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LETTER

Mapping water availability, cost and projected consumptive use in the eastern United States with comparisons to the west

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Abstract

The availability of freshwater supplies to meet future demand is a growing concern. Water availability metrics are needed to inform future water development decisions. With the help of water managers, water availability was mapped for over 1300 watersheds throughout the 31 contiguous states in the eastern US complimenting a prior study of the west. The compiled set of water availability data is unique in that it considers multiple sources of water (fresh surface and groundwater, wastewater and brackish groundwater); accommodates institutional controls placed on water use; is accompanied by cost estimates to access, treat and convey each unique source of water; and is compared to projected future growth in consumptive water use to 2030. Although few administrative limits have been set on water availability in the east, water managers have identified 315 fresh surface water and 398 fresh groundwater basins (with 151 overlapping basins) as areas of concern (AOCs) where water supply challenges exist due to drought related concerns, environmental flows, groundwater overdraft, or salt water intrusion. This highlights a difference in management where AOCs are identified in the east which simply require additional permitting, while in the west strict administrative limits are established. Although the east is generally considered 'water rich' roughly a quarter of the basins were identified as AOCs; however, this is still in strong contrast to the west where 78% of the surface water basins are operating at or near their administrative limit. Little effort was noted on the part of eastern or western water managers to quantify non-fresh water resources.

1. Introduction

There is increasing concern over the availability of water supplies to meet our nation's needs. In a recent survey, 40 of 50 state water managers in the United States expected shortages in some portion of their state under average conditions in the next 10 years, while all 50 expected some shortages in times of drought (GAO 2014). In this same report 49 state water managers reported having experienced water shortage in some part of their state over the past 10 years. These numbers indicate that water shortages are no longer a concern limited to the arid west, nor limited to the future; rather, they are a reality across the US today.

There are a number of high-profile examples of current water issues in the eastern US. The city of Tampa Bay constructed a 'drought-proof' 0.095 million cubic meters per day ($Mm^3\ d^{-1}$) desalination plant (Tampa Bay Water 2016) to augment water supply. There have been numerous occasions in the past where thermoelectric power plants have had to curb production due to low flows or water temperatures at the intake or discharge point that exceeded permissible limits (Union of Concerned Scientists 2014). For decades, Georgia, Alabama, and Florida have been battling over future water allocations for power production, municipal use and fisheries in two major river basins, the Alabama–Coosa–Tallapoosa and the Apalachicola–Chattahoochee–Flint basins (Atlanta Regional Commission 2016). The drought of 2012 was the most extensive since the Dust-Bowl era including much of the Midwest costing the nation $31.2bn and 123 lives (NCEI 2016). This same drought also disrupted critical barge traffic on the Mississippi River (EIA 2012). Challenges also extend to groundwater resources where Mississippi and Tennessee have been in and out of the courts over water allocations in a transboundary aquifer, the Mississippi Embayment system, which has been depleted at a faster rate than any aquifer system in the country save one (The Atlantic 2015).

Looking forward we are faced with the question, where in the 'water rich' east might the development of new energy, municipal, agricultural or industrial projects be challenged by limited water supply? Supporting data characterizing the physical supply and current use (withdrawal) of water are readily available through the US Geological Survey's National Water Information System (www.usgs.gov/water). Constructed on this data have been a number of metrics for identifying locations with limited or stressed water supply (Falkenmark *et al* 1989, Averyt *et al* 2013, Roy *et al* 2012, Sovacool and Sovacool 2009, Hurd *et al* 1999). However, current metrics are limited to fresh surface and groundwater, ignoring non-fresh sources as an alternative to meet future demand. Evaluation of these non-fresh water sources requires estimation of the generally higher costs to secure, treat and convey these sources of water. While existing metrics consider the physical availability of water, access to a given supply is often constrained by institutional controls like interstate compacts, administrative controls or instream flow requirements. The one case where institutional controls were considered is now dated, the 1975 Annual Water Adequacy Analysis performed as part of the Second National Water Assessment (US Water Resources Council 1978).

The objective of this study was to estimate water availability, cost, and projected change in consumptive use to 2030 (future competing demands on available water) to inform water planning decisions at a regional level. Water availability and cost metrics were developed for four different sources of water including fresh surface water, fresh groundwater, municipal wastewater, and brackish groundwater. These metrics were mapped for over 1300 watersheds in 31 eastern states complimenting a prior study in which a similar mapping was completed for the 17 contiguous western states (Tidwell *et al* 2014). These basin scale estimates of water availability, cost, and future consumptive use are not intended to support siting decisions at the local scale, or to evaluate whether available water supplies are sufficient to meet growing demands; rather, their purpose is to provide a consistent and comparable measure of the relative difficulty and expense to develop the water resources in a given basin.

