

Global Hydrology and the Construction of a Water Crisis

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This paper examines the popular discourse of the ‘global water crisis’ as it came into prominence in the 1990s. It argues that in addition to the serious problems associated with the availability and condition of freshwater resources in many parts of the world, the ‘crisis’ was generated by developments in hydrological methods that originated in the Soviet Union. Specifically, these methods produce data that permit a worldwide, or global representation of the world’s water resources. The use of this data by western scholars and writers to construct the ‘global water crisis’ is discussed with particular reference to two highly influential publications of the 1990s that have set the tone for subsequent discussion.

Keywords: global hydrology, global water crisis

In just over a decade, concerns about global water scarcity have grown from “a sleeper of a problem” (Postel 1992:7) to become one of the world’s most talked-about environmental issues. Today, the “global water crisis” has spread to the front pages of newspapers and the covers of popular magazines.¹Articles with titles such as ‘Global water crisis: the major issue of the 21st century, a growing and explosive problem’(Saeijs and van Berkel 1995) appear commonly in academic journals. And groups with various political agendas - from social activists on the left (Barlow 2001) to those calling for the commodification of water and privatization of water infrastructure on the right (Cosgrove and Rijsberman 2000) – couch their arguments in the context of “the global water crisis.”

What is responsible for the emergence of this crisis? Have the material conditions of drought and water scarcity reached such a drastic level in the past fifteen years that the matter simply cannot be ignored? Or is the ‘crisis’ something that has been constructed in the discourse of hydrologists, bureaucrats, businesspeople,

geographers and journalists? Surely the answer lies somewhere in a combination of physical circumstances and social construction. Sorting out the one from the other is an important task. To regard water scarcity and the water ‘crisis’ uncritically may pander to those who have a particular interest in proclaiming them. On the other hand, to construe water scarcity as a purely discursive construction may deny ‘features of the world which we cannot afford to ignore’ as the philosopher, Kate Soper has put it. (Soper 1996:23)

The purpose of this paper is to begin an exploration of one aspect of the construction of the water crisis. In the early 1990s, several key documents brought the matter of global water scarcity to widespread public attention. (Postel 1992; UNCED 1992; World Bank 1993; Gleick 1993) These studies provided the essential data and established the discursive space in which a host of others could elaborate the problem in academic journals and through the mass media. Underlying these foundational studies, in turn, was a hydrological approach that permitted questions of water availability and scarcity to be

treated in a *global* sense, as issues of *global* concern. While this approach was not new (it had been discussed and applied among some hydrologists in North America and Europe since the early 1960s) it achieved a kind of prominence in the early 1990s. There would appear, therefore, to be a correlation between this 'global hydrological' approach and the emergence of the 'global water crisis.' Following a brief discussion of the role of science in constructing environmental issues, this correlation is explored below.

Science, the Environment and Water

The importance scientific method in constructing environmental issues has been recognized since at least the early 1970s, when the Club of Rome's *Limits to Growth* study predicted 'imminent global disaster' resulting from resource scarcity and pollution. (Meadows et al. 1972:cover) At the time, David Harvey responded with a critique showing how a neo-Malthusian prognosis of resource scarcity was the inevitable outcome of the application of empirical methodology and extrapolation of contemporary statistical trends. (Harvey 1974) Drawing from Marxian dialectics, Harvey argued that things – including resources – cannot be understood independently of the (heterogeneous and contradictory) relations that produce them. Thus, a resource can only be understood in relation to the mode of production in which it is made useful. 'There is,' Harvey argued, 'no such thing as a resource in abstract or a resource, which exists as a "thing in itself"' (275). To predict the scarcity of a natural resource therefore presupposes certain social ends, and these define scarcity just as much as the lack of natural means to accomplish these ends.' (272) More recently Harvey has made the argument even more strongly: 'To say that scarcity resides in nature and that natural limits exist is to ignore how scarcity is socially produced and how "limits" are a social relation within nature (including human society) rather than some externally imposed necessity.' (Harvey 1996:145)

