CHAPTER 3 USE OF GIS FOR ANALYSIS OF INDICATORS OF CONFLICT AND COOPERATION OVER INTERNATIONAL FRESHWATER RESOURCES

Shira Yoffe and Greg Fiske

Submitted for publication, as part of set of three articles, to *Water Policy*, World Water Council, October 1, 2001, 28 pages, in review.

KEYWORDS

multidimensional GIS, population, international river basins, freshwater cooperation and conflict

ABSTRACT

The Geographic Information System (GIS) is an invaluable tool in manipulating and interpreting world scale datasets. In recent years it has become the standard link between water resource study and the ever-increasing numbers of high quality data sets. This paper describes the use of Geographic Information Systems for gathering and analyzing spatial information to facilitate identification of international river basins at risk for future conflict over freshwater resources. The methodology and data described here were produced as part of the Basins At Risk (BAR) project. To facilitate development of indicators to identify international river basins at potential risk for water-related conflict, the GIS was used to: 1) update the international river basins of the TFDD, allowing the best fit to the most recent USGS hydrography coverage of the world; 2) link current and historical spatial and non-spatial information of the BAR project by formulating a temporal GIS that demarcates international river basins on a one-year resolution dating from 1946 to the present; and, 3) aggregate selective gridded datasets in order to better ascertain key variables associated with cooperation or conflict over freshwater resources. Where possible, the most recent and up to date world scale datasets were used. The combination of GIS techniques and manipulation of recently available datasets proved to be extremely effective in the production of potential variables for the assessment of water related cooperation and conflict.

INTRODUCTION

With the improvement of Geographic Information System (GIS) technology and advances in global scale datasets, it is proving to be both easy and effective to interpret characteristics of large regions at a global scale. At the forefront of natural resource assessment is the study of water and its spatial distribution. In the 1993 *Symposium on Geographic Information Systems and Water Resources,* it was demonstrated that GIS has allowed a multitude of new perspectives in the realm of water resource study (Adams, Harlin et al. 1993). Since that time, GIS has become a standard link between the large-scale collection of data and wide-ranging conclusions of water resource related studies. These conclusions are limited only by the quality of the most recent data on hand.

The GIS exercises detailed in this paper were conducted as part of the *Basins At Risk* (BAR) project, under the auspices of the *Transboundary Freshwater Dispute Database* (TFDD), which is directed by Dr. Aaron T. Wolf, Oregon State University. The purpose of the Basins At Risk project was to identify historical indicators of international freshwater conflict and cooperation and, from these indicators, create a framework to identify and further evaluate international river basins at potential risk for future freshwater conflict. The GIS component of the BAR project included the creation of historical basin and country polygon coverages for the period of the study and the mapping of environmental, political, and socioeconomic variables across international drainage basins, to allow for a global-scale analysis of possible patterns which might facilitate our understanding of water resource conflict and cooperation.

GIS as a tool in complex social science research is only just beginning to be explored, but the field is expanding rapidly. GIS offers powerful tools for compiling, visualizing and analyzing potential indicators of international water resource conflict, because it has the capability to incorporate biological, physical and socioeconomic data. While there has been substantial work in mapping the physical aspects of watershed systems, much less work has been done to incorporate these physical systems with socioeconomic data. Nevertheless, in many circles GIS technology has been praised for its potential to bring policy and science together and to facilitate integration, analysis, mapping and presentation of spatial and non-spatial information in the understanding and managing of natural resources. In this light, GIS offers a great deal to this project, enabling a much more complex analysis than would otherwise be attainable.

The key unit of analysis in the BAR project is the international river basin. A river basin comprises all the land that drains through that river and its tributaries into the ocean or an internal lake or sea. An international river basin is one that includes territory of more than one country. Currently, the world encompasses at least 261 international river basins, covering at least 45.5% of the total land area of the earth, excluding Antarctica (Wolf, Natharius et al. 1999).[13] Framing questions in terms of river basins offers a way to look at water issues that mitigates problems associated with the fact that most data is classified by country and fails to account for within-country variation. River basins are considered a natural framework for studies of geomorphic fluvial processes (Leopold, Wolman et al. 1964). River basins' focus on water resources makes them equally appropriate when considering the relationships between conflict, cooperation and freshwater resources.

The idea of analyzing political, socioeconomic, and biophysical elements via watershed boundaries is relatively new in the field of political geography. For many years the dominant polygon for the display, and hence, the output of manipulated data has been defined by national borders. Readily available water data are only at the country level (Brunner, Yumiko et al. 2000). This fact has limited studies exploring spatial aspects associated with international water conflict. By breaking away from the confines of this method, a better fit can be made between those variables that may be deemed important to water-related conflict and the spatial area defined by a particular international basin. As stated by Leif Ohlsson, in his book *Environmental Scarcity and Conflict: A Study of Malthusian Concerns*,

> …the common wisdom of the literature on water negotiations is that the appropriate unit, both for analysis and negotiations, is the river basin as a whole (Ohlsson 1999).

---

[13] Since the last publication of the TFDD basins, new basins have been "found." An updated version of the TFDD database of international rivers is now in process. The current basin total is 263.

All the Geographic Information System exercises depicted in this paper focus on the international river basin as the scale of reference.

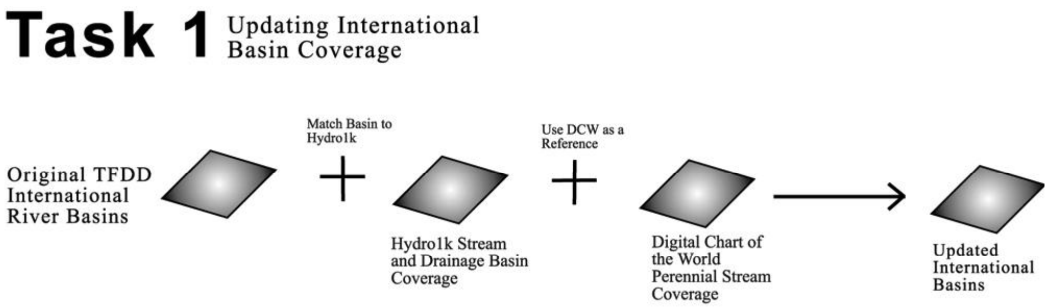
The following sections of this paper describe three separate GIS tasks. Each section contains a general description of the methods, data, and approach used as well as a brief summary of how the task contributed to goals of the BAR project.

