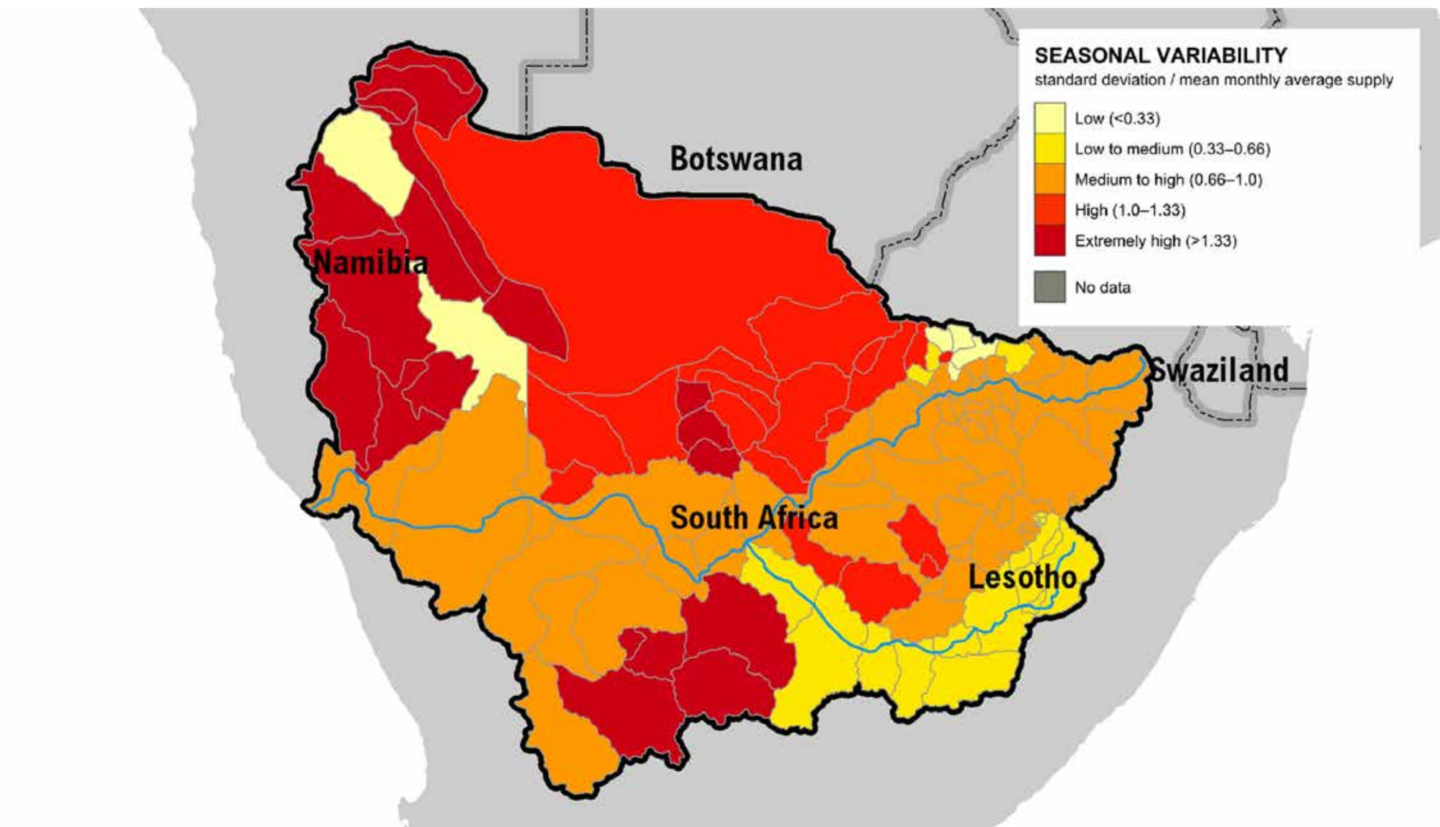
Description: *Seasonal variability* measures variation in water supply between months of the year.

Calculation: Standard deviation of monthly total blue water divided by the mean of monthly total blue water (1920–2004). The mean of monthly total blue water for each of the 12 months of the year was 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

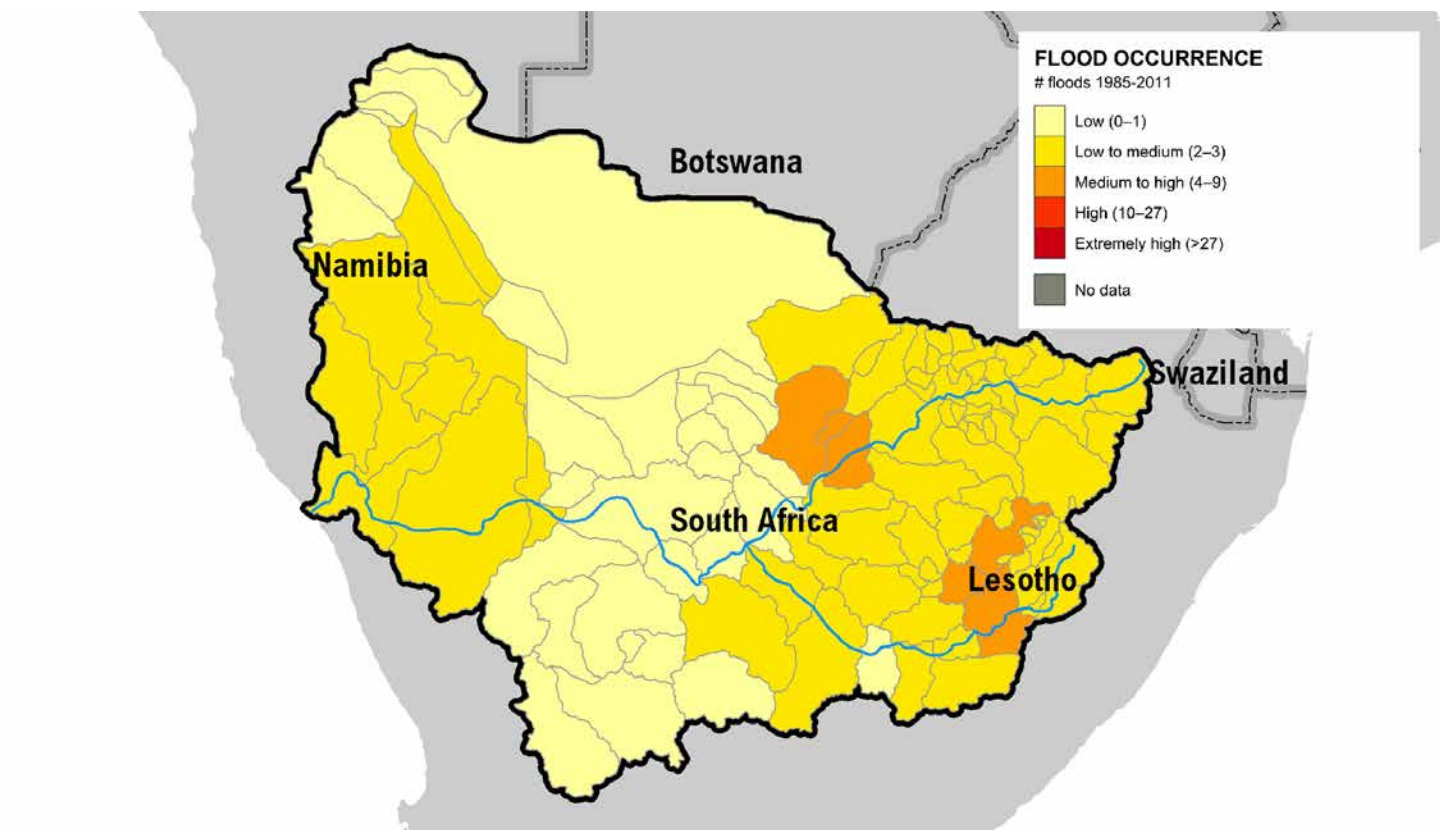
Description: *Flood occurrence* is the number of floods recorded from 1985 to 2011.

