Water Resources, Water Shortage, Water Politics; 1990, 97

* Middle East faces major water woes
* Drying out in Santa Barbara
* Water is running out in China
* Irrigation
* Prepared during about 1990 and 1997
* Read for scan May 12, 2004 (44 p) doc RJ 0353

Roy Jenne
May 12, 2004
Middle East Faces Major Water Woes

Drying out in Santa Barbara

L.A. official thirsts for Northwest water

Water Is Running Out in China

Designs on irrigation

Ray Janne
1990, 497
Drying out in Santa Barbara
California city looks for water

By Haya El Nasser
USA TODAY

SANTA BARBARA, Calif. — The drought is so draining, residents only half-see when they talk of hiring a rainmaker.

“It’s close to a panic,” says Charles Eckberg, a bank real estate officer. “We had a rain shower recently and an American Indian had done a dance demonstration. He had to come out with a statement saying ‘I didn’t do it.’”

Perhaps nowhere is the Western drought more evident than in Santa Barbara. After months of drought conditions, a savage fire last month destroyed 630 homes — turning the hills around the city into black ash and skeletal trees.

The blaze, blamed on arson, could have been controlled only by torrential rain. As rebuilding continues, the fire has emphasized the need to find new water sources.

“There’s a great deal more interest in water when people see a fire zoom down a hill and ruin a lot of homes,” says Bruce Burnworth, head of a panel looking for alternatives.

Among options:

- Convert sea water into fresh water, by building the USA’s largest desalination plant. Sea water would be processed by distillation, boiling the water and condensing it into fresh water, or by reverse osmosis, which uses a high-pressure filter system.
- Use water from the plant would cost $1,200 to $2,200 per acre-foot (one acre-foot is about 326,000 gallons) vs. normal costs of $30 to $40.
- Import water. The city would hire companies to fill tanker trucks with fresh water from lakes and rivers on Canada’s west coast. The trucks would pump their loads into city reservoirs. Cost may be higher: up to $3,000 per acre-foot.

In either case, extra water won’t be pouring into Santa Barbara until late 1991, unless the city can temporarily tap into state water pipelines.

And the city has yet to go through what promises to be grueling, acrimonious public hearings.

“It’s going to be a can of worms,” Eckberg predicts.

Water has become a political hot potato — putting environmentalists, anti-growth groups, and business owners against one another. Blame and finger-flying.

FIRE AFTERMATH: Harold and Ethel Sumida look over their backyard fish pond — the only thing left of their Santa Barbara home, destroyed in a firestorm.

ARSON SEARCH: Investigators search for evidence at point of origin in fires that destroyed hundreds of Santa Barbara homes.

Its water supply just half of normal
Santa Barbara, which gets its water from reservoirs and ground-water pumping, is scrambling to find new water sources. Here’s the reason, and some of the city’s options.

Current water supply: About 55% of normal.

How long current supply would last: About 18 months.

Price of water: Average monthly bill for a single-family home jumped from $22 to $135 since March.

Water conservation: Higher water prices and a ban on lawn watering cut water use by 45% since March.

Alternatives studied by the city: Importing water from Canada via tanker; building a plant to convert seawater into fresh water; tapping into the state water pipelines.

July 1990

- Convert sea water?
- Increase the cost of water?
- skyrock
Yakimas' suit challenges state's right to limit their water rights

The Associated Press

YAKIMA — Stung by a state judge's ruling that limits their water rights, the Yakima Indian Nation has filed a federal lawsuit questioning the state's authority over tribal water claims.

The federal suit arises out of a massive, 13-year-old state court case that is trying to sort out all the competing water claims in the Yakima River Basin.

Yakima County Superior Judge Walter Stauffacher in late May limited Indian water claims to what they currently receive, about 655,000 acre-feet. The Yakimas had laid claim to about 2.5 million acre-feet of water, which was nearly all the irrigation supply in the semi-arid valley.

The Yakimas this week filed two lawsuits in federal court against the state of Washington and its Department of Ecology, contending they did not have the right to settle Indian water claims.