RESTRUCTURING OF THE WATERSHED BOUNDARIES

The first task in this succession of methods was to update the TFDD delineation of international river basins to match new data and to better meet the needs of the BAR project. The basins of the TFDD project had their origin in a 1958 United Nations panel report entitled *Integrated River Basin Developments*. This 1958 edition of the roster included 166 international basins, a number likely limited only by the quality of the data used in their delineation. In 1978, the United Nations revised this report and the total was updated to 214 basins (United Nations 1978). The most recent version of the international basin dataset, prior to this study, was Wolf (Wolf, Natharius et al. 1999) *Register of International Basins*, completed in 1999 as part of the TFDD. The first edition to employ GIS to define and delineate international river basins, the *Register* used the recently released USGS world scale digital elevation model (DEM), GTOPO30, to define river basins by matching GTOPO30's simulated flow pattern. At the release of this document, the *Register* includes 261 international river basins.

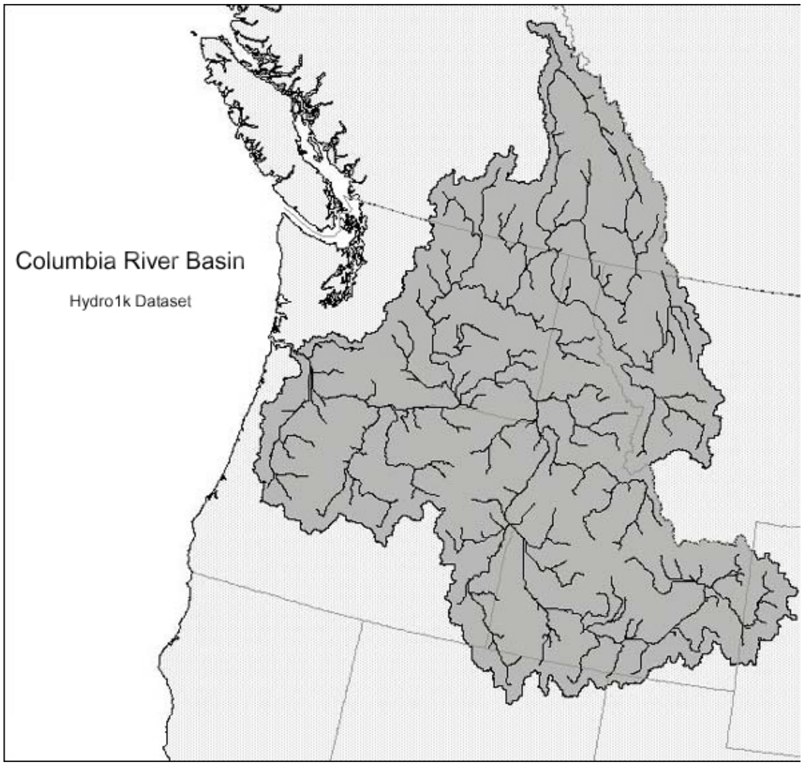
In task 1, the 261 basins depicted in the 1999 *Register* were manually matched, as accurately as possible, to the Hydro1k (USGS 2000) dataset, a global coverage of streams and drainage basins derived from digital elevation data (Figure 3.1). This on-screen exercise, completed one continent at a time, systematically linked each basin to a reasonable estimate of the real life drainage network and ameliorated inaccuracies produced in the original creation of the basin GIS.

Figure 3.1: Task 1. A basic model representing the steps taken to update the TFDD international basin coverage



In all, less that half of the basins required alteration. Where there were confounding issues or uncertainty in the exact location of a basin boundary, outside sources were consulted. One of these sources was the perennial stream coverage of the Digital Chart of the World (DCW). The DCW (Environmental Systems Research Institute 2000), developed under a contract by Environmental Systems Research Institute (ESRI) and available through the U.S. Defense Mapping Agency, is considered to have a minimum resolution of 500m (Kemp 1993). This level of detail proved particularly useful in settling most questions regarding a basin's international status. Where this digital source failed to provide an acceptable answer, hard copy map sources, including National Geographic's *7th Edition Atlas of the World* and various others from the Oregon State University Valley Library, were consulted. In the end, the result of scrutinizing each individual basin led to: 1) the best possible fit of each basin boundary to the Hydro1k dataset (see Figure 3.2); 2) the addition of three basins that were determined to have international status; 3) the merging of the Benito and Ntem river basins of West Africa; and, 4) the creation of a sound coverage for the further collection and derivation of information for the BAR project.

Figure 3.2: Columbia River Basin, USGS Hydro1k dataset



This image indicates a close match between TFDD international river basins and the USGS Hydro1k dataset.

ESTIMATING CHANGES IN THE INTERNATIONAL STATUS OF RIVER BASINS WITH THE AID OF TEMPORAL GIS

A key component of the BAR project was the creation of a database documenting historical incidents of international freshwater cooperation and conflict from 1948 to 1999. Using precise definitions of cooperation and conflict, these incidents are ranked by intensity and linked to the international basin and riparian countries with which they are associated. In order to explore correlations between events and other variables across both space and time, it was necessary to link the GIS data as accurately as possible to the BAR event database. To incorporate both temporal and spatial variability into the analysis required the creation of a temporal GIS, one which would identify spatially all the international basins that existed for each year of the study and what countries, for each year, were riparian to those basins. This historical GIS facilitated the creation of the event database by identifying whether a specific event occurred in an international basin, as many events researched turned out to be related to intra-national, rather than international waters and as not all basins were international across the entire time period of the study. More importantly, the historical GIS allowed the linkage of the incidents of international water conflict and cooperation with socioeconomic, biophysical, and political data specific to the year in which the event occurred. This linkage allowed for comprehensive spatial and parametrical statistical analyses.