Calculation: Number of flood occurrences (1985-2011). Flood counts were calculated by intersecting hydrological units with estimated flood extent polygons. Only floods whose extent polygons' centroids lay within the Orange-Senqu River Basin were counted.

Data Sources

VARIABLE	FLOOD EVENTS
Author	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 Active 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

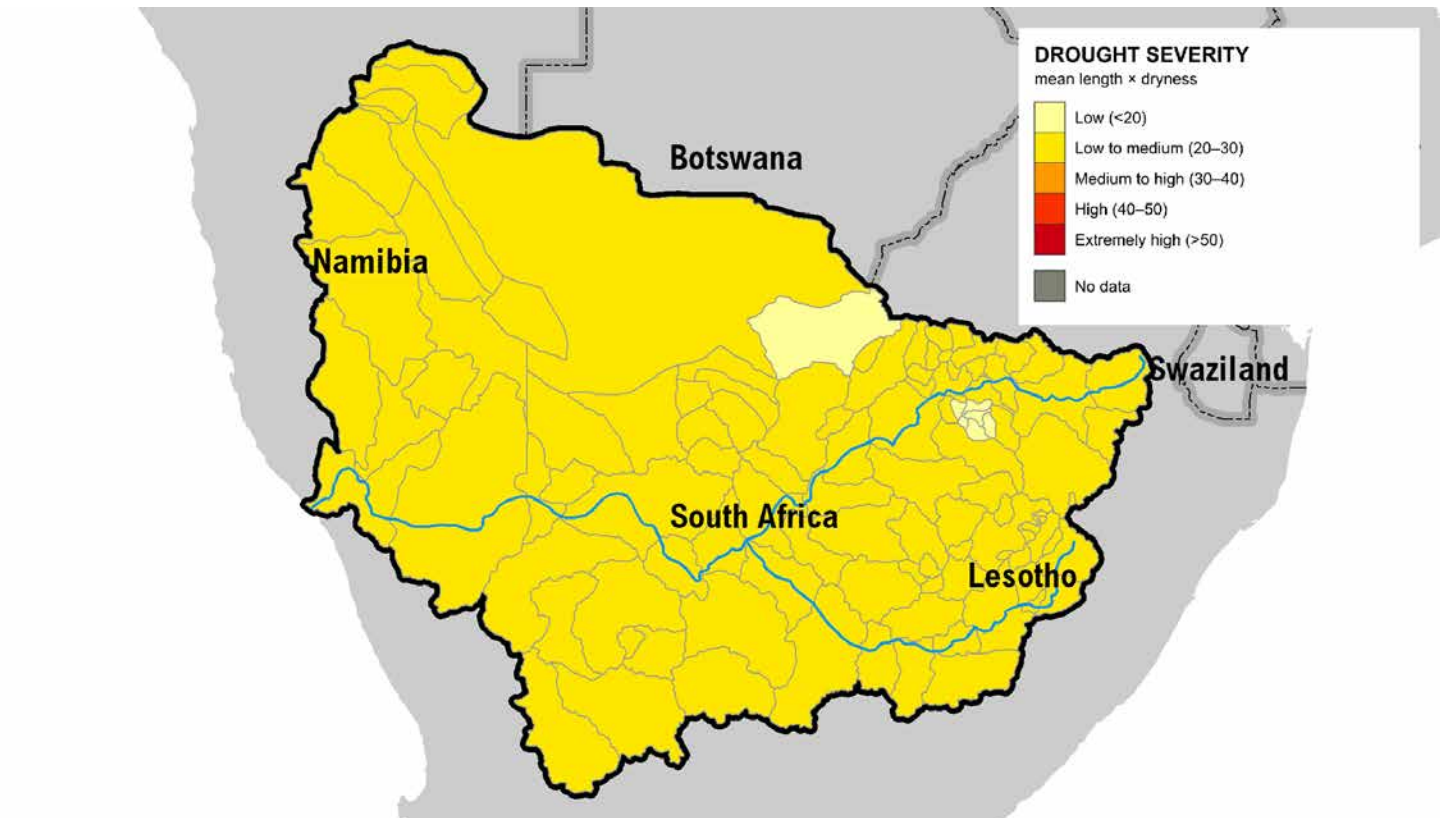
Description: *Drought severity* measures the average length of droughts times the dryness of the droughts from 1901 to 2008.

Calculation: Drought severity is the mean of the durations 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 was resampled from its 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) re-analysis, 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. inter-annual and seasonal variation) because they have more water storage capacity upstream.

Calculation: Upstream storage capacity (2010) divided by the mean total blue water (1920–2004). Multiple dam datasets were combined for more complete coverage. Areas with storage capacity equal to zero were coded as missing data.