Under the U.S. Constitution, the federal courts are where legal issues involving Indian treaty should be decided, one lawsuit contends.

The Indians also are demanding that only judges holding lifetime tenure and salary protection hear the case.

The tribe further seeks to stop enforcement of Stauffacher's ruling. And it also asked the federal court to rule as unconstitutional the 1952 McCarran Amendment that allows state courts to make a determination of treaty water rights.

No hearing date on the lawsuits has been set. The state case filed in 1977 has the state suing 5,000 named defendants, all of whom depend on Yakima River Basin water, in an attempt to sort out who is entitled to how much water.

22 June 1990

Tacoma, WA paper

News Tribune
L.A. official thirsts for Northwest water

By Debbie Howlett
USA TODAY

PORTLAND, Ore. — Cold and clean, water bubbles non-stop from each of 42 brass drinking fountains on city street corners here.

It's a "sinful" waste, says Kenneth Hahn, a county supervisor in drought-stricken Los Angeles some 800 miles away. To quench southern California's thirst, Hahn wants to tap into the flow of the mighty Columbia River.

In a region where water is cherished, Oregon Gov. Neil Goldschmidt told Hahn: "I have the distinct impression you are trying to steal my water."

While southern California scrimps to use only 5 billion gallons of water a day, the Columbia River spills 90 billion gallons into the Pacific Ocean — daily.

The situation is so desperate, Hahn wants to siphon "excess" water from the Columbia and Snake rivers in Washington, Oregon and Idaho, and ship it south to Los Angeles in a pipeline longer than the Alaska oil pipeline.

Although the area of severe drought is about 94

- So. California scrimps to use only 5 b. gallons a day.
- The Columbia River dumps 90 b. gallons into ocean.

July 1990
AMERICAN SURVEY

This little water went to market

ALAMOSA, COLORADO

THE "old politics" of water in the American west seemed simple. The west should be settled and taxpayers should subsidise the irrigation necessary to bring this about. The only argument was about which dams should be built. In the "new politics", water is now assumed to be finite, price is suddenly relevant and argument is about ownership and trade.

Last month, a judge in Alamosa, Colorado, heard a day's argument on whether a parcel of local land had been granted to its present owners' predecessors-in-title by the colonial Spanish government. That was the new politics of water. The same month, a tribal leader of the Shoshone Indians, on the Wind River reservation in Wyoming, spoke of why his religion required the tribe to be good custodians of the river's fish. That was the new politics, too.

The old way has been changing slowly. In the 1960s the environmental movement, sick of seeing vandalism like the flooding of Glen Canyon, on the Colorado River, and ably helped by federal budget constraints, scotched the idea that new dams could be built ad infinitum. The old settle-and-irrigate policy of the late nineteenth century as-

Don't blame the drinkers

Estimated freshwater use
Billion gallons per day

Total 0.0
Other 17
Domestic 1
Irrigation 0

UNITED STATES

Source: US Geological Survey Circular
Designs on irrigation

In the 1990s, developing countries which rely on irrigated agriculture for food will face a dilemma. Should they develop capital-intensive projects aiming for maximum efficiency using carefully controlled amounts of water and fertilizer to obtain high yields from the best land? Or should they involve as many people as possible in schemes which may not make the most of scarce resources?

Irrigation has boosted food grain production by 68 per cent over the past 20 years, according to the World Bank. Of the 250-million hectares under irrigation, 175-million of these are in developing countries, with Asia accounting for about 60 per cent. Shortages of water, money and land restrict the scope for new irrigation schemes,

For rich and poor countries alike, investment in drainage can improve yields. Pakistan is building a drainage network to remove salt water from the wheatfields of Sind.

In Bangladesh, the pressure on land is so intense that dry season irrigation is essential to provide a degree of food security.