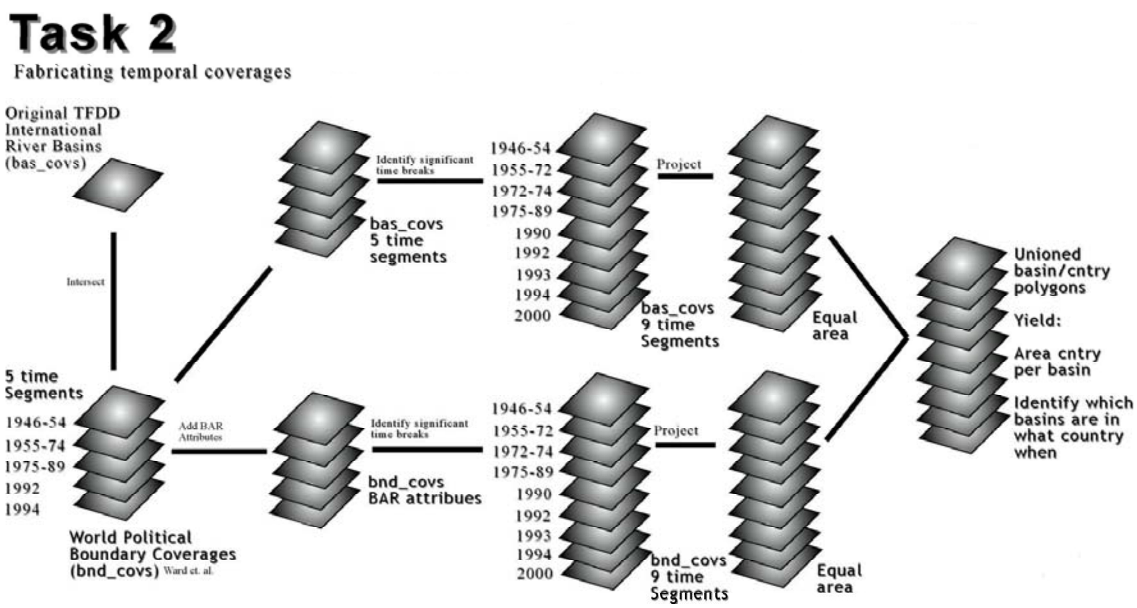
In short, the most recent GIS coverage of international river basins had to be modified to consider the status of international boundaries for each year of the BAR event database. The 1999 register of the *International Basins of the World* indicated that 47 basins became international, and were therefore added to the *Register*, due to the break-up of countries such as the former Soviet Union and the former Yugoslavia (Wolf, Natharius et al. 1999). Likewise, two international basins were removed from the list as the result of the unification of once segregated countries (i.e., Germany and Yemen). To account for these and other international boundary changes impacting the international status of river basins during the period covered by the BAR project, it was necessary to employ the temporal dimension within the GIS data. The multi-coverage/multi-time period techniques were particularly effective in tracking such dynamic phenomena.

In current GIS study, the idea of exploring the temporal dimension is becoming more established. By delineating the internationalization or de-internationalization of basins as international political boundaries shift, a better fit can be made between the spatial and non-spatial portions of the BAR database. Spatial analysis of an inventory of socioeconomic, political, and environmental data can be more accurately represented and understood with the use of a dynamic information format that considers change throughout time. The concept of a changing inventory is one of the fundamental elements of a temporal GIS. As quoted from Gail Langran, *Time in Geographic Information Systems*:

> A critical temporal GIS function is to store the most complete possible description of a study area, including changes that occur in the living world and in the database. A temporal GIS should be able to supply the complete lineage of a single feature, the evolution of an area over time, and the state of a specified feature or area at a given moment (Langram 1993).

Indeed this concept was fully utilized when spurred by the recognition that incidents in the BAR event database would only be included in statistical analyses if they were associated with basins that were international at the time the event occurred. Moreover, the spatial data derived at the basin and country scale needed to be temporally matched to the event data in order to conduct time-sensitive statistical analyses. Therefore, the GIS had to account for all changes in international river basins and national political boundaries from 1948 to the present, both spatially and temporally.

Figure 3.3: Task 2. A basic model showing the steps taken in the creation of a temporal spatial database for the Basins At Risk Project.



The GIS coverages that comprise the temporal portion of this study are divided into nine time segments (Figure 3.3), which were chosen to capture periods of significant changes in international political boundaries, as well as polity changes. Dates of significant changes in boundary locations include, among others: 1990, East and West Germany united; 1990, North and South Yemen united; 1991, break up of the former Soviet Union; 1992, former Czechoslovakia break up; 1992, break up of the former

Yugoslavia; 1993, formation of Eritrea.[14] The GIS contains correct attributes for all the polity and boundary changes.

For each time segment, a complete coverage of the world's international boundaries and international river basins was created. These coverages most accurately represent the status, both through their spatial characteristics and their attributes, of the international political boundaries of the time period. Years were grouped into a common coverage for periods in which there were no major changes in the location of international boundaries. Otherwise, single-year coverages were created. This method resulted in nine temporal coverages, covering the period 1946-2000, for countries and their associated international basins.