2. Methods

The approach taken to mapping water availability, cost and future consumptive use followed closely the methods adopted in a complimentary study by Tidwell *et al* (2014) that focused on the western United States. This effort extends the prior study by mapping the remaining 31 eastern states. Consistency was maintained with the prior study so as to yield a uniform and comparable set of water metrics for the contiguous United States. For purposes of this analysis, water availability was defined as the supply of water in excess of that currently allocated for consumptive use in a particular basin, that is the amount of water available for new development. The cost to deliver water of potable quality was also calculated to provide a basis for comparing the relative difficulty in developing different sources of water (e.g. fresh surface water versus brackish groundwater). The growth in future water use to the year 2030 was also calculated to address potential competition for available supplies of water.

A key feature of this work was the incorporation of institutional controls into the metrics of water availability, cost, and future consumptive use. This required the direct engagement of each state along with the that of major River Basin Commissions (RBCs) (see figure 1). Where states/RBCs had set administrative limits on water availability or had estimated future water use, those values were adopted. Where such values were lacking water metric values were estimated. These metrics were formulated with the help of subject matter experts to be broadly applicable (different environments and water management regimes), while limited to measures for which data was consistently and uniformly available across the US. Supplementary information (SI) available at stacks.iop.org/ERL/13/014023/mmedia, collected from different sources, were often reported at differing geographic resolutions (e.g. point, county, watershed, state) requiring translation to a consistent reference system. For purposes of this study, the eight digit Hydrologic Unit Code (HUC) watershed classification (e.g. Seaber *et al* 1987) was adopted, which resolved the 31 eastern states into 1332 unique hydrologic units.

As the methods adopted here follow that of Tidwell *et al* (2014) no effort is made to reproduce details related to the formulation of the water metrics. A complete discussion of the methods and metrics is available in Tidwell *et al* (2014) which is also reproduced in the SI associated with this paper.

3. Results

3.1. Water availability

Water availability data were compiled for four different sources, fresh surface water, fresh groundwater, municipal wastewater and brackish groundwater. Maps for each of these sources, resolved at the HUC-8

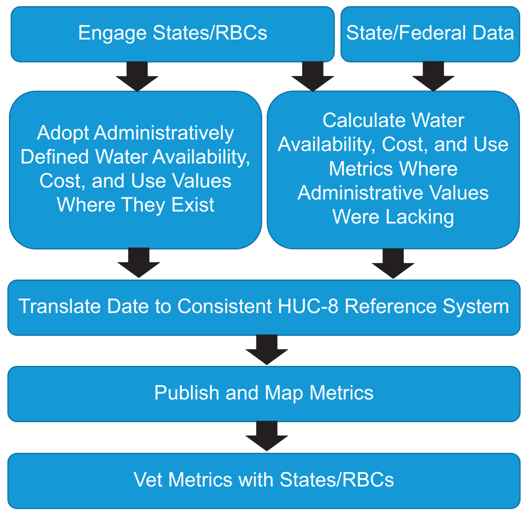

Figure 1. Schematic of water metric development process. RBC stands for River Basin Commission.

watershed level, are given in figure 2 (larger format maps are provided as SI). All were mapped to a consistent color scale with highest availabilities being indicated by cooler colors. White indicates a watershed with no availability of that particular source. A quick review of all four maps clearly reveals significant variability across the sources of water as well as watershed-to-watershed variability for each source of water. The expressed variability is a function of the physical hydrology, water use characteristics, and water management practices unique to each watershed.

Only three states/RBCs had established limits on fresh surface water availability (Arkansas, New Jersey and the Susquehanna RBC), which are mapped in figure 2(*a*). For all other basins lacking established limits, fresh surface water availability metric values (see SI) were calculated and mapped (figure 2(*a*)). Inspection of this data indicates state/RBC established availabilities tend to be smaller than that estimated using the calculated metric. The average of state/RBC defined values was 1.8 $\mathrm{Mm^3\ d^{-1}}$, while the average of the calculated metric values was 19 $\mathrm{Mm^3\ d^{-1}}$. Nevertheless, results suggest that fresh surface water is broadly available across the east. The largest availabilities were associated with major rivers; particularly, the Mississippi, Ohio, Missouri, Delaware, Susquehanna and Tennessee Rivers. In contrast, there were 35 watersheds scattered throughout the east that had a fresh surface water availability metric of zero, most of which are partial watersheds cut by state boundaries.

Although few states/RBCs had established limits on fresh surface water availability, eastern water authorities identified watersheds that are areas of concern (AOCs). Watersheds gained such designation where they experienced supply issues due to drought in the past, were home to critical habitat, or were culturally sensitive areas. Such designation did not necessarily mean that the area was experiencing water supply issues currently or that specific limits to development had been set; rather, it simply identified regions that require special attention and often permitting. In total 315 watersheds were identified as AOCs designated by a red outline in figure 2(*a*). Differences in management practice are evident given the clustering of AOCs in certain states (Florida, Tennessee, and Maine) and RBCs (Great Lakes and Delaware). Low water availabilities, as estimated with the fresh surface water availability metric, corresponded well with AOCs throughout most of the east except in a few cases such as central Illinois and the Long Island region, again reflecting different water management styles.