At the other end of the prosperity scale, the arid, oil-rich countries of the Middle East can afford expensive desalinated water to turn desert into productive farmland using hi-tech sprinklers or drip irrigation.
Middle East Faces Major Water Woes
Nations Struggling With Scarce Resources Add to Potential for Political Strife
10 March 1990

By Caryle Murphy
Washington Post Foreign Service

DAMASCUS, Syria, March 9—
The Middle East is on the verge of an explosive crisis, some experts and officials say, over a commodity that could become more precious than oil: water.

From the Euphrates to the Nile—and especially in the volatile Jordan River basin, where the intertwined water resources of Jordan, Israel and the occupied West Bank add a complex dimension to peace efforts—governments face growing water demands from swelling populations, increasing urbanization and rising agricultural and industrial requirements.

To satisfy these needs, officials are racing to draw on rivers shared with neighbors who have competing demands, and on underground water supplies that are being depleted at alarming rates.

Signs of the crisis are many. In Egypt, which imports half of its food, the biggest constraint on new agricultural production is water. In the Israeli-occupied Gaza Strip, drinking water is salty because sea water has tainted the drawn-down underground water, or aquifer.

In Jordan, the government recently installed an irrigation system for 6,000 acres, but has no water to supply it. In Damascus, residential water taps go dry every day from 2 p.m. until 6 the next morning.

Experts foresee critical water shortages in this decade in several countries of the Middle East, which averages 3 percent population growth annually.

- Limited water
- Growing demands
Water Is Running Out in China

A severe shortage and wasteful water-use habits threaten to leave northern provinces thirsty.

By Ann Scott Tyson
Staff writer of The Christian Science Monitor

BEIJING

CRISP, ripe watermelons cooled under running taps are a traditional panacea for millions of Beijing residents seeking respite from the heat and dust of summer.

But as the peak water use months of June to September begin, a severe water shortage threatens to leave the capital's thirst for cold melon, long showers, and other aqueous luxuries unquenched.

Like meandering cracks on a sunbaked earthen pot, rivers are running bone dry through the scrub-topped hills and arid flatlands that surround the city.

The flow of water into Beijing's largest reservoir, Miyun, is dropping daily, officials say. Guanting Lake, the other major reservoir supplying the city's 10 million residents, is drying up.

Hard-to-replenish groundwater in and around Beijing is falling so drastically from over tapping that the city is sinking, according to sources envisage "paralysis" of the city, with factory shutdowns, loss of crops, and water cutbacks for residents unless steps are taken to curb demand and channel in fresh supplies.

Without such measures, they predict that by the year 2000 Beijing will face a crippling daily shortfall of 550,000 cubic meters (715,000 cubic yards) of water, or two-thirds of what city waterworks supply today.

"Beijing is facing an intense water shortage problem," says Chen Chunhai, a senior official at the Ministry of Water Resources. "If this continues for two more years, Beijing won't survive," he said in an interview.

The water crisis is not limited to Beijing. Severe water shortages are plaguing the whole North China Plain, a densely populated region with some 200 million inhabitants that stretches far to the Yangtse River, the experts predict will have a population of 600 million by 2030.

In Beijing and the major seaport of Tianjin, water resources per capita are about 390 cubic meters (507 cubic yards) a year -- less than one-sixth of China's national average, and only 4.7 percent of the world average.

"Demand for water in China is growing," supply...

"Beijing is facing an intense water shortage problem. ... If this continues for two more years, Beijing won't survive."

-- Chen Chunhai, government official
Water Observations for USA

♦ Rivers

♦ Precipitation, snow, temperature (max, min)

♦ Mountain Snow
Figure 9.--Number of daily-record gages in operation during year shown
All Stations with Major Rivers

450 Rivers
Hydro-Climatic Data Network:


HYDRO-CLIMATIC DATA NETWORK (HCDN):
A U.S. GEOLOGICAL SURVEY STREAMFLOW DATA SET FOR THE UNITED STATES FOR THE STUDY OF CLIMATE VARIATIONS, 1874-1988

By J. R. Slack and Jurate Maciunas Landwehr

U.S. GEOLOGICAL SURVEY
Open-File Report 92-129

Rex ton, VA

1992

U.S. GEOLOGICAL SURVEY
OPEN-FILE REPORT 92-129
Figure 1c. HCDN stations in relation to major rivers of the conterminous U.S.
SNOW COURSES

Snow courses consist of a number of sample points (usually about 10) along a transect at a permanently marked location. At each point, snow depth and water equivalent observations are made. Densities are also computed to verify each sample's accuracy. After all the sample points are measured, the depth and water equivalent values are averaged.