The world international basin and international boundary coverages were constructed from a base map, which was graciously shared by Dr. Michael Ward, Professor of Political Science, University of Washington. This base map came in the form of Arc/Info coverages spanning five time segments, 1946-54, 1955-74, 1975-89, 1992, and 1994 (Figure 3.3). The coverages delineate national boundaries for each time segment from the early 1990's (which saw the break up of the Soviet Union and Yugoslavia) back to 1946 (Ward, Shin et al. 2000). These crude, yet fully viable, delineations of the international boundaries of each time period were particularly valuable in the success of Task 2. International boundaries and attribute labels showing political ownership of each polygon were comparable to BAR's year 2000 country coverage. From this starting point the compulsory manipulation of the country and basin coverage for each time segment could be built.[15]

A link was created between the polygon attribute data of the donated coverages and the BAR country coverage and data via BAR country codes and the Polity 3 dataset country codes (McLaughlin, Gates et al. 1998) used by Ward. Polity 3's country codes

---

[14] Other less significant boundary changes, which were part of the original political boundary coverages, but are not incorporated into the nine, final temporal political boundary coverages, include spatial changes occurring in controversial boundary zones, such as along the border of India and China. Current border disputes are captured, however, in the most recent version of the TFDD basin coverages.

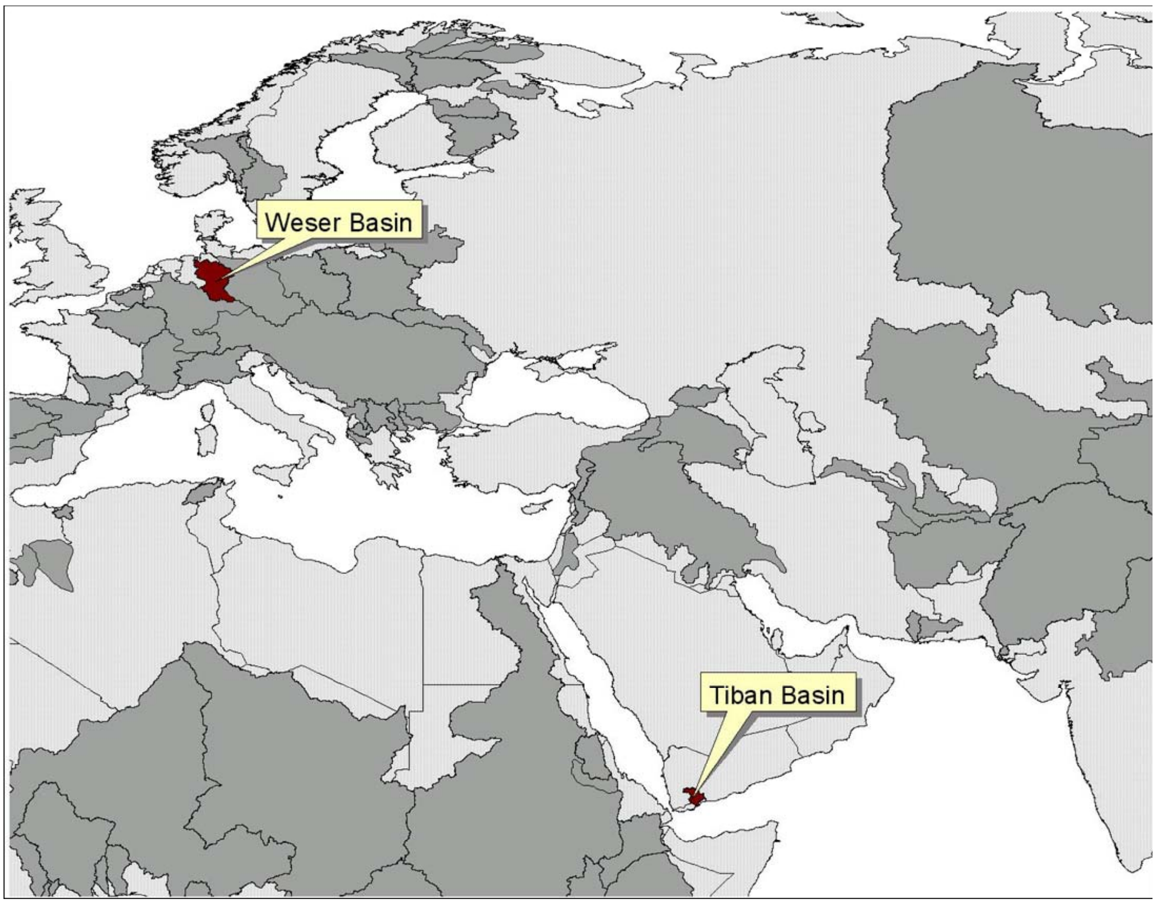
[15] Compared with other forms of GIS data, finding coverages of historically accurate international political boundaries represented a much more involved treasure hunt. Historic GIS coverages are rare. While there is a large body of work, especially in political science and political geography, involving analysis of political boundaries (e.g., Gleditsch and Ward 2001), these studies are rarely conducted using a GIS.

were converted to BAR's country codes in the final coverages, as BAR country codes link all country-scale spatial and tabular data used in the BAR project. The linking of the two sets of country codes allowed the polygon attribute tables of each time segment's country coverage to be restructured to reflect the critical attributes of the BAR database.

With BAR attributes (most significantly the BAR country code) added to the donated country coverages, it was then possible to determine which time segments saw the addition or subtraction of international basins due to their spatial relationship with contemporary international boundaries. A union of the current basin coverage with the political coverage of each time segment yielded a list of basin and country codes. Analysis of these basin and country code pairs determined the political status of each basin. In order to bring the resolution of the time segments to one year, additional coverages were created to represent other boundary changes. The final time segments are as follows: 1946-54, 1955-72, 1972-74, 1975-89, 1990, 1992, 1993, 1994, and 2000. Each time segment reflects those basins that were international at that time period. The emergence of new nations and shifts in international boundaries resulted in the addition of 30 international basins from 1946 to 2000. Only two international basins were removed – the Weser, shared between the former East and West Germany, and the Tiban, shared by the former North and South Yemen (Figure 3.4). Both the Weser and Tiban lost their international status in the 1990s, with the unification of their respective riparian countries.