Harvey's analysis notwithstanding, falling oil prices have probably done more than critical theory to quell anxiety about resource scarcity over the past 20 years. But while concerns about such things as dwindling fossil fuel and magnesium reserves have evaporated, worries about water scarcity have grown. Applying Harvey's critique to global water scarcity, there is no doubt that part of the problem reflects various 'social ends' and the demands of capitalist production. At the same time, it must be recognized that the need for water is not always contingent on social relations. 'Water...' as one hydrologist notes 'is the most fundamental ingredient of all life on Earth; it is more universally necessary even than free oxygen.' (Jones 1997:2) In approaching issues involving water and water scarcity it is therefore important to insist on an approach that tempers constructionism with a recognition of the undeniable fact of, and the universal need for, water.

In the 1990s there was a general shift of attention from earlier concerns about resource scarcity and regional pollution to global-scale problems associated with the externalities of growth. These problems involved such things as destruction of the stratospheric ozone layer, global loss of biodiversity and global warming. Scholarssuch as Benton and Redclift (1994), Wynne (1994) and Demeritt (1998; 2001) have considered the emergence of these concerns as a product of the scientific practices that have made them manifest. 'The hardening of a scientific consensus around a particular way of constructing an environmental problem' note Benton and Redclift 'may appear to result from the evidence but could, in fact, be a result of mutual reinforcement by networked scientific and policy communities.' (Wynne 1994:23; See also Latour 2000: Chapter 4)

While drawing attention to the role of scientific practice in constructing global environmental issues, these critiques recognize that scientific knowledge is constrained by the objective world that scientists seek to understand. For example, Demeritt, in his critique of the science of global warming, adopts what he calls a

'heterogeneous constructionist' approach by which he carefully defines 'precisely what I mean by the construction of global warming.' He points out that this approach, 'does not deny the ontological existence of the world, only that its apparent reality is never pre-given; 'reality' is only ever realized as such through the configuration of [scientific] practices that make existence manifest...' (Demeritt 2001:310,311)

This kind of approach is useful for considering how scientific practices and social relationships might be thought of as having contributed to the global water crisis. Although several fields – including demography, human geography, and environmental studies – have contributed to the literature of global water scarcity, the essential data upon which the water crisis have been built is hydrology. The following section provides a brief, historical introduction to this discipline as it has developed in the west and describes the emergence of what has been termed 'global hydrology.'

Modern Hydrology

It is often thought that 'the hydrological system is simple to grasp' as the popular Canadian chronicler of water, Marq de Villiers, has put it. (de Villiers 2000) Actually, the hydrological system, as we now conceive of it, is the product of generations of philosophizing, hypothesizing, contestation, observation and measurement. (Biswas 1970) The idea that water is in a state of constant flow has been described and debated at least since the time of Homer. Until as recently as the early 18th century, it was widely held that rainfall was insufficient to account for the enormous volumes of water pooled in lakes and flowing in rivers. Philosophers from Plato to Descartes supposed that the circulation of water on earth was predominantly a subterranean affair, in which vast underground caverns and conduits channeled water from the oceans to reservoirs contained within hills and mountains. They held that it was from these reservoirs that water discharged from springs onto the surface, from

whence it returned to the oceans via streams and rivers.² An 'atmospheric' theory of the water cycle was described as early as the fifth century BC and was developed independently in China at approximately the same time. However it was the Roman architect and engineer, Marcus Vitruvius, who is thought to have conceived the main theoretical outlines of what is now generally accepted as the modern concept of the hydrologic cycle. Although several Renaissance writers made contributions to the water cycle concept, it was by quantifying the water balance of specific river basins that 'the science of hydrology, as contrasted to the arts of hydraulic and hydrologic engineering' became fully established. (Kazmann 1972:11) Thus it is claimed that the practice of 'scientific hydrology' began with Pierre Perrault's measurements and computations of precipitation and runoff in a delimited basin of the upper Seine River in the 1670s. (Rodda 1995: 362)