No state/RBC had established limits on fresh groundwater availability in the eastern US. Given the lack of institutionally defined limits, calculated fresh groundwater availability metric values are mapped in figure 2(*b*). Again, availabilities tended to be high as a majority of the watersheds exceeded 1.5 $\mathrm{Mm^3\ d^{-1}}$. However, there were also large areas of the east where the fresh groundwater availability metric indicated no sustainable fresh groundwater availability. These areas included Connecticut, eastern Iowa, northern Missouri, northern Illinois, the coastal Carolinas and Virginia, and Florida. In total, 399 basins (out of 1332) had a groundwater metric of zero. Such metric values were due to a number of causes including intensive groundwater pumping (e.g. lower Mississippi River Valley, central Florida), saltwater intrusion (e.g. the coastal Carolinas and Virginia), and/or aquifers of limited capacity (e.g. Missouri).

Three hundred ninety-eight watersheds were designated as fresh groundwater AOCs. Except in a limited number of cases, state/RBC defined AOCs (figure 2(*b*)) correspond well with low fresh groundwater availability metric values. However, there were cases where an AOC was associated with a healthy metric value such as in eastern Mississippi, Tennessee or northern Missouri. These were largely associated with areas with environmental sensitivities, limited aquifer capacity, or concern over cross-contamination between fresh and brackish groundwater. There were also cases where an AOC did not correspond to a low fresh groundwater availability metric value, which simply reflected the state's prerogative to make such determinations.

Only the state of Kentucky had estimated wastewater availability in their state. These estimates along with calculated wastewater availability metric values for the remaining eastern states are mapped in figure 2(*d*). Wastewater availabilities were comparatively smaller than either fresh surface or groundwater; however, some wastewater availability was noted for almost every watershed in the east. Two hundred forty-seven watersheds lacked wastewater availability. These were related to rural watersheds where no wastewater treatment plant exceeds 0.14 $\mathrm{Mm^3\ yr^{-1}}$, which was the lower limit for inclusion in the EPA datasets. As would be expected the largest availabilities were associated with watersheds containing or adjacent to metropolitan areas.