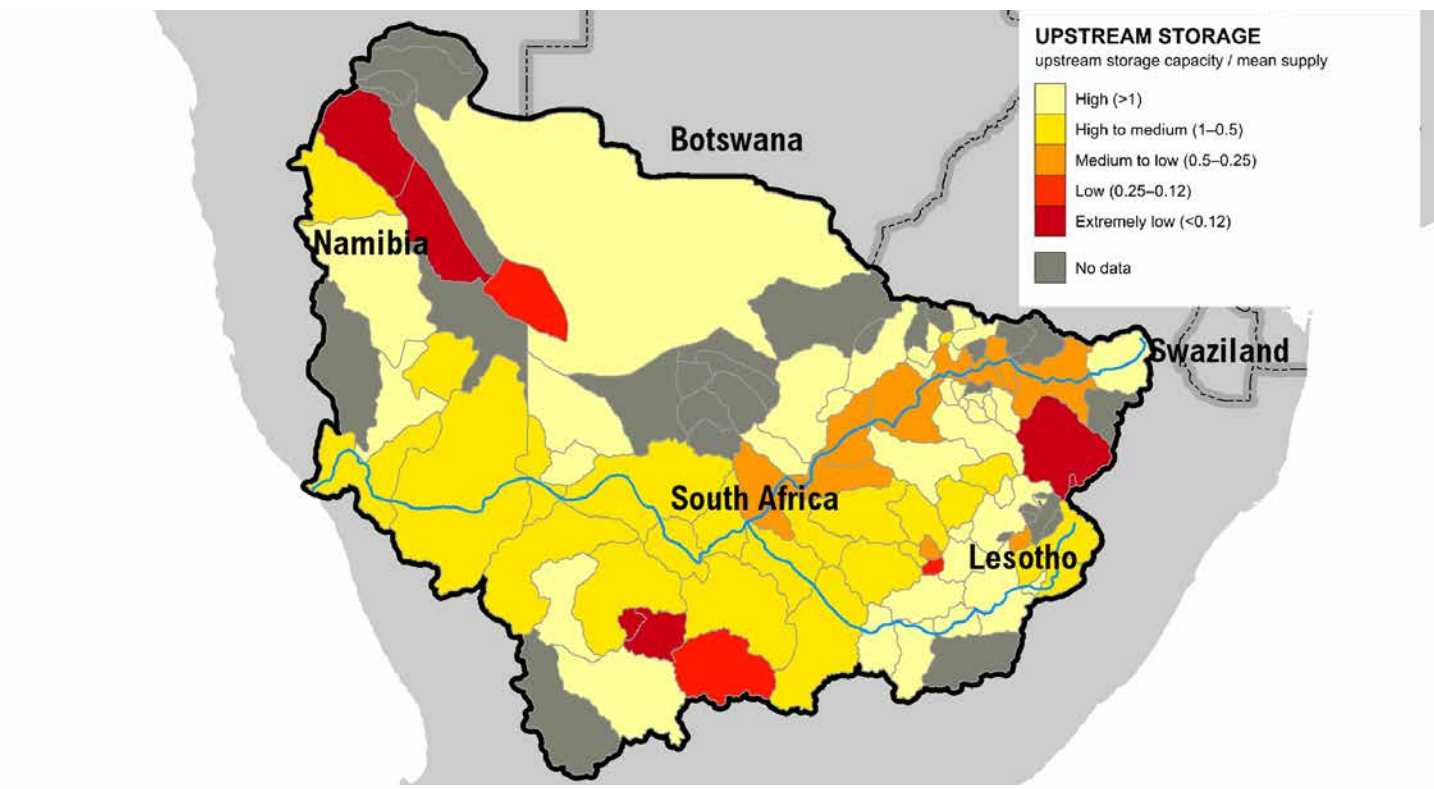
Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Data Sources

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.php?option=com_content&task=view&id=207&Itemid=68
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. The GRanD database was cross referenced with the U.S. Bureau of Reclamation website and extended with two additional reservoirs. Flow accumulated reservoir storage for each hydrological basin was calculated as the sum of reservoir capacity within that basin and all upstream basins.

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 lower water quality in areas that lack sufficient treatment infrastructure and policies.

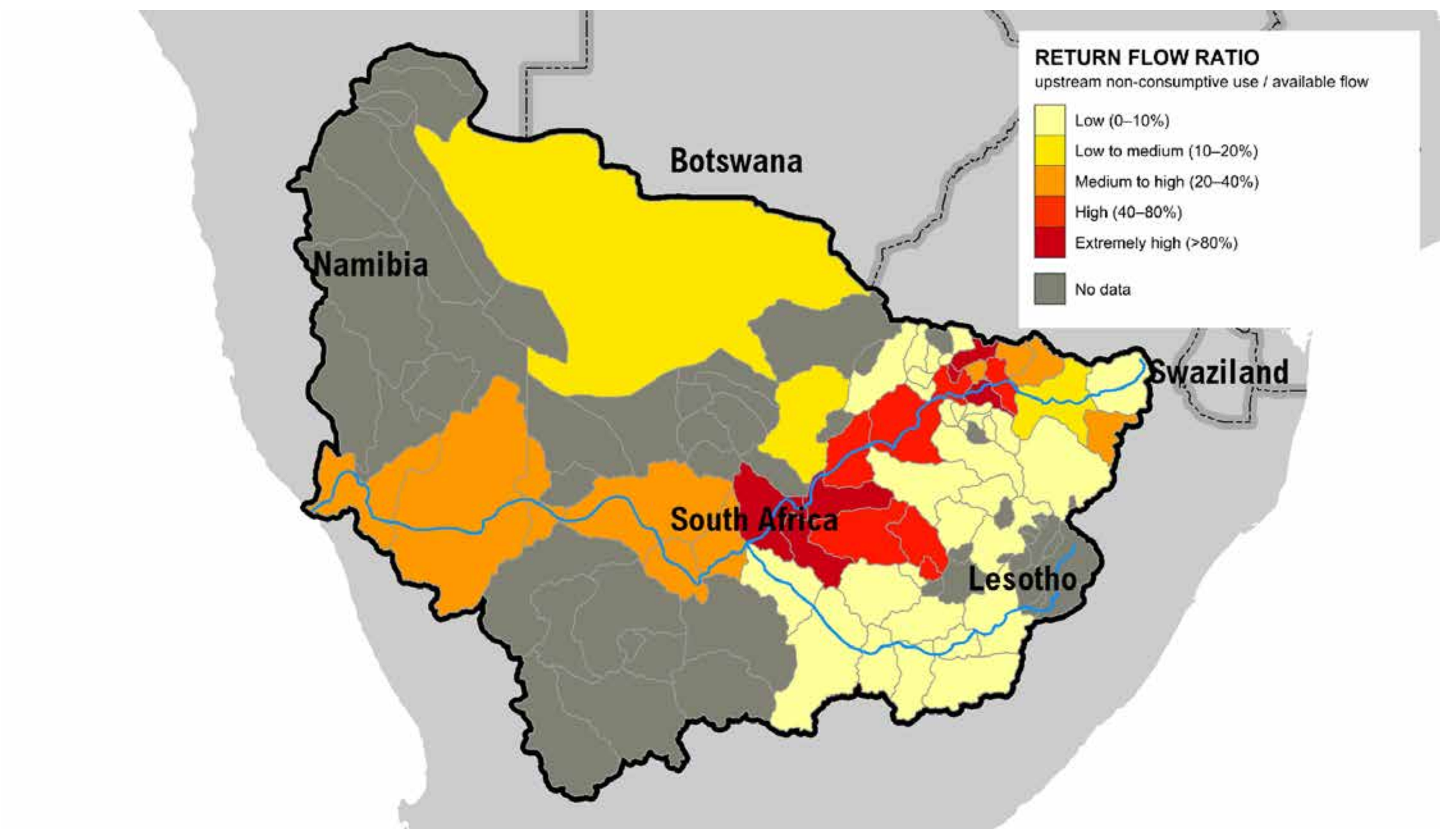
Calculation: Upstream non-consumptive use (2011) divided by the mean of available blue water (1920–2004).