The typical snow course is measured monthly, just prior to the first day of the month. Most snow courses are measured February 1 through May 1. However as the seasonal snowpack varies across the Western US, variations to that schedule occur.

While some of the earliest snow courses were established between 1905 and the 1920's, there were less than 100 of these in existence. The greatest number of sites occurs in the mid 1980's when approximately 1600 snow courses existed, and nearly 6,500 measurements were taken annually. Since then, with the introduction of improved data collection methods, the number of snow
The installation of SNOTEL sites began in 1979 with a significant addition of new sites for the first several years of the program. While new sites are added each year, the total number of sites has leveled off somewhat and currently stands at 614 sites throughout the Western United States.
This is a graphical view of data from a typical SNOTEL site. This example shows the accumulated precipitation throughout the water year and the accumulation and melt-out of snow water equivalent. While throughout the winter months these two sensors are essentially measuring the same precipitation amounts, they continue to have their own unique characteristics that can vary from site to site. It is not uncommon to have the snow pillow measure more winter precipitation than the precipitation gauge. This is primarily due to the decreased catch efficiency of the precipitation gauge to measure snowfall. This discrepancy will vary from site to site, and is strongly influenced by the sites susceptibility to wind.
Information about Data

1. The Handbook of Applied Meteorology (1461 pages)
   - John Wiley & Sons, 1985
   - Has a 100-page chapter about data (Jenne & McKee)

2. Selected contents about Water Data
   - P 1202: Pollution data, precipitation chemistry
   - P 1203: USGS observing networks
     — Stream flow, lakes, quality, sediment
   - P 1219: USGS data services
   - P 1215: Data services from Asheville (USGS)
   - P 1210: Long-term precip trends
   - P 1214: Stream flow & other water data in Canada
   - History:
     — History of world nets (precip, temp, pressure)
     — Stations in US (306 in 1850, 3057 in 1900)

Roy Jenne
Dec 1997
World Monthly Precipitation Grids

See Eischeid, et al.
(Journal of Applied Meteorology, Dec 1995: Vol. 34, No. 12)

1. The 5° monthly grids available since ~1990
   • 1851-1995
   • And 1880-on is quite good

2. Based on the monthly station data
   • 7500 precip stations
   • 6000 temperature stations

3. These observations and grids were used in IPCC 1995.

4. 2.5° grids will be available February 1998
   • These are anomaly grids
   • One is a land-only precip grid
   • One includes MSU satellite precip anomaly over the oceans (1979-on). They blend quite easily.
   • Two forms: less smoothing or more smoothing

5. Compare grids over land with Arkin grids
   • The numbers are about the same
   • The Arkin (NOAA-CPC) grids are smoother
Monthly Station Precipitation

GHCN (Global Historical Climate Network):

- World monthly station precipitation
- Based on several previous efforts
- A project of Oak Ridge and Asheville
- (Includes monthly precip, temp, pressure)

The Data:

- First version out in ~1990
- Second version due ~January 1998

Trouble getting data:

- Data for 1995 not as good as 1900
- Coverage for 1985-1995 not very good

Two Centers in Germany

- Global Precipitation Center
- Global Runoff Center
Precipitation Data for USA

1. Hourly precip data (USA)
   - 2500 stations (1948-1996) — NCDC
   - Hourly US Precip grids by CPC (1963-on)
   - NCEP:
     a. Hourly real time precip, stn archives, started Jan 1996
     b. Hourly US precip grid, stations only, start Jan 1996
     c. Hourly US precip, radar only, started Jan 1996
     d. Hourly US precip, radar plus stations, start Apr 1996