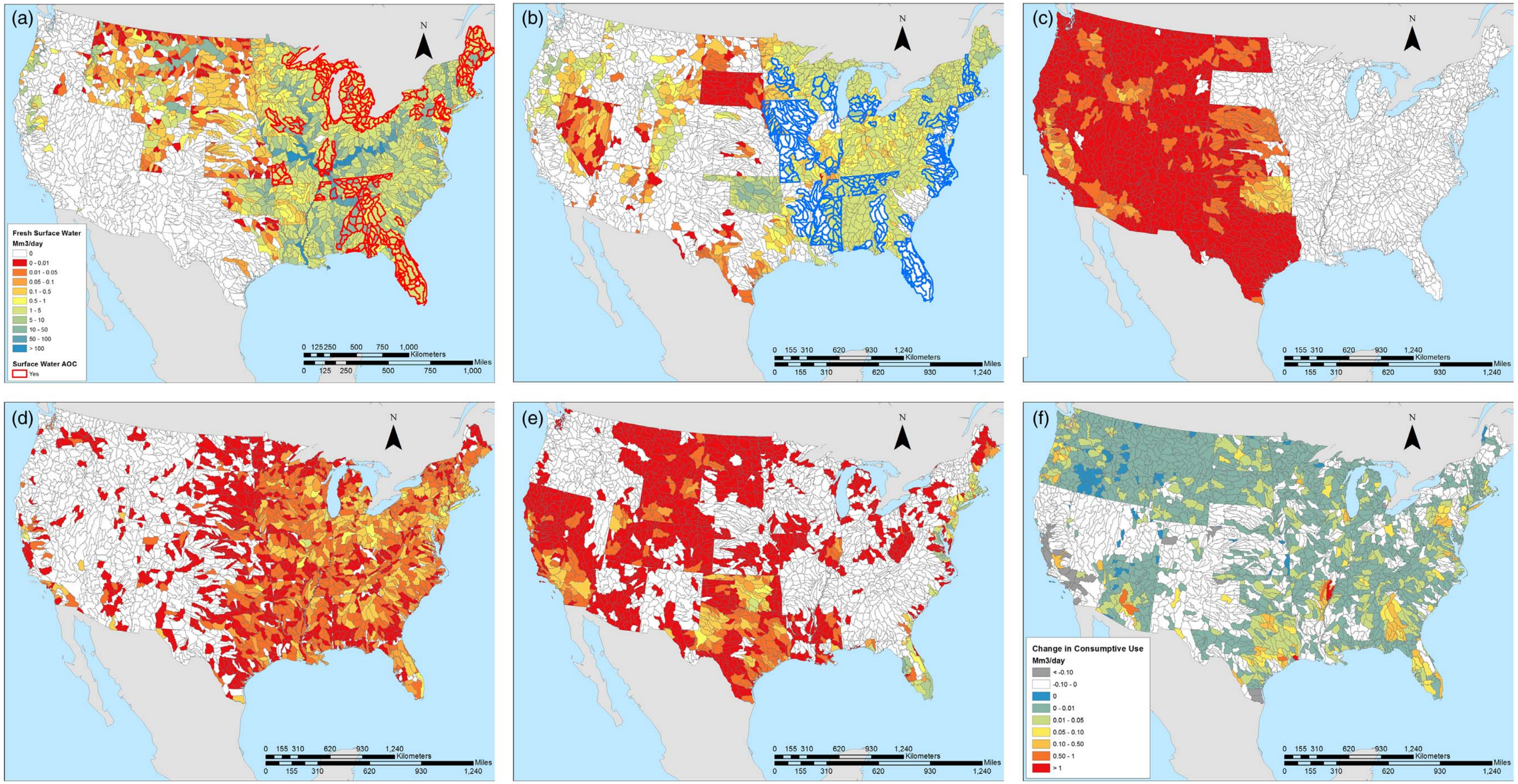

Figure 2. Water availability mapped by eight digit HUC watershed for the contiguous United States. Mapped are (*a*) fresh surface water, (*b*) fresh groundwater, (*c*) appropriated water, (*d*) municipal wastewater, and (*e*) brackish groundwater. Outlined watersheds (red and blue) have been designated by eastern states/RBCs as areas of concern. Also mapped is the projected change in consumptive water use between 2010–2030 (*f*).

No state had estimated availabilities of brackish groundwater. Calculated brackish groundwater availability metric values are mapped in figure 2(*e*). This was the most sparsely distributed source among the four mapped. Availabilities were largely limited to coastal regions, West Virginia, southern Mississippi, northern Missouri, and southern Illinois. In total, only 368 watersheds were identified with a measurable supply. Availabilities tended to be larger along the coast, while very limited toward the west. Note that the limited availability of brackish water more reflects the limited nature of data than the actual supply of brackish water.

3.2. Costs

Costs associated with each of the water sources are mapped in figure 3. In order to map all four costs comparably, a non-linear color scale was used to capture the broad range in values. Note that costs were not calculated for watersheds where a particular source of water was unavailable (watersheds mapped white in figure 2).

Each water source showed some degree of watershed-to-watershed variability in cost. This variability was masked to some extent for the brackish and wastewater maps by the large bin sizes necessitated for the scale. Costs for fresh surface water (figure 3(*a*)) were simply related to recovery costs levied by various RBCs. Variability in cost for fresh groundwater (figure 3(*b*)) corresponded to the average depth to groundwater. Municipal wastewater costs (figure 3(*d*)) tended to increase as the size of the wastewater treatment plant decreased and the level of treatment increased. Brackish water costs (figure 3(*e*)) tended to increase as depth and TDS increased.

The most important feature of these maps was the significant variability across sources, particularly between fresh and non-fresh. Average costs for fresh surface water was \$0.66 per thousand cubic meters (Tm^3), while fresh groundwater ran \$92 Tm^{-3}. Alternatively, non-fresh supplies were considerably more expensive with municipal wastewater running \$802 Tm^{-3} and brackish groundwater \$1535 Tm^{-3}. Differences in cost across sources largely reflected the increasing effort required to treat the water.

3.3. Future consumptive use

Projected change in the consumptive use of water between 2010 and 2030 is mapped in figure 2(*f*). Note that the map uses a different scale than the water availability maps (figures 2(*a*)–(*e*)) and the color scale was reversed with warmer colors designating the highest growth in consumptive use. Most watersheds have a projected growth of less than 75 $\mathrm{Mm}^3\ \mathrm{d}^{-1}$. over the 20 year period; however, much higher growth rates were realized in large metropolitan areas such as the southeast coast of Florida, District of Columbia and Chicago. Distributed population growth was also projected in central Florida and much of Georgia. The highest growth was projected for the lower Mississippi River, reflecting areas with expected growth in agricultural irrigation (Arkansas was the only state to project changes in the agricultural sector). In contrast, there were also a number of pockets where projected growth in water consumption was zero or negative. These watersheds were in rural areas or contained cities experiencing population decline.

3.4. Water budget

The difference between water availability and projected change in consumptive use provides a relative measure of the difficulty to be expected when securing a permit for a new water use. Where the projected increase in consumptive use exceeds estimated water availability, permitting is expected to be most difficult (assuming all other factors affecting permitting were held constant). To explore this issue, water availabilities estimated for all water sources (figures 2(*a*)–(*e*)) were aggregated (figure 4(*a*)) and the projected increase in consumptive use (figure 2(*f*)) subtracted to yield a simple water budget at the eight digit HUC level across the contiguous US (figure 4(*b*)).

Review of the water budget map (figure 4(*b*)) provides encouraging results as all eastern watersheds yielded a positive water budget; that is, estimated water availability exceeded projected increases in demand through 2030. Some of the lowest water budget values are associated with Arkansas watersheds. This is a result of Arkansas establishing administrative limits on fresh surface water availability as well as being the only state to project growth in future water use for irrigation. Also of note are several metropolitan regions that have lower water budget values including Chicago, Detroit, Milwaukee, and New Orleans.