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 (NH_3-N)

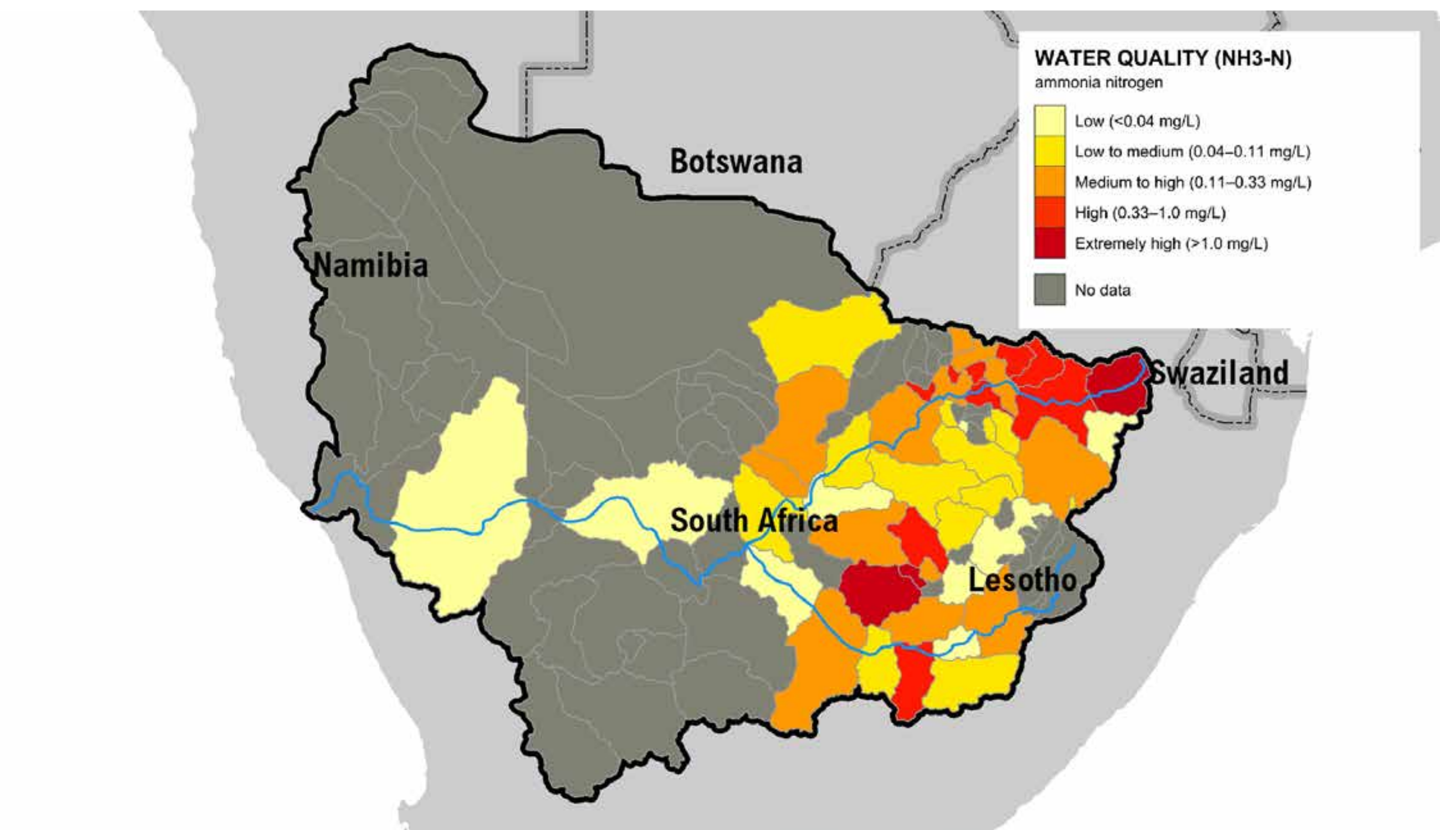
Description: *Ammonia nitrogen (NH3-N)* is the measure of the level of nitrogen. Higher values, often driven by fertilizer use or by domestic and industrial discharges may have a detrimental effect on water quality.

Calculation: NH3-N 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 sample data for a given parameter were coded as missing data.

Data Sources

VARIABLE	AMMONIA NITROGEN (NH_3-N)
Author	South African Department of Water Affairs
Title	Resource Quality Services–Water Management Systems
Time covered in analysis	2011
URL	http://www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp
Date Accessed	October 26, 2011
Resolution	Sites (point)

Water Quality – Ammonia Nitrogen



WATER QUALITY—ELECTRICAL CONDUCTIVITY (EC)