In its broadest sense, modern hydrology encompasses 'the study of the occurrence, the movement, and the physical and chemical characteristics of water in all its forms within the Earth's hydrosphere.' (*Britannica* 15thed. s.v. Earth Sciences, 17:593) In practice, most hydrologists restrict their study to water at or near the earth's surface. Measuring the quantity and flow of water is the basic activity of hydrology. The various sub disciplines that comprise hydrological sciences are defined according to the site at which water is examined: glaciology is the study of glaciers and polar ice caps; groundwater hydrologists examine the occurrence and flow of water underground; potamologists study water in surface streams; limnology is the study of water in bodies such as lakes and ponds. Underlying all these sub-disciplines is the concept of the hydrologic cycle, expressed in formulaic terms as the 'water balance' or 'water budget.' Here is the water balance equation stated in its simplest form:

$$\text{Runoff} = \text{Precipitation} - \text{Evaporation} \text{ plus or minus Storage}^3$$

Most hydrological sciences are concerned with evaluating one or more of the terms of the water balance equation. Because of the difficulties entailed in measuring the movement of water across boundaries of well-defined areas under study, the water balance is most easily calculated at the scale of the river basin (sometimes described as ‘catchment basin’ or, ‘watershed’). Until recently, river basins defined the scale of most hydrological investigation in North America and western Europe. For example, writing in 1976, the Swiss hydrologist Nemeč described the difference between the need for international cooperation in meteorology and hydrology in terms of the different scalar orientations of the two sciences: ‘Whilst meteorology requires a macro scale continental and global approach, hydrology requires international cooperation in basins which are divided by national boundaries.’ (Nemeč 1976, 333) By the mid-1960s, the need for the type of international cooperation referred to by Nemeč had prompted in a ten-year hydrological programme sponsored by UNESCO. The International Hydrological Decade, 1964-1974, (IHD) also resulted from concerns in many countries about ‘the scarcity of water and the difficulties of developing new sources of supply.’ (Nemeč 1976:335) For the most part, this programme sought to improve the quantity and quality of hydrological data on a basin scale – including international basins – as a prerequisite to planning regional and international water supply and management projects.⁴

The Emergence of ‘Global Hydrology’

Rudimentary studies of water resources on a world scale were attempted as early as the latter part of the 19th century. (Rodda 1995, 362) The first modern western hydrologist to study and write on ‘global hydrology’ appears to have been Raymond L. Nace, whose monographs, published by the U.S. Geological Survey, dealt with world water supply and the global water budget in the 1960s. (i.e. Nace 1965) Nace’s interest in global

hydrology was sparked by reading a paper published in 1945 by the Soviet hydrologist, M. I. L’vovich.⁵(Nace 1979; iv)

Here, the development of hydrology in the Soviet Union becomes a subject of interest. L’vovich, along with his colleagues working in the hydrology division of the Geography Institute of the Soviet Academy of Sciences, was a pioneer in the development of methods that yielded hydrological information in circumstances where ‘hydrological data were very scanty.’ (L’vovich 1979: v) The production of this information was made necessary by the demands of the Soviet system of central economic planning. As L’vovich and other Soviet hydrologists improved their techniques for producing information on the hydrology of the vast territory of the Soviet Union, they began to apply their methods on a global scale. Writing in 1974, L’vovich explained: ‘Because information available about sizable parts of the earth is less complete than the information available about other parts...’ the Soviet ‘kind of approach... has to be taken to hydrological studies of the earth’s water balance and water resources.’ (L’vovich 1979:v; see also Korzun 1978:7-9)