The dataset provided by this representation of international river basins and their riparian countries for each year from 1946 to 2000 allows for a wide range of applications to BAR and other projects. These coverages allow interactions between pairs and groups of countries in shared river basins to be more accurately linked with other datasets. At the time of this report, utilization of these historical coverages included linking riparian countries to their associated basins for each year, calculating the area of each riparian nation's portion of current and historical international river basins, and aggregating some ancillary datasets to those basins that are no longer international. In the future, BAR plans to link the event data with the historical basin coverages, calculate climate and water availability variables for non-current international basins, and back-calculate other spatial data, such as historical population per basin and basin-country polygon for each year of the study. Much of this data will be made available on the TFDD website, to facilitate access for researchers and policy-makers.

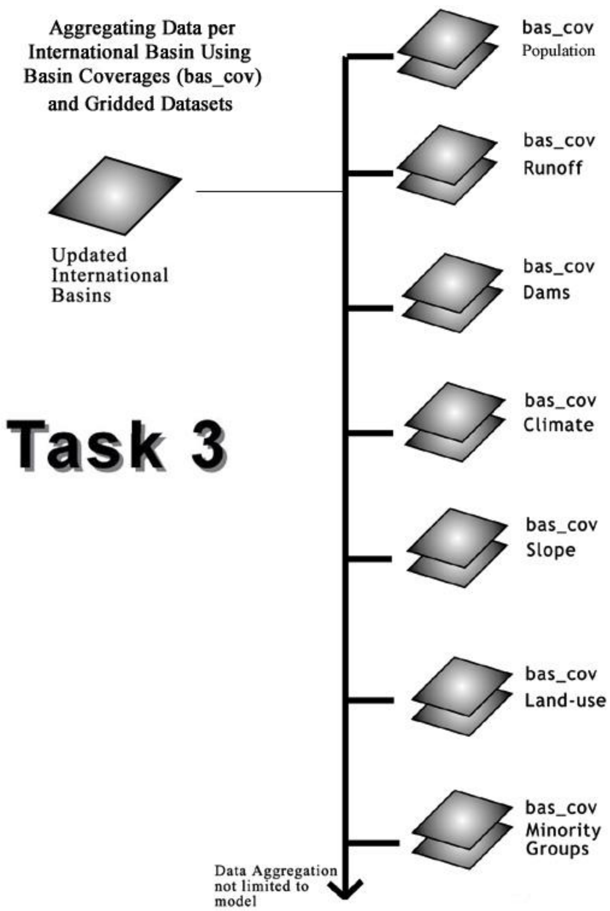
Figure 3.4: Historical International River Basins



AGGREGATING DATA PER BASIN

With the establishment of updated basin boundaries and a reasonable estimate of international basin status (past and present), accurate aggregation of various datasets to the basin boundaries was possible (Figure 3.5). Aggregation of data at the basin level include population, climate, runoff, number of dams, elevation, land use, and minority groups. As examples, population and runoff are described in further detail below.

Figure 3.5: Task 3



A basic model showing some of the datasets that were merged with the updated basin coverages to obtain data values at the basin scale.

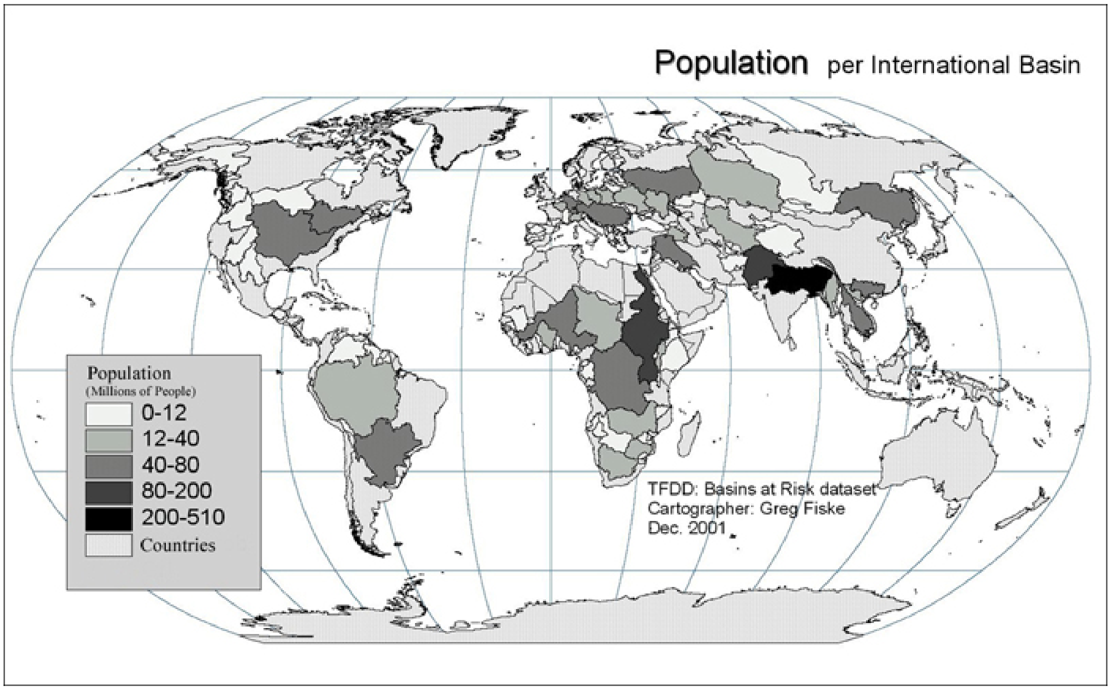
Population

Recent studies have shown that population growth is a key factor in assessing water scarcity (Brunner, Yumiko et al. 2000). Research conducted jointly by the World Resources Institute (WRI) and the University of New Hampshire (UNH) concluded that in evaluations of water scarcity, an investment in the monitoring of socioeconomic data should be as important as the hydrologic information gathered (Brunner, Yumiko et al. 2000). The location an assessment of regional water resources should therefore be coupled with information regarding regional population distribution. Population assessments traditionally have been conducted within the spatial boundaries of a political unit (e.g., the nation-state). The spatial variability of water resources, however, rarely matches the contours of political boundaries.