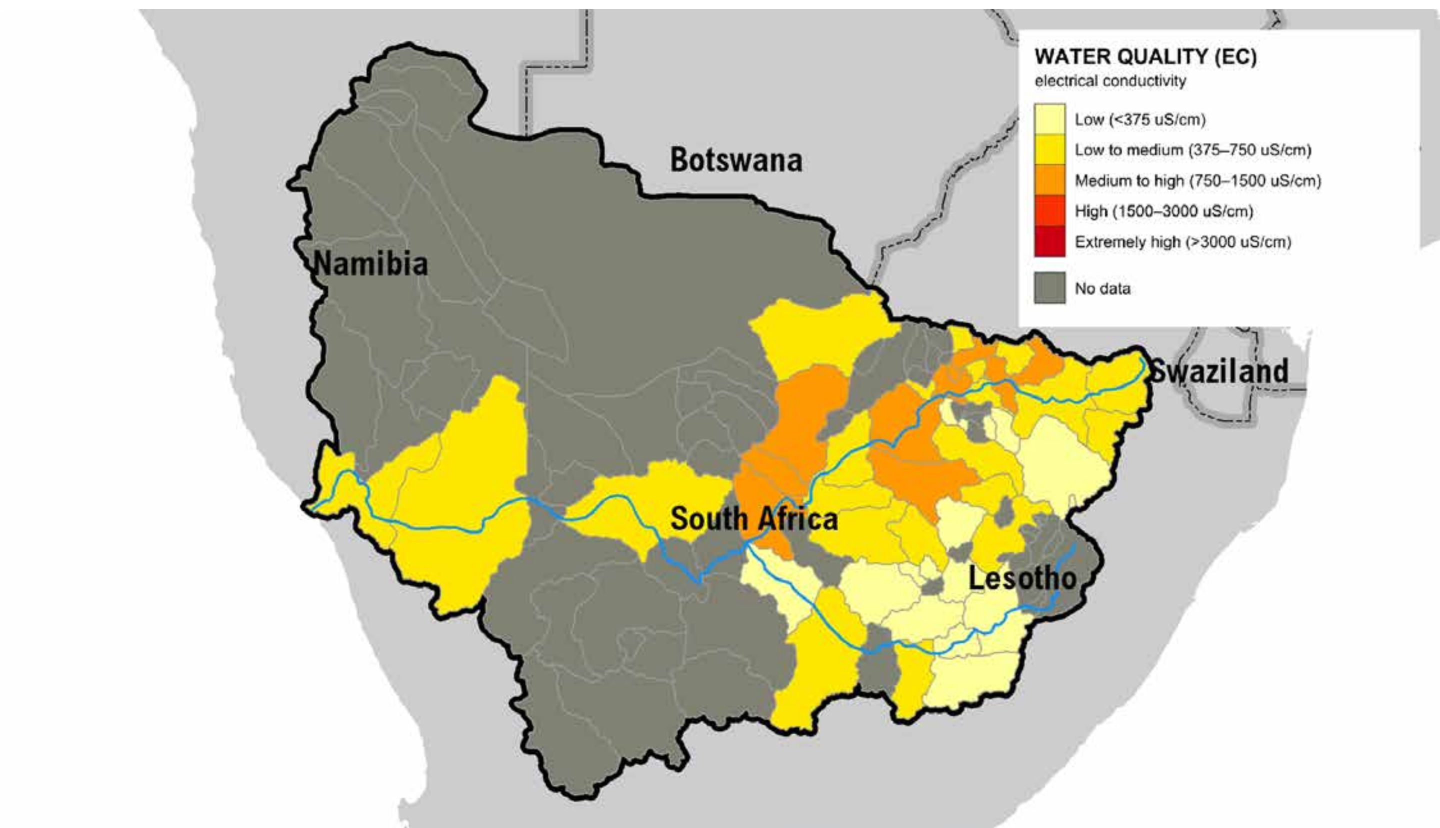
Description: *Electrical conductivity (EC)* measures how easily electricity passes through water and is a common proxy for salinity. In general, higher values reflect higher salinity, thus lower water quality.

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 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	South African Department of Water Affairs
Title	Resource Quality Services–Water Management Systems
Time covered in analysis	2011
URL	http://www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp
Date Accessed	October 26, 2011
Resolution	Sites (point)

Water Quality – Electrical Conductivity



WATER QUALITY— PHOSPHATE (PO_4-P)

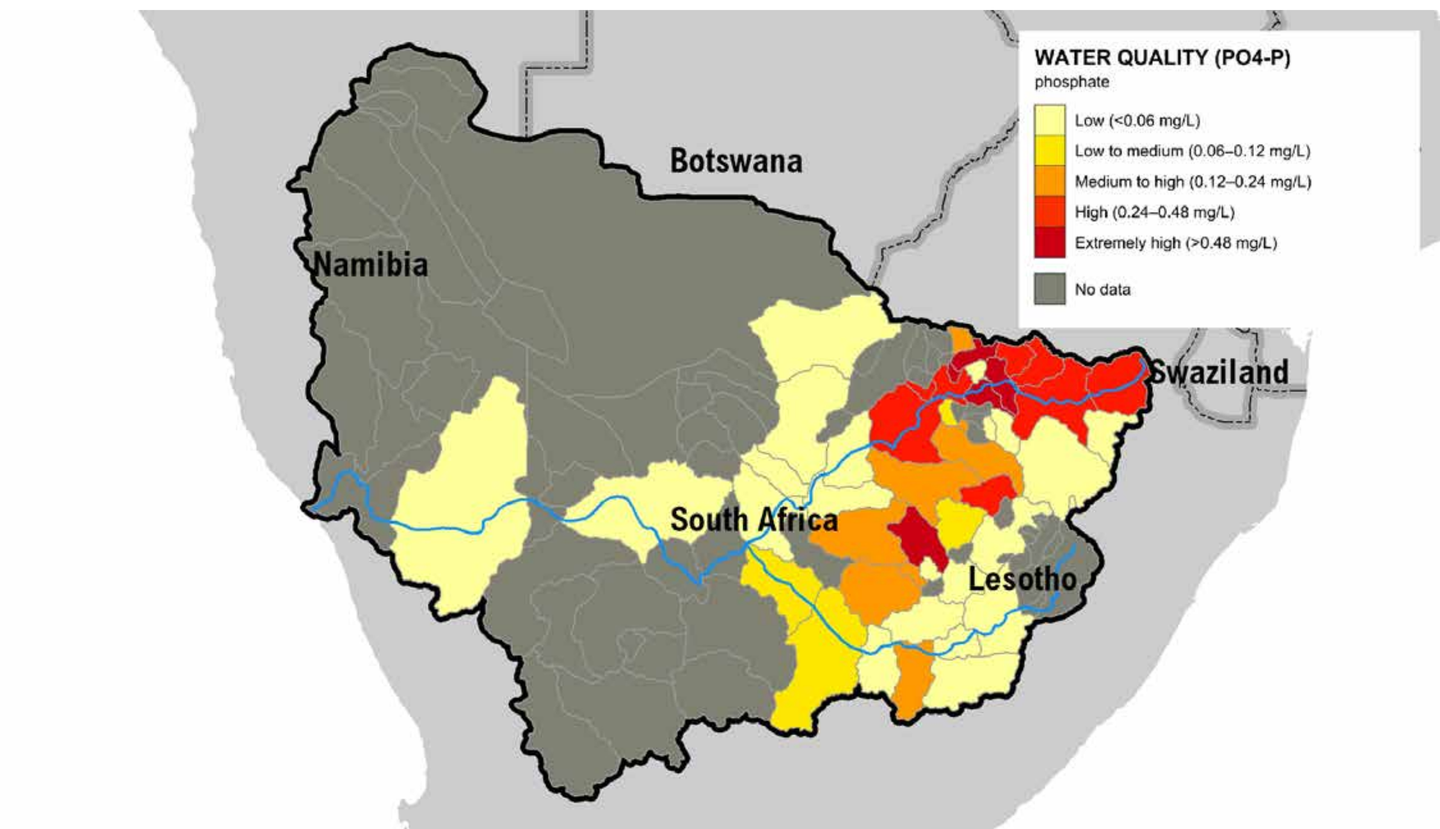
Description: *Phosphate (PO4-P)* measures levels of phosphorus. In general, higher values, often driven by fertilizer use as well as domestic and industrial discharges, reflect lower water quality.