The work of Nace and some of the Soviet hydrologists began to appear in a few American-published articles, compilations of hydrological statistics and textbooks in the late 1960s and early 1970s (Nace 1965; 1967;1969; Barry 1969; Todd 1970:62-63; van der Leeden 1975:456-459; Chorley 1969:22-23) The development of methods and data in the calculation of a global water budget was a subsidiary activity directed by Nace under the auspices of the International Hydrological Decade. (UNESCO 1971; IASH-UNESCO-WMO 1972) As a United Nations-sponsored activity, the IHD provided a forum in which Soviet hydrological science was made available to western audiences. (USSR Committee for the International Hydrological Decade 1978) In general, however, the idea of global-scale hydrology met with considerable skepticism (Nace 1972:3) and was taken up seriously by only a handful of hydrologists in the United States and Western Europe. Writing in 1983, the

hydrologist J.T. Houghton observed:

It is only recently that hydrologists have begun to think in global terms, largely because it is only recently that meteorological information with global coverage has become available and that theoretical models of global extent have been developed. This global thinking is at an early stage. Greatly improved data and much better formulations of physical processes are required before further progress can be made. (Houghton 1983:2)

By the mid-1990s, the concept of global hydrology had become much more widely accepted among the community of western hydrologists. In his preface to a 1997 textbook on 'global hydrology' – the first of its kind – John C. Rodda, President of the International Association of Hydrological Sciences wrote:

Of course, a text entitled *Global Hydrology* would have been impossible to publish twenty or even ten years ago. Then the science was strongly dedicated to the river basin, with few hydrologists able to acknowledge that hydrology extends beyond the individual watershed towards a global dimension. But for a number of reasons this has all changed during the last decade and the science has 'gone global'. (Rodda 1997:xi)

Although Rodda does not elaborate, part of the reason for hydrology 'going global' is due to improvements in the quality and quantity of data on parameters such as groundwater and surface stream flow, evapotranspiration and precipitation in different parts of the world. Another reason may have had to do with geopolitical changes that had taken place during the years intervening between Houghton and Rodda's observations. The collapse of the Soviet Union and the end of the Cold War had the effect of freeing a number of Soviet hydrologists – who practiced hydrology in the

tradition and with the methods of L'vovich and his contemporaries – to work in the west for the United Nations and other agencies.⁶

Global Hydrology and the Water Crisis

Popular expressions of concern about a 'water crisis' have been made in North America since the 1960s. Prior to the 1990s, however, the crisis was presented as a North American, not a global problem.⁷ For example, Senator Frank Moss' *Water Crisis* (1967) describes water scarcity and pollution issues in the United States. Another American publication, titled *The Water Crisis* and published the same year as Moss's study, brings together contributions on a variety of water issues facing Americans. (Nikolaieff 1967) With the exception of one important intervention, the monumental Water For Peace conference held in Washington in 1967 discussed papers presented on national and regional water issues.⁸ Earlier Canadian publications on water concerns were similarly restricted in scale. Foster and Sewell's *Water: The Emerging Crisis in Canada* (1981) identifies water quantity, quality and environmental issues at a national scale. And Terry Anderson's *Water Crisis: Ending the Policy Drought* (1983) is a call for the allocation of water by market principles in North America. As for the earlier studies of broad environmental concerns on the global scale, water was generally not considered much of a problem. For example, the Club of Rome's famous study of *The Limits to Growth* is remarkable for its near-absence of concern about water resources.⁹

When popular concerns about a 'water crisis' surfaced in the 1990s, the scale of the crisis was different. This time, it was resolutely global. Judging from the hydrological data used to construct the 1990s version of the water crisis, it appears to be related to the emergence of global hydrological studies. Below, I examine what are perhaps the two most influential documents in raising awareness of global water issues in the 1990s. These are Sandra Postel's 1992 book, *Last Oasis: Facing Water Scarcity*

and Peter Gleick's 1993 collection, *Water in Crisis: A Guide to the World's Freshwater Resources*.