2. Daily precip data (USA)
   - 7500 co-op stations (1900-on) — NCDC
   - NCEP
     a. Daily precip obs (real time) started Apr 1995
     b. Daily US grids started Apr 1995
Water Data from Climate Models & Reanalysis

1. Climate models
   a. They have daily storms.
   b. Some types of runs
      • Simulate present climate
        — Can check with 30-year statistics of observations
      • Simulate future climate

2. Reanalysis
   a. Gives the location of daily storms
      • They are in the right location
      • Can use this with satellite observations
   b. Reanalysis output: used to help check climate models

3. Selected outputs from both reanalysis & climate models
   a. Precipitation
   b. Snow
   c. Soil water
   d. Runoff
   e. Evaporation
   f. And: radiation, heat flux, wind, etc.
   g. Plus: temperature, pressure, wind, etc. in whole atmosphere

4. Water observations.
   • Ground based
   • And satellite help

5. Warning: the mountains are too smooth in models.
Compare Snow Cover Obs vs Models

SNOW-MASS INTERCOMPARISONS IN THE BOREAL FORESTS

Table 1. Snow-mass (10^{13} kg) values for six GCMs compared to SDC data. Negative and positive values are percentage differences of the modeled snow mass compared to the SDC snow mass. BF = Boreal Forest.

<table>
<thead>
<tr>
<th></th>
<th>SDC</th>
<th>GLA</th>
<th>ECHAM</th>
<th>GENESIS</th>
<th>GISS</th>
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<tbody>
<tr>
<td>North America</td>
<td>206.0</td>
<td>-16.5</td>
<td>-13.6</td>
<td>-16.0</td>
<td>-45.9</td>
</tr>
<tr>
<td>(February)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>108.0</td>
<td>-25.5</td>
<td>-9.5</td>
<td>-33.7</td>
<td>-36.5</td>
</tr>
<tr>
<td>BF (February)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eurasia</td>
<td>303.0</td>
<td>-7.3</td>
<td>-12.2</td>
<td>+16.5</td>
<td>-19.8</td>
</tr>
<tr>
<td>(February)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eurasia</td>
<td>138.0</td>
<td>-22.0</td>
<td>-2.4</td>
<td>-23.9</td>
<td>-1.7</td>
</tr>
<tr>
<td>BF (February)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

February

N. Am
Eurasia

April

N. Am
Eurasia

↑ from James Foster, et al. - Goddard

↑ Goddard

↑ NCAR

↑ GISS
Climate Model Precip

Model 1X/Observed Climate
TRENDS '93

A compendium of data on global change

Editors
Thomas A. Boden
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Frederick W. Stoss

Production Editor
Gay Marie Logsdon

CARBON DIOXIDE INFORMATION ANALYSIS CENTER
WORLD DATA CENTER-A FOR ATMOSPHERIC TRACE GASES CENTER FOR GLOBAL ENVIRONMENTAL STUDIES OAK RIDGE NATIONAL LABORATORY
Precipitation

England and Wales area-average precipitation amount

P.D. Jones, T.M.L. Wigley, and J.M. Gregory (continued)

ENGLAND AND WALES

Trends

The England and Wales area-average precipitation time series produced by Jones, Wigley, and Gregory show no obvious long-term trends in precipitation amount. Wigley and Jones (1987), in analyzing these series (which at that point extended through 1985), observed a tendency towards wetter springs over the period 1956–69 and drier summers from the late 1960s through the mid-1970s. When the series were updated and analyzed through 1989, however, Gregory et al. (1991) found no further evidence of these trends, pointing out that they may represent normal fluctuations that help to illustrate the scale of natural climatic variability.

Annual precipitation for England and Wales. Annual totals are depicted by the thin line, while the thick line represents the annual totals smoothed with a five-term binomial filter.
where $r_{ij}$ represents the annual total for the station, $\bar{r}_i$ is the mean annual rainfall (over the whole period of record) at station $i$, and $\sigma_i$ is the standard deviation of the annual totals for the station. The areally integrated annual rainfall departure for each region is then represented as

$$R_j = \frac{1}{I_j} \sum x_{ij},$$

where $I$ is the number of stations available for the year $j$. 