Calculation: Phosphate 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 sample data for a given parameter were coded as missing data.

Data Sources

VARIABLE	PHOSPHATE (PO_4-P)
Author	South African Department of Water Affairs
Title	Resource Quality Services–Water Management Systems
Time covered in analysis	1970–2010
URL	http://www.dwaf.gov.za/iwqs/wms/data/WMS_pri_txt.asp
Date accessed	October 26, 2011
Resolution	Sites (point)

Water Quality – Phosphate



UPSTREAM PROTECTED LAND

Description: *Upstream protected land* measures the percentage of the 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.

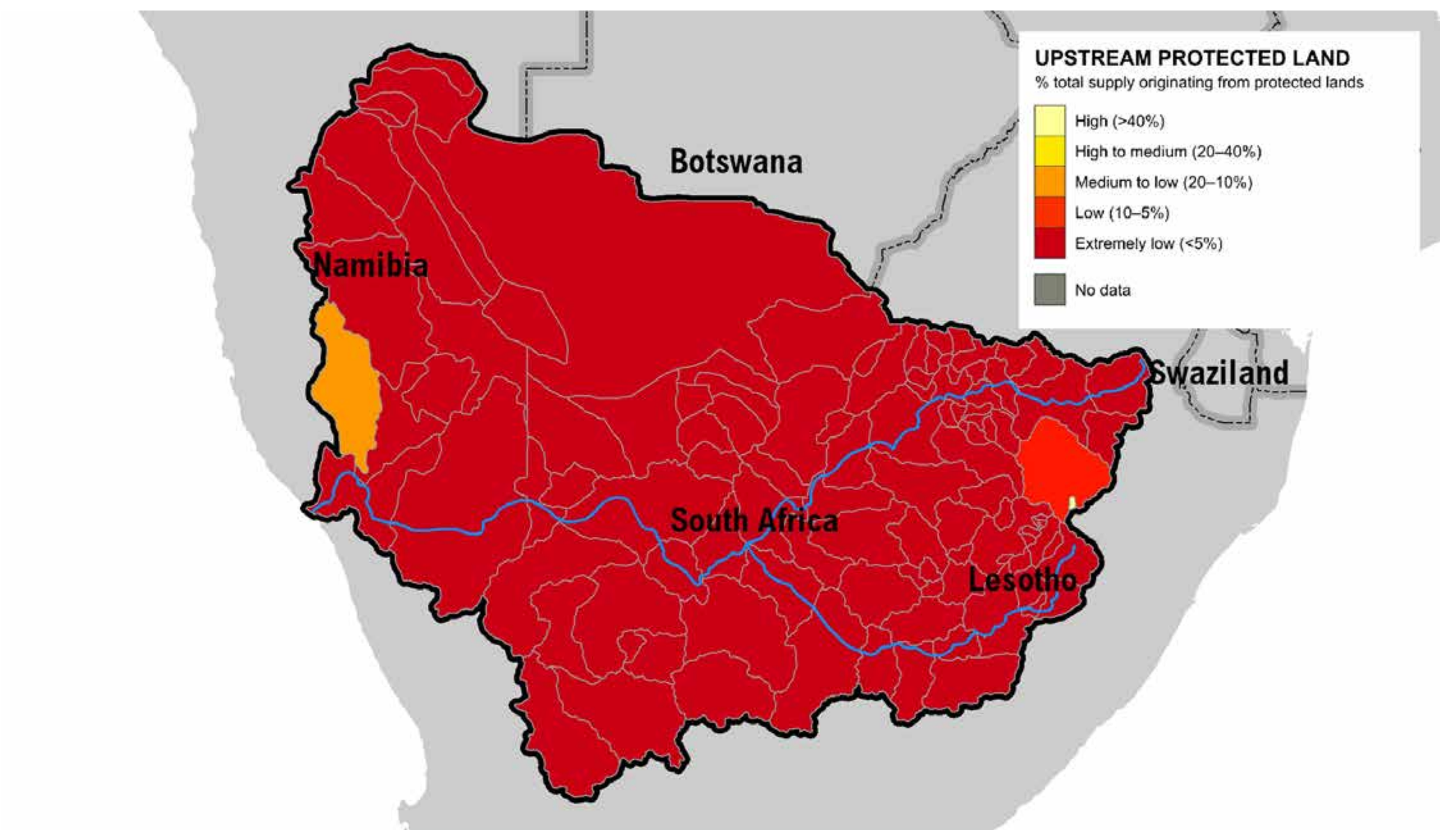
Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Data Sources