The Last Oasis

The thesis of Postel's book is that the world has entered 'a new water era' marked by 'water scarcity' and that our 'last oasis is to be found in improving the efficiency with which water is used. (Postel 1992) That Postel's work was one of the first (it could be argued that it was the first) popular statements of the issue is indicated by her description of 'the escalating pressures we are placing on water systems, on our rivers, lakes, wetlands, and underground aquifers' as 'a sleeper of a problem.' (7-8) On the front cover of the book is a composite photographic image of a dried lake-bottom with a sand dune in the middle range and a barren mountainscape in the background. Following this visual entrée, Postel begins the textual construction of global water scarcity by conjuring the image of our 'strikingly blue planet' from space. It is 'hard to believe' she points out, that 'scarcities could arise in the midst of such amazing water wealth.' (Postel 1992:27) She then applies a device that has been used with great frequency to describe the amount of fresh water on the earth – its portrayal as a tiny fraction of a fraction of the total amount of water on the planet:

“The total volume of water, some 1,360,000,000 cubic kilometers would cover the globe to a height of 2.7 kilometers if spread evenly over its surface. But more than 97 percent is seawater, 2 percent is locked in icecaps and glaciers, and a large proportion of the remaining 1 percent lies too far underground to exploit.” (Postel 1992:27)

Of the 500,000 cubic kilometers of precipitation that falls on the earth every year, most pours into the oceans. After these reductions, we are left with only 40,000 cubic kilometers as 'the world's renewable freshwater supply.' Moreover, fully two thirds of this

amount 'runs off in floods, leaving about 14,000 cubic kilometers as a relatively stable source of supply.' (Postel 1992:28) Presented in this way, fourteen thousand cubic kilometers of water seems like a very small amount indeed.

The data that permits Postel to construct this scenario is derived mainly from the work of Soviet hydrologists. Specifically, her information on the total volumes of saltwater and freshwater on earth is from Nace, as cited in van der Leeden et al. (1990). As discussed above, Nace's work drew from Soviet sources, and was inspired by the global-hydrological approach of L'vovich. Postel's data on the amount of renewable fresh water flowing through the global hydrologic cycle is from L'vovich (1979). The data on global runoff are from the Institute of Geography, National Academy of Sciences of the Soviet Union as published in World Resources Institute (1992). And the '14,000 cubic kilometers as a relatively stable source of supply' is from L'vovich (1979). (Postel 1992:194)

As shown by Postel, data on regional water balances derived from L'vovich and other Soviet scientists, together with demographic data, has permitted construction of the concepts of 'water stress' and 'water scarcity.'¹⁰

“One of the clearest signs of water scarcity is the increasing number of countries in which population has surpassed the level that can be sustained comfortably by the water available. As a rule of thumb, hydrologists designate water-stressed countries as those with annual supplies of 1,000-2,000 cubic meters per person. When the figure drops below 1,000 cubic meters (2,740 liters per person day), nations are considered water-scarce – that is, lack of water becomes a severe constraint on food production, economic development, and protection of natural systems.” (Postel 1992:28-29)

On the basis of Soviet studies of regional water

balances combined with demographic information, Postel is able to state: 'Today, 26 countries, home to 232 million people, fall into the water-scarce category.' (Postel 1992:29) *The Last Oasis* appears to have been one of the first popular books to present the concept of countries that suffer from water stress and water scarcity. It is worth noting that these concepts have been applied very frequently in the literature over the past decade. Moreover, perhaps because water stress and water scarcity are calculated on a national basis, researchers in the field of international environmental security have made use of them. For example, a forecast of countries likely to face 'water stress' by 2015 yields the following conclusion:

'By 2015, nearly 3 billion people – 40 percent of the projected world population – are expected to live in countries that find it difficult or impossible to mobilize enough water to satisfy the food, industrial and domestic needs of their citizens. This scarcity will translate into heightened competition for water between cities and farms, between neighboring states and provinces, and at times between nations.' (Postel and Wolf 2001:61)

The concept of 'water stress' has become so pervasive in the international water literature that it often used without reference to its hydrological origins. For example, Aaron Wolf, one of the foremost authorities on water and international conflict has written:

'The scarcity of water for human and ecosystem uses leads to intense political pressures, often referred to as "water stress." As a consequence, competition for water resources has contributed to tensions around the globe...' (Wolf 2001)

Part of Postel's argument is formed by water use information that has been aggregated at the global scale. Water withdrawals and consumption, for example, are

presented as global phenomena. Thus we learn that 'global water use has tripled since 1950, and now stands at an estimated 4,350 cubic kilometers per year – eight times the annual flow of the Mississippi River.' This total 'amounts to some 30% of the world's stable renewable supply.' (Postel 1992:39) Like the data on the world's water supply and global water balance, this information is based largely on data from Russian hydrologists.¹¹ More recently, Postel and others have used this data to render the calculation that humans now utilize over half the available runoff (water flowing in rivers and streams) on the face of the earth. (Postel et al. 1996)¹²

Water in Crisis

Peter Gleick's monumental *Water in Crisis* (1993) was considered by many in the 1990s as an essential, if not *the* definitive statement of the condition of freshwater resources on the planet.¹³ On the cover is a photograph of the dry bed of Russia's Aral Sea, with the rusting remains of several ships in the foreground. The book is led off by a chapter on 'World fresh water resources' by Igor A. Shiklomanov (1983). Shiklomanov, who was then based at the State Hydrological Institute in St. Petersburg, seems to have inherited L'vovich's informal title as 'the dean of Soviet hydrology.' (Nace 1979, iv) In a world where popular concern about water issues has given some hydrologists a certain measure of prominence, it may be said that Shiklomanov is world-famous. Chosen by the United Nations to lead the massive collaborative inventory known as the Comprehensive Assessment of the Freshwater Resources of the World (Shiklomanov 1997), his work is cited in the vast majority of studies dealing with global water issues in the past decade. In his award-winning book *Water*, Canadian author Marq de Villiers describes Shiklomanov as 'a formidable figure in the water world' and even 'the central figure in the water universe.' (de Villiers 1999:30, 364)

Shiklomanov's tables depicting global water resources and global water balances are 'respectively,

based on data ,collected by Soviet scientists' and 'based on research conducted by Soviet scientists.' (Shiklomanov 1993:13, 15) Moreover, the data he used in 1993 were not new – they came from sources that were originally published in the 1960s and 1970s, all or almost all of which can be traced to the work of Soviet hydrologists. (Shiklomanov 1993:24) These are the same sources of hydrological information used by Postel in her presentation of global water resources, global water balance and global water use.

Gleick's book presents the world water crisis as having several facets: In addition to the introduction and conclusion, there are chapters on 'Water quality and health', 'Water and ecosystems', 'Water and agriculture', 'Water and energy', 'Water and Economic Development' and 'Water, politics and international law.' As with Postel's book, the data presented in Shiklomanov's chapter - placed immediately following the introduction and titled 'World fresh water resources' - provides the essential numbers that allow Gleick to declare that 'water' is 'in crisis' and that the crisis is global in scale. Where *Water in Crisis* differs from *Last Oasis* book is in stressing that these numbers should be read with caution. In his article, Shiklomanov warns: 'It should be noted that the data on the amount of water on earth (as the authors of the cited monograph themselves note) should not be considered very accurate; they are only approximations of the actual values.' (Shiklomanov 1993:14) He urges that while '[c]onsiderable advances have been made in the study of global water balance and water resources... the imperfection and inadequacy of our knowledge of water resources become increasingly apparent.'(23)

In a section prefacing the tabular data at the back of the book, Gleick repeats these cautions, noting, 'There are likely to be errors in these data, either inadvertently propagated from errors in the original sources, or introduced in transcriptions and conversion.' (Gleick 1993:117) There are, he points out, 'many problems and pitfalls with ... 'computed data', difficulties with 'uneven regional data coverage and uneven data quality' and issues

associated with 'verifiability, uncertainty and illusory precision and accuracy.' (117-118) In particular, information on water resources, by country, 'should be viewed with healthy skepticism.' (128) Moreover, data that 'differ substantially' from the water balance information presented by Shiklomanov are given in tables in Part II of the book.