---

**African rainfall stations and geographical regions.**

Trends

According to Nicholls and Lavery (1992), the data from Dowerin show no clear long-term precipitation trends. Annual precipitation is dominated by winter (April–September) precipitation, which shows marked interannual variability over the period of record. In contrast, summer precipitation is less variable, as evidenced on the graph below by consistent spacing between the lines representing the 11-point running means for 12-month (April–March) and winter precipitation.

Winter (Apr.–Sept., thin solid line) and 12-month (Apr.–Mar., dashed line) precipitation amount at Dowerin. The summer (Oct.–Mar.) precipitation amount is represented by the spacing between the thin solid and dashed lines. The spacing between the two thick solid lines (the winter and 12-month, 11-point running means) indicates long-term changes in summer precipitation.
Data for Geophysical Research, Especially Hydrology

Runoff from continents, 1900-1980

Needs for Water Data
— Hard to get data

The overall global hydrology cycle

Problem with water shortage

Water observations for USA

Sources of precipitation datasets

Long-term trends, precipitation and runoff
Figure 1. Comparison between the total runoff fluctuations for the different continents and for the whole world. Five-year moving averages were calculated on standardized data. [From Probst and Tardy, 1987.]
Needs for Water Data Archive

- Many measurements of water data
  - Surface observations (precipitation, snow, rivers, etc.)
  - Ocean precipitation from satellites (SSMI, TRMM, etc.)
  - Precipitation from weather radar

- Analyses of water observations in atmosphere
  - Operational
  - Reanalyses

- Water data from climate archives
The Volume of Data

1. World observations for reanalysis

<table>
<thead>
<tr>
<th></th>
<th>Period</th>
<th>Years</th>
<th>Volume</th>
</tr>
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<tbody>
<tr>
<td>a. The rawinsondes, pibals</td>
<td>1946-97</td>
<td>52</td>
<td>40 GB</td>
</tr>
<tr>
<td>b. Surface synop (3 hr)</td>
<td>1946-97</td>
<td>52</td>
<td>90 GB</td>
</tr>
<tr>
<td>c. Other aircraft</td>
<td></td>
<td></td>
<td>2 GB</td>
</tr>
<tr>
<td>d. Surface ocean</td>
<td>1946-97</td>
<td>52</td>
<td>6 GB</td>
</tr>
<tr>
<td>e. Satellite sounder (2.5°)</td>
<td>1969-96</td>
<td>28</td>
<td>27 GB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>165 GB</td>
</tr>
</tbody>
</table>

2. Archives from global reanalysis (204 Km resolution)
   • All archives (54 GB/yr), 50 years, 2600 GB
   • Most used archives, 50 years, 500 GB

3. Data from US GOES satellites.
   1978-1996 (19 yr) 200 TB/19 yr
   • Capture/archive cost $150K/year
   • Cost to copy & improve archive $2 million

4. Data from US weather radars
   • Copy, mailing, archive cost $800K/yr 100 TB/yr

5. Data from NASA EOS satellites
   • Launch mid-1998
   • Volume primary data 80 TB/yr
   • Cost for Archive, make products ($230 m/yr)

Roy Jenne
Dec 1997
Water Observations are Needed for Research
(But there are policy problems)

1. Need observations to study climate variations & change.

2. World governments are very interested.
   - About climate
   - Climate research
   - Expected trends

3. It is now easier to store & exchange data.

But

Compared with 1975
   - People are less willing to share data
     — Keep a monopoly
     — Try to make money
   - It is harder to obtain surface data
The Global Water Cycle

- Precipitation, evaporation, runoff

- World fresh water

- Precipitation & Runoff
  - By continents
  - By rivers

- Ice Caps
  - During ice age
  - Now

- Sea level change (ice age cycles)
  - Measure from coral reefs
  - Information from under water caves
  - Oxygen isotopes in ocean sediments
Fig. 1. Diagram of the water cycle. The numbers in the figure are the values of the relevant elements of the world water balance: those not in parentheses are in cubic kilometers and those in parentheses are in millimeters. 1--Precipitation; 2--streamflow; 3--evaporation.