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



MEDIA COVERAGE

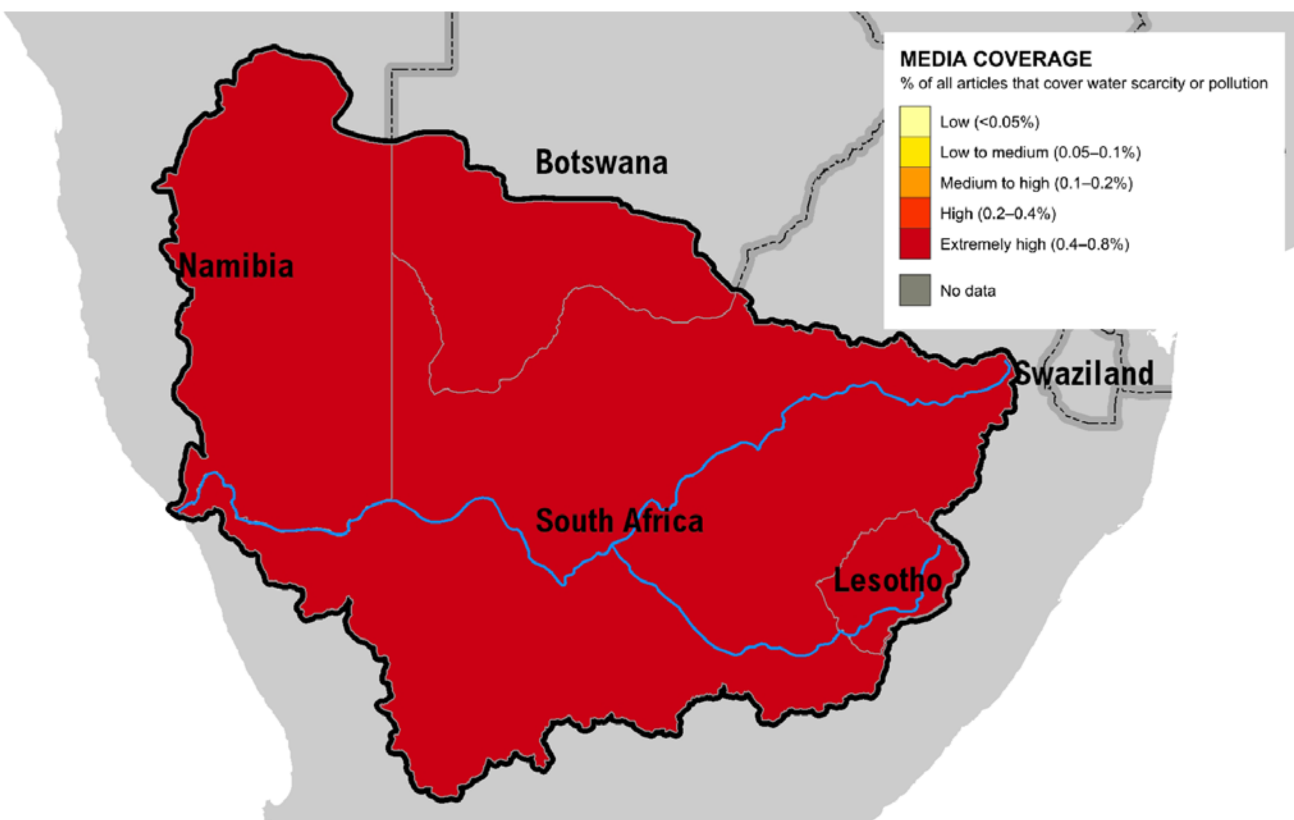
Description: *Media coverage* measures the percentage of media articles in an area on water-related issues. Higher values indicate areas with higher public awareness of water issues, and consequently higher reputational risks to those not sustainably managing water.

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. "Orange River + water shortage + Gauteng"). The time frame was limited to the past 10 years from January 1, 2002 to December 31, 2011. For each state and 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. Media Coverage is calculated at the state level in South Africa and country level in Botswana, Lesotho, and Namibia.

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	December 07, 2011
Resolution	Country and province

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.

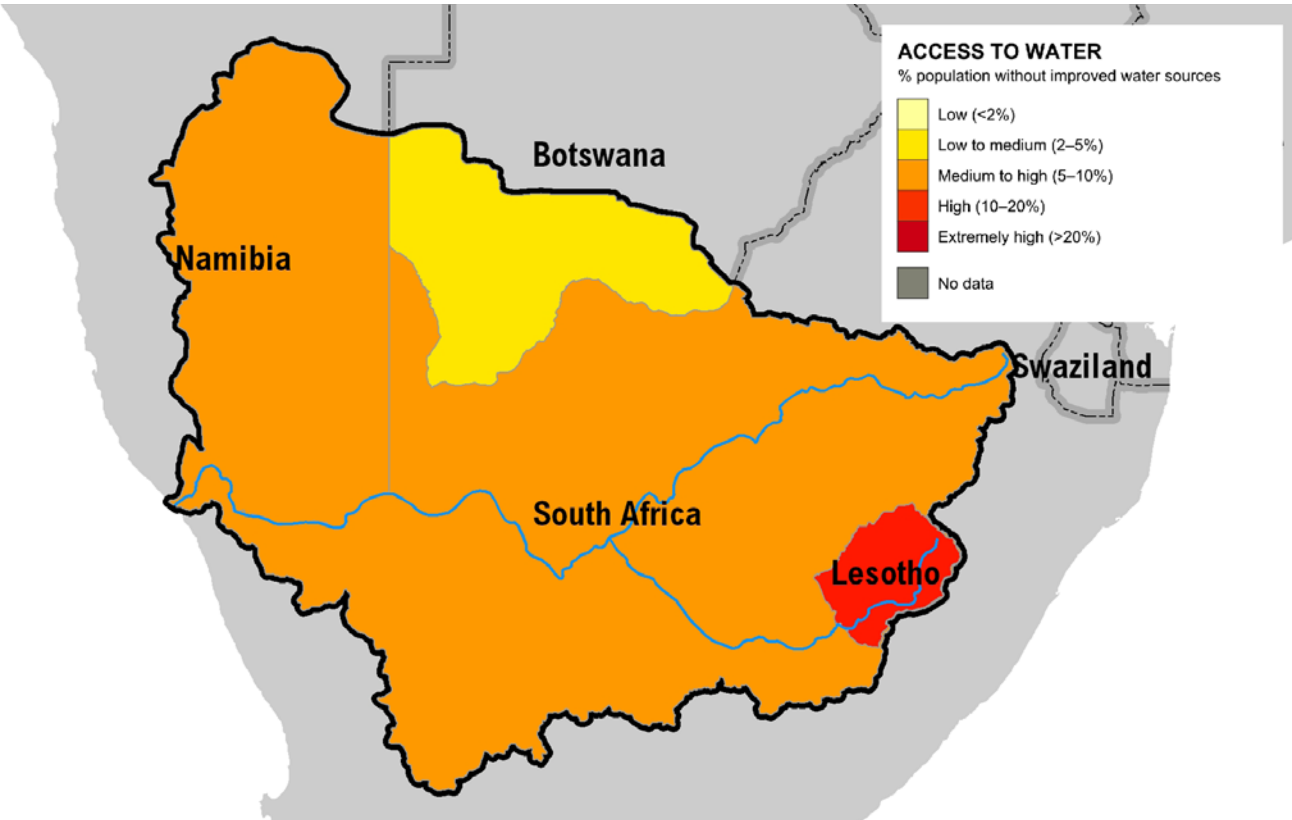
Calculation: Percentage of population without access to improved drinking water. An improved drinking water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter. Data for Botswana, Lesotho, and Namibia were obtained from the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF). Data for South Africa were obtained from Statistics South Africa.