Conclusion

Given the space constraints of this paper, a detailed analysis has been made of just two of the (albeit foundational) documents underlying the discourse of global water crisis. In addition to the studies by Postel and Gleick noted above, one might also consider more recent publications such as Cosgrove and Rijsberman's influential, *World Water Vision: Making Water Everybody's Business*, in which the term 'water crisis' is used fourteen times in the foreword, preface, summary. (Cosgrove and Rijsberman 2000) Here too, 'the crisis' is constructed on the basis of updated global hydrological data produced by Shiklomanov, using the methods discussed above. Or one could cite the United Nations World Water Development Report for 2003, which opens by stating: 'The fact that the world faces a water crisis has become increasingly clear in recent years.' (United Nations Educational, Scientific and Cultural Organisation 2003:5)

My point in raising links between the discourse of global water crisis and the production of hydrological information is not to question the adequacy of approaches based on methods developed in the former Soviet Union. Rather it is to suggest that the very notion of water as a pressing *global issue* is related to the production of quantitative data that present a worldwide, or global image of water resources – data that happen to derive mainly from Soviet hydrological methods. To repeat a point made above, the ability to quantify the amount of the world's freshwater *in relation to* the total amount of water on the planet yields an image that produces, almost by default, a rather startling picture.

Consider the following excerpt from the *Encyclopaedia Britannica's* treatment of the hydrologic sciences:

Quantitative studies of the distribution of water have revealed that *an astonishingly small part* of the Earth's water is contained in lakes and rivers. Ninety-seven percent of all the water is in the oceans; and, of the fresh water constituting the remainder, three-fourths is locked up in glacial ice and most of the rest is in the ground. (my emphasis)

Furthermore, this admittedly brief survey of the hydrology of global water resources suggests that 'the global water crisis' first proclaimed in the 1990s and the subject of much attention in recent years, was constructed on data that the hydrologists themselves have warned are uncertain. In addition to the cautions noted above by Shiklomanov, other sources indicate wide discrepancies in the quantification of global water stocks and flows. For example, an Environment Canada publication from 1990 presents the range of values in 'ten recent studies' of the world's water supply. Here estimates of the amount of groundwater on earth vary from 7 million cubic kilometers to 330 million cubic kilometers. The range of values is similar for the amount of water estimated to be in the soil (soil moisture) – from 165,000 cubic kilometers to 150 cubic kilometers. For the amount of water available in lakes, the range is between 30,000 cubic kilometers and 150,000 cubic kilometers. (Environment Canada 1990)

A further note of caution is sounded in a 1995 article by John Rodda, who as noted above, was president of the International Association of Hydrological Sciences: He finds it 'something of a paradox' that at this time, when concern about growing demands for water are leading to predictions about 'a world water crisis', 'knowledge of the world's water resources is waning.' The gathering and analysis of hydrological data is, he notes, 'rudimentary in many areas' and 'there is no operational world-wide system for collecting and exchanging these

data.' These considerations lead Rodda to conclude that 'statements of world water resources and world water use are almost certainly seriously in error' and given the present state of affairs, 'only educated guesses can be made about the dimensions of the world's water resources.' (Rodda 1995:360, 367)

It is beyond doubt that the availability and condition of water resources poses a serious and growing problem for people in many parts of the world. Nevertheless, given the considerations discussed above, it seems obvious that uncritical statements about the 'global water crisis,' 'water scarcity' and 'water stress' need to be considered with great care. As something that is exploited and appreciated in very different ways by different people living in different places, there is an important sense in which water resists generalization. It is in the particularity with which water enters into the lives of people and defines places that the 'water crisis' can be most effectively identified and resolved.