From Leibovich, 1974 (AGU book 1979)
World Fresh Water

1. Glaciers 24,000,000 Km³ Mostly Antarctica & Greenland

2. Annual water over land (not ice caps)

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Equivalent</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precip</td>
<td>113,500</td>
<td>(910 mm)</td>
<td>100%</td>
</tr>
<tr>
<td>Evap</td>
<td>72,500</td>
<td>(560)</td>
<td>62%</td>
</tr>
<tr>
<td>Runoff</td>
<td>41,000</td>
<td>(350)</td>
<td>38%</td>
</tr>
</tbody>
</table>

3. Irrigation water use
   - About 2,000 Km³ in 1970

4. Lakes, reservoirs, soil water

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Lakes &amp; reservoirs</td>
<td>155,000 Km³</td>
</tr>
<tr>
<td>Reservoirs</td>
<td>1,855</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>83,000 (~570 mm)</td>
</tr>
</tbody>
</table>

5. Annual consumption (selected)

<table>
<thead>
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<th>Component</th>
<th>Number</th>
<th>Water use Km³</th>
</tr>
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<tbody>
<tr>
<td>People (drinking water), (1m³/yr)</td>
<td>3300 million</td>
<td>3.3</td>
</tr>
<tr>
<td>Domestic animals (1965)</td>
<td>1607 million</td>
<td>22</td>
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</table>

Roy Jenne
Precipitation & Runoff

<table>
<thead>
<tr>
<th></th>
<th>Precip</th>
<th>Runoff</th>
<th>Natural Stable</th>
<th>Water in Reservoirs</th>
<th>Area</th>
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<tbody>
<tr>
<td></td>
<td>Km³</td>
<td>(Km³)</td>
<td>Runoff (Km³)</td>
<td>1970; Km³</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>7165</td>
<td>3400</td>
<td>1125</td>
<td>200</td>
<td>9.8</td>
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<tr>
<td>Asia</td>
<td>32690</td>
<td>13,190</td>
<td>3440</td>
<td>560</td>
<td>45.0</td>
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<td>Africa</td>
<td>20780</td>
<td>4,225</td>
<td>1500</td>
<td>400</td>
<td>30.3</td>
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<tr>
<td>North America</td>
<td>13910</td>
<td>5,950</td>
<td>1900</td>
<td>500</td>
<td>20.7</td>
</tr>
<tr>
<td>South America</td>
<td>29355</td>
<td>10,380</td>
<td>3740</td>
<td>160</td>
<td>17.8</td>
</tr>
<tr>
<td>Australia</td>
<td>6405</td>
<td>1,965</td>
<td>465</td>
<td>35</td>
<td>8.7</td>
</tr>
<tr>
<td>Total:</td>
<td>110,305</td>
<td>38,830</td>
<td>12,170</td>
<td>1855</td>
<td>132.3</td>
</tr>
</tbody>
</table>

Note: use for irrigation about 2000 Km³ in 1970.

The Amazon River

Annual river flow 149,950 m³/sec (for 1928-1946)
- Depth of runoff 1008 mm
- Runoff in Km³ 4730 Km³

Area of basin 4.688 million Km²

See: World Water Resources & Their Future, L'vovich (AGU, 1979)

Roy Jenne
3 Dec 1997
Discharge of Selected Rivers of the World  
(A UNESCO Publication)