Data Sources

VARIABLE	ACCESS TO WATER – BOTSWANA, LESOTHO, AND NAMIBIA
Authors	World Health Organization (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

VARIABLE	ACCESS TO WATER – SOUTH AFRICA
Author	Statistics South Africa
Title	Statistical Release P0318 General Household Survey 2009 (revised)
Year of publication	2011
Time covered in analysis	2008
URL	http://www.statssa.gov.za/publications/P0318/P0318June2009.pdf
Resolution	State

Access to Water



THREATENED AMPHIBIANS

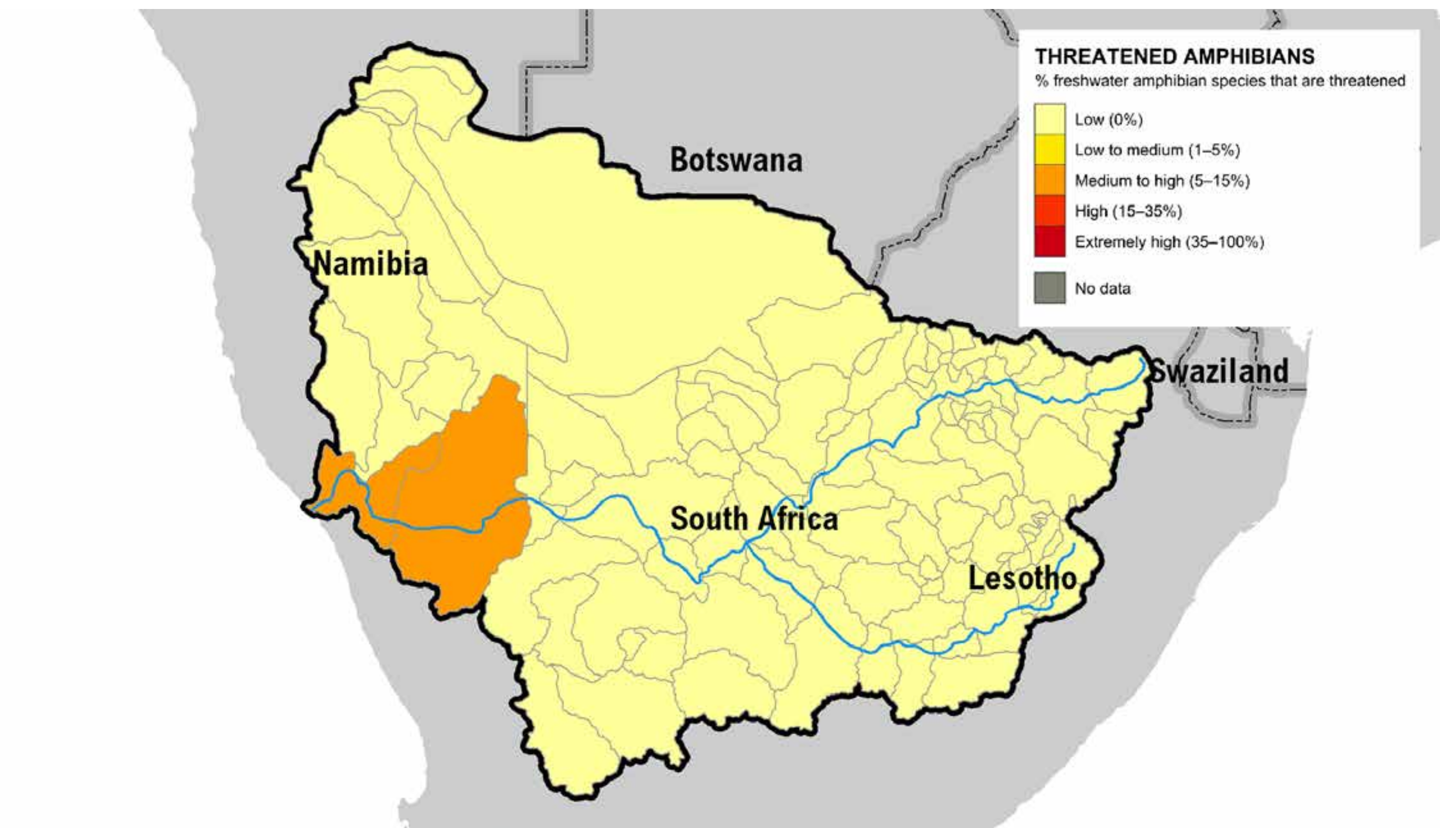
Description: *Threatened amphibians* measures the percentage of freshwater amphibian species classified by IUCN as threatened. Higher values indicate more fragile freshwater ecosystems and thus areas more likely to be subject to water withdrawal and discharge regulations.

Calculation: The percentage of amphibian species classified by IUCN as threatened in a particular area. For each catchment, the total number of threatened freshwater amphibian species was counted and divided by the total number of species whose ranges overlap the catchment. Catchments with fewer than two amphibian species were 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.
Comments	Freshwater 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. Reig, P., T. Shiao and F. Gassert. 2013. "Aqueduct Water Risk Framework." Working Paper. Washington, DC: World Resources Institute. Available online at http://www.wri.org/publication/aqueduct-water-risk-framework.

ABOUT WRI

WRI focuses on the intersection of the environment and socio-economic development. We go beyond research to put ideas into action, working globally with governments, business, and civil society to build transformative solutions that protect the earth and improve people's lives.

Solutions to Urgent Sustainability Challenges
WRI's transformative ideas protect the earth, promote development, and advance social equity because sustainability is essential to meeting human needs today, and fulfilling human aspirations tomorrow.

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WRI spurs progress by providing practical strategies for change and effective tools to implement them. We measure our success in the form of new policies, products, and practices that shift the ways governments work, businesses operate, and people act.

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We operate globally because today's problems know no boundaries. We are avid communicators because people everywhere are inspired by ideas, empowered by knowledge, and moved to change by greater understanding. We provide innovative paths to a sustainable planet through work that is accurate, fair, and independent.

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- Phera Ramoeli, Southern African Development Community
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- Caryn Seago, WRP Consulting Engineers
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- Horst Vogel, GIZ

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giz | On behalf of Federal Republic of Germany The Federal Government

UKaid from the Department for International Development

Australian AID

And the Aqueduct Alliance:

- Goldman Sachs
- General Electric
- Skoll Global Threats Fund
- Bloomberg
- Talisman Energy Inc.
- Dow Chemical Company
- Royal Dutch Shell
- Dutch Government
- United Technologies Corporation
- DuPont
- John Deere
- Procter & Gamble Company