The population data produced by BAR surpasses previous measures of population at the basin scale in two ways. The first is that population is evaluated on the scale of the TFDD international watershed. By evaluating the population of a region in comparison to its relative location within a river basin, inaccuracies produced by linking country population values to water resource supply can be partially ameliorated. The second is by using the most current and truthful approximation of the world's population distribution yet available – the 1998 Landscan gridded population of the world. This 30 by 30 second resolution data was produced by the Landscan Global Population Project and funded by the United States Department of Defense. The project, led by Jerome Dobson of Oakridge National Laboratories, was aimed towards estimating populations at risk during both natural and human induced disasters. Accuracy of the dataset can be partially attributed to the utilization of recent remote sensing data. With the help of GIS, it was possible for the Landscan team to use remotely sensed slope, land cover, road proximity, and night time lights to further refine the gridded population cell values (Dobson, Bright et al. 2000). The Landscan project is an excellent example of the strength of GIS in assessing spatially distributed phenomena using recent remotely sensed images. Indeed the goals and results of the Landscan project were ideally suited for the task at hand in this study. The relative accuracy of aggregating population values at the international river basin scale was due, in large part, to the success of the Landscan project.

With use of Arc/Views Spatial Analyst extension, the summation of gridded population density values could be tabulated per TFDD international river basin. Due to the relatively fine resolution of the Landscan dataset, a summation of gridcell values could be produced for all 263 international river basins including those of the smallest spatial extent. By combining this table with the area of each basin, a population density could be calculated (Figures 3.6 and 3.7).

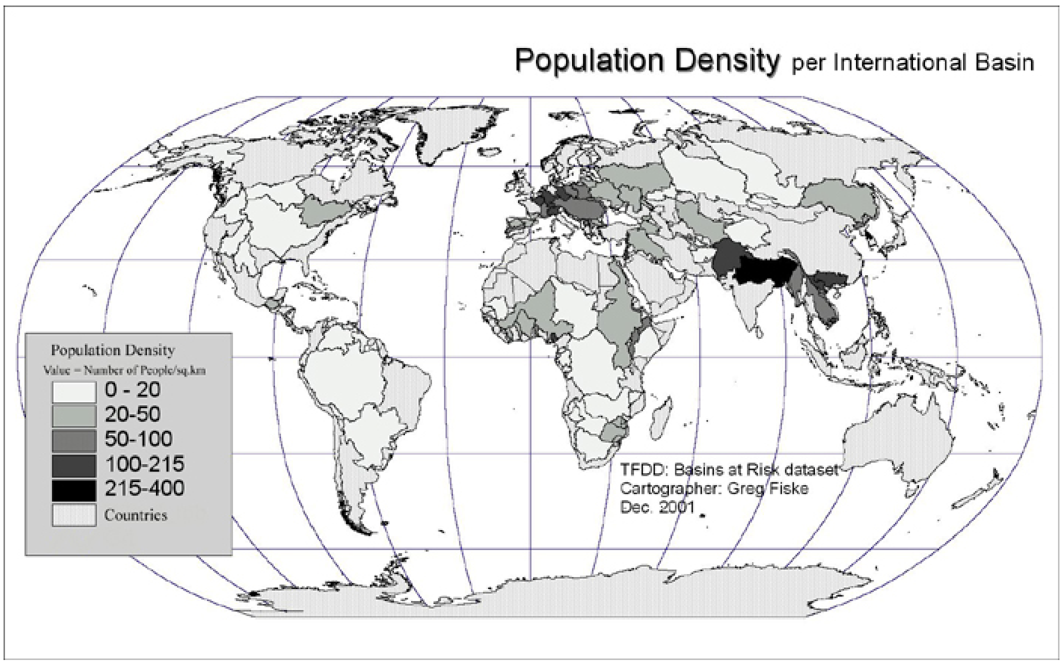
Figure 3.6: A map showing population per international basin



Runoff

Any assessment of a water resource related issue would be incomplete without some approximation of water availability within the study area. The *Symposium on Geographic Information Systems and Water Resources* in 1993 promulgated the many burgeoning attempts at estimating a river basin flow via hydrologic models. With the basics of watershed modeling (i.e., watershed boundaries and flow direction) being old news, the next challenge of the GIS community is to accurately simulate and quantify the runoff in a watershed. Modern hydrologic models are mathematical simulations that may use rainfall data, land use/land cover, soil type, topography, and drainage coverages to produce an estimation of runoff amounts (Luker, Samson et al. 1993). With increasing technological capabilities it is becoming easier for the GIS to handle these types of applications, which have multiple complex spatial parameters. GIS is the link between the spatial parameters of the natural hydrologic cycle and a decent estimation of a region's runoff. Output data of this quality can create a wide range of new opportunities for GIS analyses, including the correlation of water availability to conflict occurrence.

Figure 3.7: A map showing population density per international basin



Though widespread discharge gauging stations give the approximate yield of many of the world's rivers, the spatial distribution of runoff amounts for obscure river basins and within large watershed systems is less abundant. In modern environmental modeling, estimating runoff (or flow amounts) stands as a formidable challenge to the GIS. For this data gathering task, BAR utilized a world-scale gridded flow dataset to acquire estimated runoff per international river basin. This world scale dataset was in the form of a 30-minute spatial resolution grid of composite runoff fields produced through a joint effort of the Complex Systems Research Center at the University of New Hampshire (UNH) and the Global Runoff Data Center (GRDC) in Koblenz, Germany. Fekete et. al. (Fekete, Vorosmarty et al. 2000) were able to produce the composite runoff fields by accessing GRDC discharge data, selecting significant global gauging stations, and geo-registering the discharge information to locations on a simulated topological network. To produce a disaggregated spatial distribution of runoff, they employed a water balance model. With the exception of regional inaccuracies due to climate fluctuations (e.g., evaporation and precipitation) and man-made removal of water (e.g., for irrigation and municipal uses), the combination of observed discharge and a simulated runoff model will produce a reasonable estimate of runoff in a large region. As quoted in the report written by Fekete et. al., "The combination of the two sources of information (observed discharge and simulated runoff) to estimate continental runoff has the possibility of yielding the most reliable assessment at present" (Fekete, Vorosmarty et al. 2000). The use of this gridded dataset was the most reasonable path to obtain a summation of water availability per international river basin.