3.5. East versus west

Figure 2 also presents water availability metrics and projected future consumptive water use estimates for the western states, taken from Tidwell *et al* (2014). Note that an additional source of water was included in the west, appropriated water, which only applies to western states where water rights can be exchanged.

Across all the metrics a distinct difference was apparent between the eastern and western US. The rough dividing line was the 100th meridian where irrigation becomes necessary for most agricultural exploits. The clearest difference was related to the fresh surface water availability metric where broad areas of the west were mapped as having little or no availability (figure 2(*a*)). This difference was particularly evident along the major rivers systems of the east where availabilities were high, while few river systems can even be traced in the west (e.g. Colorado River, Rio Grande, Columbia River). This difference was largely related to limited water supply due to the aridity of the climate combined with high water consumption for irrigation—the case being the exact opposite in the east.

Likewise, large areas of the west had limited availability of fresh groundwater, juxtaposed with more

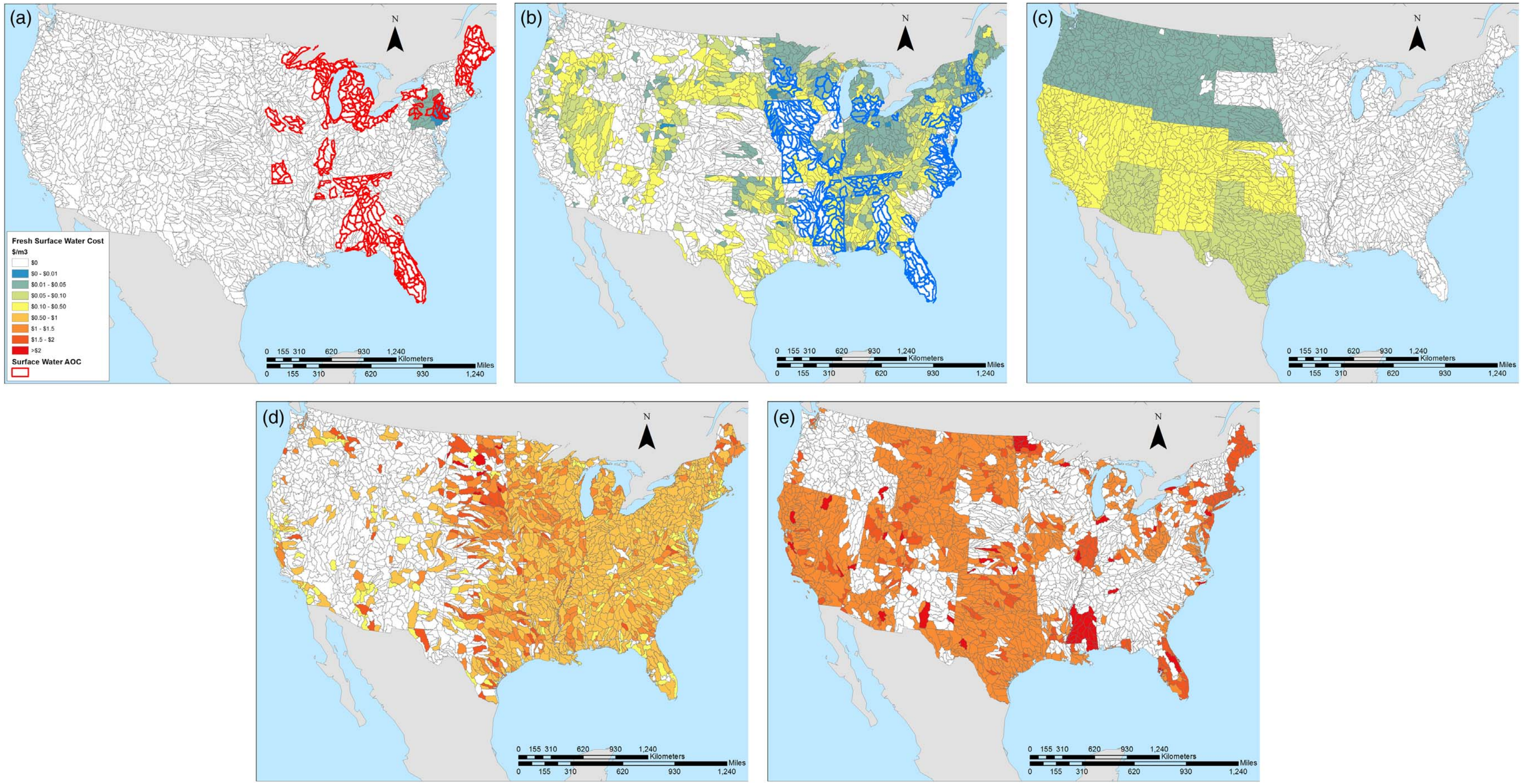

Figure 3. Water cost mapped by eight digit HUC watershed for the contiguous United States. Mapped are (*a*) fresh surface water, (*b*) fresh groundwater, (*c*) appropriated water, (*d*) municipal wastewater, and (*e*) brackish groundwater.