Footnotes

1 For example, *The Ottawa Citizen* ran a five-part special series titled 'The Global Water Crisis' from Monday, August 13 to Friday, August 17, 2001. (Lee 2001). See also Leslie (2000).

2 Except where otherwise indicated, information in this and the following two paragraphs is from *Encyclopaedia Britannica* (15th ed.) s.v. Hydrology (Vol. 6:193); *Earth Sciences* (Vol. 17:573-577, 593-594); *Hydrosphere* (Vol. 20:770-771).

3 Where evaporation includes transpiration from plants and storage is the change in the amount of water stored in the rocks and soil. (Jones 1997:58)

4 The establishment of a global water balance was a subsidiary activity undertaken through the International Hydrological Decade, as described below.

5 Able to read in Russian and translate Soviet hydrological literature into English, Nace was a key figure in the transmission of these methods and data to the west (For example, see Nace 1979; L'vovich 1979; USSR

Committee for the International Hydrological Decade (1978; Nace 1969:32) and was the leading western proponent and practitioner of global hydrology in the 1960s and 1970s. (For example, see UNESCO 1971; Nace 1970; Nace 1969; Nace 1967; Nace 1965)

6 As a matter of speculation, these geopolitical changes might also have had the effect of freeing the inhibitions of scientists working in places like the United States and England who might formerly have been disinclined to accept Soviet methods.

7 Raymond Furan's *The Problem of Water: A World Study*, originally published in France in 1963 is something of an exception to these regional definitions of the water crisis in the 1960s. Furan amassed examples of pollution and impending water scarcity from around the world to conclude that water was soon to become a problem that 'affects the entire world.' His analysis, however, is constrained by a paucity of data on global water resources and includes water balance data only at the scale of the river basin. (Furan 1967)

8 Doxiadis (1967) presented global water resource data and described a 'crisis in the relationship between water and man.' While the source of his data is not given, this appears to be derived from Soviet studies, or possibly from Nace, who used Soviet data and methods.

9 The report discussed water in the context of the impending limits to food production (Meadows et al. 1972:62-63). However, overall, the study gives far more attention to 19 key, non-renewable, resources (fossil fuels, minerals, metals, etc.)

10 Postel (1992:194) relies on Falkenmark (1989) and World Resources International (1992) for these indices, both of which rely on L'vovich (1979) for the regional water balance data with which to construct them.

11 Global water use data are from a 1990 study by Shiklomanov. (Postel 1992:196)

12 In addition to the data described above, *The Last Oasis* presents a great deal of regional hydrological information gathered from a wide variety of sources. Nevertheless, the basic hydrological data deployed to

describe water resources, the hydrologic cycle and water scarcity as global phenomena are derived from the work of Soviet hydrologists. These data provide the foundation upon which the idea of global water scarcity has been built.

13 It is cited with great frequency in the water crisis literature of the 1990s and more recently. See for example, among numerous others; Patrick 1994; Ohlsson 1995; de Villiers 1999; Buckley 2001; United Nations Educational, Scientific and Cultural Organization 2003.

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Hydrology is the scientific study of the movement, distribution and management of water on Earth and other planets, including the water cycle, water resources and environmental watershed sustainability. A practitioner of hydrology is called a "hydrologic engineer", working within the fields of civil and environmental engineering, earth or environmental science and physical geography. Using various analytical methods and scientific techniques, they collect and analyze data to help solve water related The emerging global water crisis: Managing scarcity and conflict between water users. *Advances in Agronomy*, 95, 1-76. Kargbo, D.M., Wilhelm, R.G., Campbell, D.J., 2010. A Comparison of a Lattice-Boltzmann model, a fullmorphology model, and a pore network model for determining capillary pressure-saturation relationships. *Vadose Zone Journal*, 4, 380-388. Zawahri, N., Sowers, J., Weinthal, E., 2011. The Politics of assessment: Water and sanitation MDGs in the Middle East. *Development and Change*, 42, 1153-1177. Zeitoun, M., Messerschmid, C., Attili, S., 2009.