For the purposes of this study, GIS was used to manipulate the composite runoff fields produced by Fekete et. al. and to sum runoff amounts per international basin. Runoff is considered to be the total amount of surface flow in a given area. The cell values are in mm/yr for the annual composite runoff field grid. These values (mm/yr) were multiplied by the area of the associated grid cell (sq. km) to produce a runoff volume grid ($mm*km^2/yr$). An estimate of annual basin discharge is produced by converting the cell value units of the runoff volume grid to km3/yr. Discharge is considered to be the output of the river basin's main stem channel at the ocean. The discharge values are ranked and evaluated accordingly (Figure 3.8). Due to the resolution of the 'Standard Topological Network' in which the composite runoff fields were derived, a reasonably accurate assessment of discharge amounts is restricted to areas greater than 25,000 sq. km. (Fekete, Vorosmarty et al. 2000). This confined our calculation of runoff per international river basin to approximately half the 263 watersheds. Furthermore, the nature of the employed dataset does not account for those river basins that have a decrease in river discharge towards the outlet. River basins such as the Colorado that are deemed 'exotic' lose a great deal of water volume at the end of their path due to natural and man-made withdrawals.[16]

With a reasonable estimate of population and discharge for each international basin (> 25,000 km^2), it was possible to manipulate the data one step further and calculate

---

[16] The discharge numbers calculated compared closely with discharge data from alternate sources, with larger and wetter basins matching most closely.

"water stress" within each basin (Figure 3.9). A commonly used index for water management, Malin Falkenmark's (Falkenmark 1989) Water Stress Index measures freshwater availability per capita within a country. Falkenmark's water stress index usually has been calculated by combining population by country with freshwater availability by country, thereby missing regional variability. By calculating this number by basin, a more accurate assessment of water quantity issues is possible. BAR used the calculated population per basin combined with the calculated discharge per basin to map Water Stress per basin. The thresholds of water stress (<1700 cu.m/person/year), chronic water scarcity (<1000 cu.m/person/year) and absolute scarcity (<500 cu.m./person/year) are represented in the results (Figure 3.9). These data, evaluated by basin using the most up to date world scale runoff and population datasets, represent the current, best known estimate of water availability per person per international river basin.

Figure 3.8: A Map showing estimated discharge per international basin in cu.km/yr.

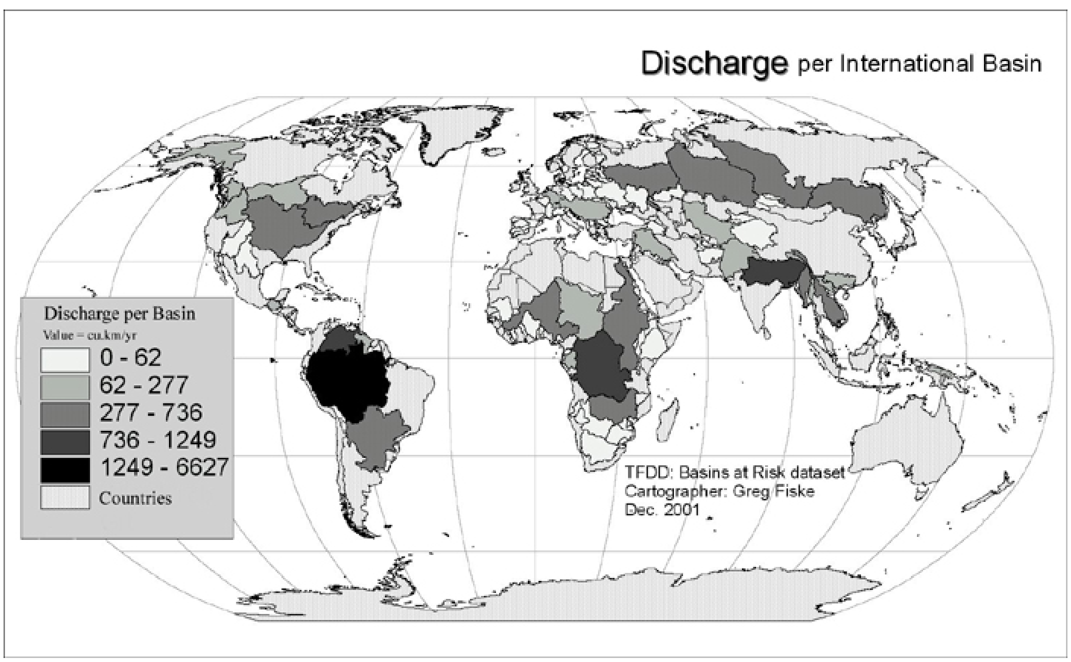
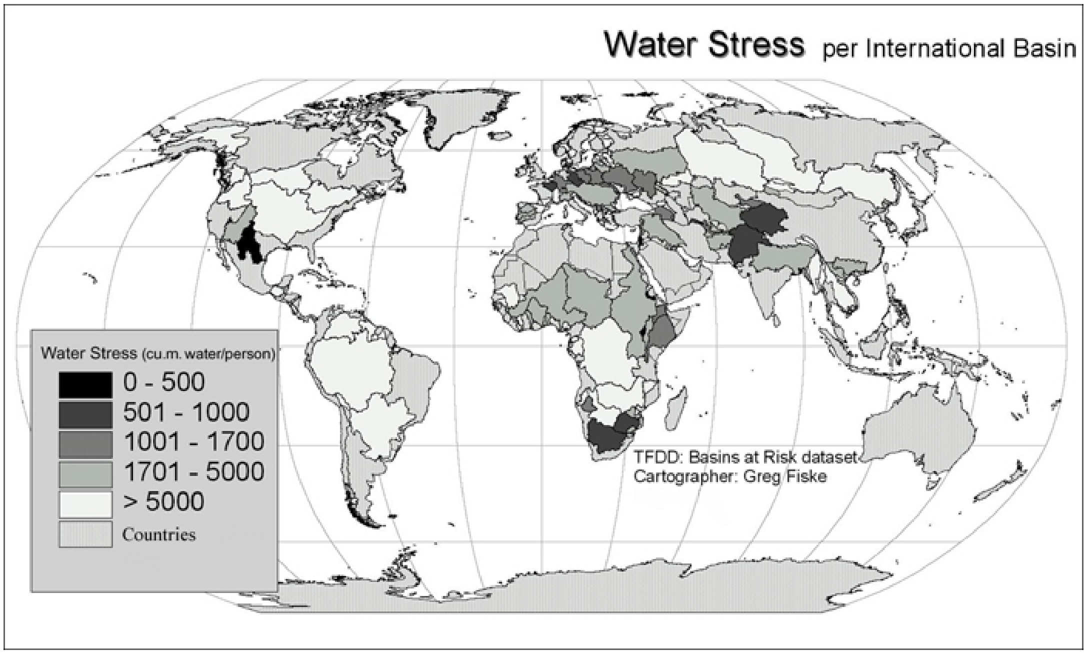