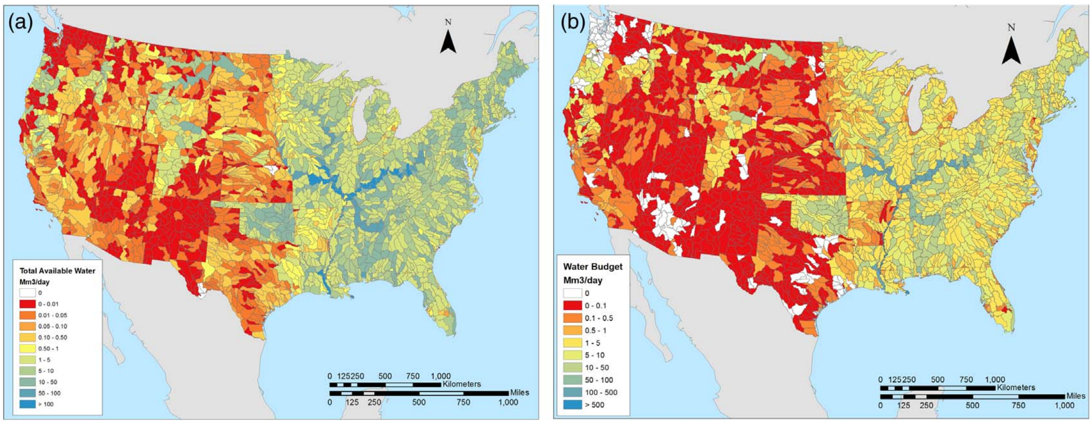

Figure 4. Total available water (*a*) mapped by eight digit HUC watershed for the contiguous United States, calculated by adding all water sources (figures 2(*a*)–(*e*)). Water budget for 2030 (*b*) calculated by subtracting projected change in water consumption (figure 2(*f*)) from total water availability (figure 4(*a*)).

abundant supplies in the east (figure 2(*b*)). However, there were pockets of limited groundwater availability in the east as a result of localized groundwater overdraft, saltwater intrusion, or poor aquifer conditions.

In contrast was the occurrence of appropriated water in the west which is absent in the east (figure 2(*c*)). Appropriated water is that quantity of fresh water (both surface and groundwater) that could be made available by abandonment and transfer of the water right from its prior use to a new use. As water in the eastern US is administered according to the riparian doctrine the right to water cannot be separated from the land, thus water rights cannot be sold or traded (Kimmell and Veil 2009).

East to west differences were also noted for non-fresh water sources. There was a distinct decrease in wastewater availability in the west (figure 2(*d*)). This reflected the lower population density throughout much of the west, growing re-use of wastewater, and that much of the wastewater in the west belonged to other downstream users and thus was not available for development. The opposite trend was evident in the case of brackish groundwater where availabilities appeared more abundant in the west (figure 2(*e*)). Whether this was actually the case was difficult to know as few brackish water studies have been conducted in the east and there was less use, both of which biased the availability metric.

Consistent from east to west was the fact that watersheds containing urbanized areas were characterized by a growing demand for water (figure 2(*f*)). Alternatively, many rural counties were projecting zero or negative growth in future consumptive water use. This projected decline in consumptive use corresponded to large blocks of watersheds in the west where limited growth in rural populations was expected combined with some attrition in irrigated agriculture (Tidwell *et al* 2014). In the east declining consumptive water use was distributed among smaller pockets of watersheds experiencing negative population growth or deteriorating economic conditions.

4. Discussion

Working closely with state and RBC water managers, water availability, water cost and projected future water consumption to the year 2030 were mapped for over 1300 watersheds in the eastern United States. Four different sources of water were considered including fresh surface and groundwater, municipal wastewater and brackish groundwater. This study complemented a prior effort which mapped a similar set of water metrics for the 17 contiguous western states. Below we comment on what was learned from this analysis concerning water in the eastern US. This is followed by a brief discussion of the limitations concerning the water metrics presented here. Finally, we conclude with a discussion of how this information might best be used.

4.1. Water in the east

Few states/RBCs have established administrative limits on freshwater availability in the eastern US. In the specific case of fresh surface water availability only Arkansas, New Jersey and the Susquehanna RBC have defined limits. In contrast, 11 of the 17 contiguous western states have set administrative limits (figure 5(*a*)), identifying 1190 of 1520 (78%) (including partial watersheds cut by state boundaries) watersheds as having no availability of fresh surface water (Tidwell *et al* 2014). Rather than establishing administrative limits, eastern states/RBCs have opted to designate AOCs. Within these regions development is allowed; however, permitting is more closely scrutinized due to issues of drought, critical habitat, assets of high social/cultural value, water quality or other factors. Eleven states and one RBC have identified AOCs (figure 5(*a*)), which include 315 of the 1332 (24%) eastern states' watersheds.