<table>
<thead>
<tr>
<th>River Discharge</th>
<th>Basin Km²</th>
<th>River ID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m³/sec</td>
<td>Km³</td>
</tr>
<tr>
<td>Parana, Posadas (Argentina)</td>
<td>11,800</td>
<td>1024</td>
</tr>
<tr>
<td>Orinoco, Ccd (Venezuela)</td>
<td>25,200</td>
<td>2186</td>
</tr>
<tr>
<td>Amazon (obidos)</td>
<td>6210</td>
<td>539</td>
</tr>
<tr>
<td>Mississippi (Vicksburg) US</td>
<td>15,800</td>
<td>1371</td>
</tr>
<tr>
<td>Colorado (Arizona)</td>
<td>489</td>
<td>42</td>
</tr>
<tr>
<td>Columbia (The Dalles, OR)</td>
<td>5520</td>
<td>479</td>
</tr>
<tr>
<td>Yukon, (Kaltag, Alaska)</td>
<td>6210</td>
<td>539</td>
</tr>
<tr>
<td>Mekong (Pakse, Laos)</td>
<td>10,300</td>
<td>894</td>
</tr>
<tr>
<td>Amur</td>
<td>10,300</td>
<td>894</td>
</tr>
<tr>
<td>Lena (Kusur)</td>
<td>16,300</td>
<td>1414</td>
</tr>
<tr>
<td>Neva (Novosaralovka)</td>
<td>2540</td>
<td>220</td>
</tr>
<tr>
<td>Volga</td>
<td>8380</td>
<td>727</td>
</tr>
<tr>
<td>Ob</td>
<td>12,200</td>
<td>1059</td>
</tr>
<tr>
<td>Rhine (Rees)</td>
<td>2210</td>
<td>192</td>
</tr>
<tr>
<td>Danube (Orsoya, Romania)</td>
<td>5427</td>
<td>471</td>
</tr>
<tr>
<td>Main Nile (Kajnarty)</td>
<td>2730</td>
<td>238</td>
</tr>
<tr>
<td>Blue Nile (Khartoum)</td>
<td>1640</td>
<td>142</td>
</tr>
</tbody>
</table>

**Total:** (16,356)  
Sum ~20.9 x 10⁶ Km²

Note: These 17 rivers give 42% of world runoff  
- They have 16% of world land area

Roy Jenne  
Dec 1997
<table>
<thead>
<tr>
<th>ICE SHEET</th>
<th>VOLUME (10^6 \text{ km}^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>present</td>
</tr>
<tr>
<td>Antarctic</td>
<td>30.0</td>
</tr>
<tr>
<td>Greenland</td>
<td>2.6</td>
</tr>
<tr>
<td>North American</td>
<td>-</td>
</tr>
<tr>
<td>Eurasian</td>
<td>-</td>
</tr>
</tbody>
</table>

\[32.6 \quad 83.8\]

Ice Cap Change

- A change of 51.2
  * gives 113m of sea level
- Sea level rise, ice age to 6000 years ago
  * is 120 meters

Ice volume is expressed in equivalent sea-level rise

- East Antarctic Ice Sheet: 60 m
- West Antarctic Ice Sheet: 6 m
- Greenland Ice Sheet: 6 m
- Remaining ice: 0.3 m

Note that melting of ice shelves, sea ice, and grounded ice below sea level does not affect sea level.

THE ICE SHEETS OF GREENLAND AND ANTARCTICA

<table>
<thead>
<tr>
<th></th>
<th>GREENLAND</th>
<th>ANTARCTICA</th>
</tr>
</thead>
<tbody>
<tr>
<td>area (10^6 \text{ km}^2)</td>
<td>1.7</td>
<td>14</td>
</tr>
<tr>
<td>mean ice thickness (m)</td>
<td>1530</td>
<td>2160</td>
</tr>
<tr>
<td>ice volume (10^6 \text{ km}^3)</td>
<td>2.6</td>
<td>30</td>
</tr>
<tr>
<td>maximum surface elevation (m)</td>
<td>3300</td>
<td>4000</td>
</tr>
<tr>
<td>annual accumulation (cm ice depth/yr)</td>
<td>34</td>
<td>17</td>
</tr>
<tr>
<td>loss of ice by calving</td>
<td>50 %</td>
<td>99 %</td>
</tr>
<tr>
<td>melting</td>
<td>50 %</td>
<td>1 %</td>
</tr>
</tbody>
</table>