Figure 3.9: A Map showing estimated water quantity per person for each International River Basins (>25,000 sq. km.)

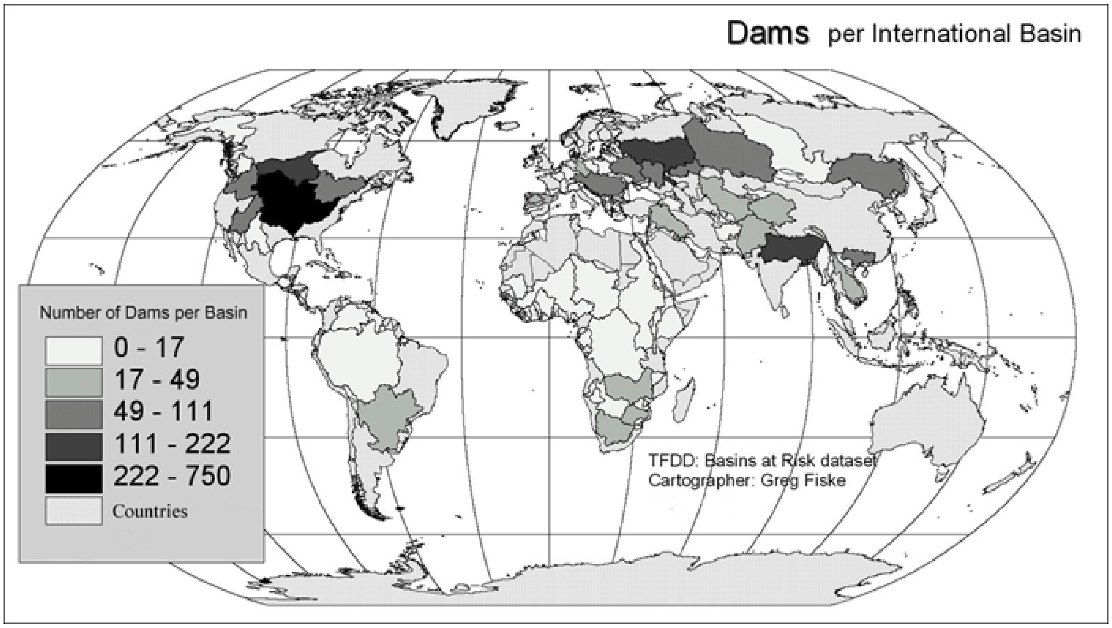


Other Datasets

Similar GIS techniques to those described above were used to derive data from other gridded and polygonal coverages. These data were gathered as part of the Basins At Risk project's analysis of potential indicators of conflict and cooperation over international freshwater resources.[17] At the time of this report, the datasets that have been aggregated per international river basin include: 1) a completed table of climate zones per basin based on a Koeppen Classification of Climate Grid (FAO-SDRN Agrometeorology Group 1997); 2) the number of dams and dam density per international basin, derived via Digital Chart of the World data (see Figure 3.10). In some cases, the derivation of these datasets was limited to international basins with an area of 25,000 km^2 or greater due to the resolution of the input data.

[17] For a full description of the Basins at Risk project and its results, see Yoffe (2001).

Figure 3.10: A map showing estimated dams per basin.



CONCLUSION

The GIS proved an invaluable tool in assessing global-scale spatial data and applying it to the *Basins At Risk* project. Currently available world scale datasets are at a level of accuracy that allow for the manipulation and derivation of variables that may or may not relate to water conflict or cooperation in an international basin. For the BAR project, the GIS was used to: 1) update the international basins of the TFDD, allowing the best fit to the most recent USGS hydrography coverage of the world; 2) better match the spatial and non-spatial information of the BAR project by formulating a temporal GIS that demarcates the international river basins on a one-year resolution dating from 1946 to the present; and 3) aggregate selective gridded datasets in order to better ascertain key variables associated with cooperation or conflict over international freshwater resources. Each successfully completed task demonstrates the efficacy of standard GIS methodology to assess one of our planet's most critical natural resources. Furthermore, this exercise has yielded information that can conceivably benefit further global-scale, water-related research.

ACKNOWLEDGEMENTS

This research benefited from the support and teamwork of the many researchers participating in the Basins At Risk project, in particular the guidance and insights of Dr. Aaron Wolf. The project also benefited from the many individuals and institutions who contributed generously of their time and data. We extend our thanks to Jeff Danielson and Kent Lethcoe, EROS Data Center; Jerry Dobson, Oak Ridge National Laboratories; Balazs Fekete, Complex Systems Research Center, University of New Hampshire; and Kirsten Thompson, World Resources Institute. Furthermore, we would like to thank Dr. Dawn Wright, Oregon State University, for the use of her lab and its resources.