In the east, no administrative limits have been established for fresh groundwater availability; however, 16 states and two RBCs have identified AOCs (figure 5(*b*)). In total, 398 (30%) watersheds have been identified as

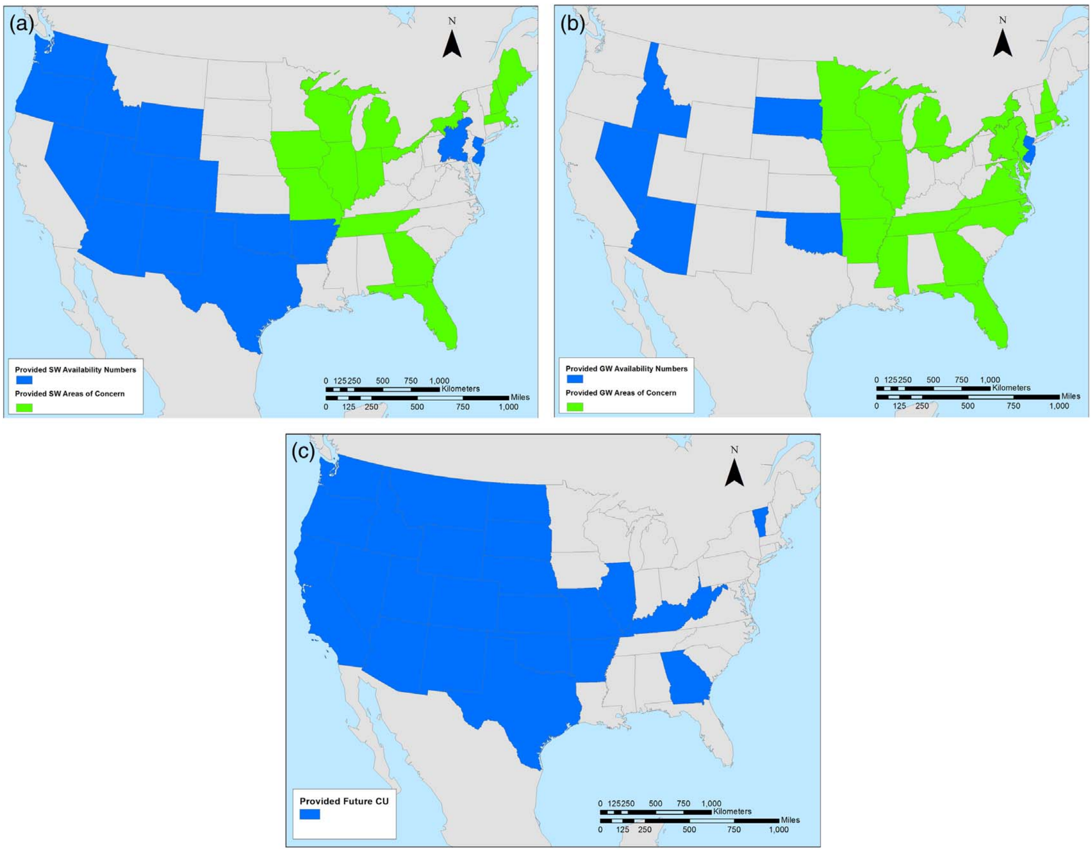

Figure 5. States and river basin commissions with established administrative limits or identified areas of concern for (*a*) fresh surface water, (*b*) fresh groundwater, or (*c*) had estimated future consumptive water use.

AOCs across the 31 eastern states. In the western US six states have defined fresh groundwater availabilities. Often this groundwater is made available only because the state allows for some degree of managed depletion (i.e. mining) of the aquifer (Tidwell *et al* 2014).

Together, these data suggest that freshwater, both surface and groundwater, are broadly available for development in the east given that no state/RBC has administratively closed basins to further development. However, development will not always be easy as 24% of the watersheds and 30% of the groundwater basins require an increased level of permitting. Particularly challenging will be the 151 watersheds/groundwater basins that are designated as both fresh surface water and groundwater AOCs.

Little to no effort has been made by eastern states/RBCs to quantify non-fresh sources of water, except for the case of Kentucky that has estimated the availability of municipal wastewater. Interestingly, this is also largely the case for the 17 contiguous western states. A clearer understanding of the availability and character of these non-fresh sources of water could help reduce pressure on co-located freshwater sources, particularly in watersheds designated as AOCs (or administratively closed basins in the west). While non-fresh water sources offer the advantage of drought resilience they generally carry an added cost of utilization (see section 3.2).

Seven eastern states have made efforts to estimate future water use (figure 5(*c*)). In these limited cases only Arkansas estimated changes in the agricultural sector, while none considered growth in the energy sector. Development of future water use scenarios that encompass all sectors is a critical link in effective water planning as the largest changes are potentially associated with energy and agriculture. In contrast, seventeen western states had compiled future water use estimates which in most cases included the agricultural sector but lacked consideration of energy.

4.2. Data limitations

A clear distinction must be drawn between freshwater availability metric values contributed directly from regional water managers versus those that were estimated as part of this analysis. Metric values acquired from the states/RBCs, including both administrative limits and designated AOCs, should be attributed a high pedigree. The reason being that these metric values were contributed by the same authority responsible for managing water development in their state/RBC.

Calculated freshwater availability metrics are viewed with much less confidence; that is, actual values could be very different from the actual availability. The largest deficiency in the calculated values is the difficulty in fully accounting for the complex range of institutional controls operating in a basin, which include such factors as treaties, interstate compacts, negotiated settlements, environmental flows, allowable depletions, and water operations constraints. These calculated metrics also suffer from lack of nation-wide data to treat key physical processes such as seasonal to inter-annual variability, surface-groundwater interaction and local heterogeneities in physiology and system dynamics. While the absolute values of these calculated freshwater availility metrics may be suspect, this does not pose a significant problem as water managers have largely been forced to establish limits or at least identify challenged basins (i.e. AOCs) where availabilities are likely to be limited in the foreseeable future.

Estimating the availability of non-fresh sources relied almost exclusively on calculated metrics. Fortunately, wastewater availabilities were based on a set of closely monitored and reported data, wastewater discharge rates (EPA 2008, 2011). Conversely, brackish groundwater availabilities were estimated from very limited data and thus hold low confidence. Future estimates can benefit from recent efforts by the USGS to characterize brackish groundwater in the US (Stanton *et al* 2017), which was published after this analysis and initial paper draft were completed.

Estimated consumptive water use values for 2030 suffer from issues inherent to projecting any future trend; that is, the future is uncertain. State estimated values are at a slight advantage as regional water managers have the best insight into trends unique to their local. Regardless, it is very difficult to project some of the more important sources of change to water use; specifically, thermoelectric power generation and irrigation. Few states, either in the east or west, attempted to estimate changes to the thermoelectric sector. The siting and retirement of thermoelectric generation is challenging as it depends on a number of interacting variables such as available transmission capacity, projected changes in demand, environmental controls, technology costs, and water availability to name a few. Currently it accounts for about 5% of the nation's water consumption and has the potential to both increase or decrease slightly depending on the mix of fuel type and cooling type adopted along with the mix of plants retired (e.g. Tidwell *et al* 2013). Most western states had estimated changes in consumptive water use by agricultural irrigation, while only Arkansas provided such values in the east (no attempt was made here to independently estimate changes to irrigation). Small changes in irrigation can lead to dramatic changes in water demand, as evidenced by projections from the state of Arkansas (figure 2(*f*)). While the general trend is toward less irrigation in the west (reflected in broad regions where future consumptive water use is zero or negative, figure 2(*f*)) and increasing irrigation in the east (Maupin *et al* 2014), without local knowledge pinpointing where the changes will occur is very difficult.

States provided no direct input to the water cost metrics. These are recognized as very rough estimates as nation-wide data was lacking to estimate such factors as utility specific cost recovery pricing, technology choice for water treatment, local variations in depth to groundwater (averaged at the HUC-8 level here) and other siting features.

According to the limitations spelled out above, these HUC-8 level estimates of water availability and cost are of insufficient detail to support siting decisions at the local scale (new water use at a specific location). Even in the case of metrics provided directly by state water managers, these availability and cost values do not guarantee such conditions persist at every point within the watershed. Thus, local siting decisions must be accompanied by much more detailed local assessment of water availability and cost.

Rather, the water availability and cost metrics developed here are intended to support regional-level analysis, providing a consistent and comparable measure of the relative difficulty and expense to develop the water resources in a given basin. Although confidence in the absolute value of the calculated metrics is often questionable, as outlined above, the metrics were developed using a consistent set of measures based on a consistent and uniform set of data thus capturing in relative terms key aspects of the spatial and source to source variability. Also important is where critical limits are being approached, particularly in the case of fresh surface and groundwater availability, states and RBCs have calculated and provided these metrics.

4.3. Utility of the data

These metrics were compiled for the purpose of supporting water planning exercises. These data are best suited for studies related to relatively broad scales, i.e. HUC-4 and larger watersheds, state, regional, national. In fact, this data was specifically collected to support long-term transmission planning for the Western Interconnection (Tidwell *et al* 2016) and more recently the Eastern Interconnection (paper in preparation). Nevertheless, this general set of data could be used for a wide variety of planning exercises aimed at understanding where and how the availability of freshwater might constrain future development while providing insight into alternative sources of water.

This compiled set of water metrics is unique thus providing an improved basis for planning. First, water metrics were developed with the direct assistance of regional water managers incorporating state/RBC administrative controls where they exist. Second, metrics were developed for multiple sources of water, including fresh and non-fresh sources, allowing tradeoffs to be drawn between alternative supplies. Third, available supplies were put in context of projected growth in water use. Fourth, metrics quantifying the relative cost to deliver water of potable quality were estimated, providing a rough measure of the substitutability of one source of water for another. Finally, all metrics were developed in a consistent manner and with a uniform set of data allowing comparisons at the eight digit HUC level across the contiguous United States.

To assist with dissemination of this data, a decision support system was developed to allow interested parties access to view, explore and download the data. The portal was developed within ArcGIS Online (http://water.sandia.gov/). Water availability, cost and consumptive use data in a tabular format can be downloaded from the site. Detailed spreadsheets containing all supporting data, metric calculations, and data source citations are also available for download at the site, organized by state.

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