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The New Tower of Babel: Divergent Water Quantification in the Southwestern United States

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ABSTRACT: This research contributes to the academic discussions on the politics of water quantification by analysing the factors that generate divergent water figures in the southwestern United States. The controversies surrounding the construction of the Lake Powell Pipeline (LPP) are the case of study as its proponents and opponents use conflicting water data. This analysis associates four kinds of contradictory data related to the LPP with epistemological questions (value, ranking, perspective and delimitation) to explain why having more data does not solve conflicts. Since having adequate data is essential to making informed decisions, this study concludes by calling for a critical review of water figures that considers the logical limits of quantification and the political factors influencing its production and use.

KEYWORDS: Quantification, metrics, comparison, perspective, delimitation, standardisation, Lake Powell Pipeline, United States

INTRODUCTION

Reliable data is essential for identifying the causes and consequences of water shortages and those most affected by them; it is also essential for creating effective responses to current problems, improving water management, and preventing future hazards. A significant difficulty that is commonly experienced worldwide by water authorities, activists and researchers is that institutions quantify water in multiple ways. Water data represents a 'new Tower of Babel' where communication between actors appears to be fragmented.

In the case of global water scarcity metrics, Damkjaer and Taylor (2017) contend that general water stress thresholds used by multiple institutions were established arbitrarily in academic reports. Although these thresholds have become more nuanced due to holistic metrics, measurements do not always consider regional variability, local adaptation, and different forms of freshwater storage. Methods such as the Water Stress Index (WSI) are applied in different parts of the world for purposes other than those for which they were designed, and other methods of measurement such as the Mean Annual River Runoff (MARR) do not consider groundwater resources and thus generate erroneous data on freshwater availability. According to Richard Taylor of the UCL Department of Geography, "How we understand water scarcity is strongly influenced by how we measure it. Grossly misrepresentative measures of water scarcity can identify scarcity where there is sufficient and sufficiency where there is scarcity" (UCL, 2017).

In water data in the United States, there is a discrepancy of sometimes up to 23% between federal agencies due to insufficient coordination between institutions and the challenges of unifying information (Josset et al., 2019). A critical report by the Australian Bureau of Meteorology (2017) warns that the lack of reliable water data generates vulnerability to extreme weather events, makes it difficult to evaluate the effectiveness of proposed solutions, and increases mistrust among the general public, companies and government institutions. The assessment highlights that,

> [a]round the world, water sector participants are expressing frustration that their nation's water data arrangements are not meeting their needs. This is often despite the urgency to tackle profound and worsening water management problems. Data is gathered by many actors but not openly shared. There are many gaps in the water data information base. The quality of the data is uneven and often poor. Even the good data that is available is rarely made into a form that encourages objective decision-making. Those facing impending water crises agree that valuable time is being lost arguing over data instead of debating the merits of different policy responses (ibid: 3).

To explore the causes of divergence in water data, this paper studies the contradictory figures that both justify and challenge the construction of a water pipeline in the southwestern United States. The Lake Powell Pipeline (LPP) project is designed to transport water from the Colorado River to Washington County in southern Utah in order to respond to the growing threat of water shortages there. According to state projections, in the coming years Washington County's water demand will outstrip its supply due to rapid population growth and climate change, and conservation strategies will be insufficient to reduce this problem. Many Utah activists and academics are deeply critical of the water figures that justify the construction of this infrastructure.

The conflicting water figures surrounding the defense of, and opposition to, the LPP make this an ideal case for studying the political, scientific and institutional factors that drive water data divergence. This analysis is relevant because the use of water data creates and holds political authority and thus calls for critical evaluation. Also, people's stances for or against water infrastructure construction are mainly based on figures. Moreover, it is necessary to understand what factors cause data divergence to offer more reflective tools to activists and decision-makers in territorial planning debates.

This research used a multi-method approach to examine the controversies around the construction of the LPP; it conducted a contextual analysis of historical documents, engaged in interviews, and recorded field notes. By studying institutional reports, audits, scientific papers and press, and by having conversations with stakeholders and visiting sites of interest, the author created an interpretive context for understanding the production and use of water data related to the LPP. In combination, this set of methods allowed us to understand the motivations, expectations and conditions of the production of water data in Utah.

The remainder of the paper is divided into four sections. I first describe the water-related figures that create disagreement between promoters and critics of the LPP. I argue that to analyse divergent water figures, it is necessary to group them with particular epistemological questions. I then offer a theoretical review of how numbers are socially shaped. This is followed by a presentation of the empirical research findings with subsections that address: (1) how fights over the legitimate use of water lead to the selection of particular metrics that justify opposing positions; (2) the moral judgements embedded in conflicts over what, how and who compares water use between cities and states; (3) how 'drought' is a fraught term that is multiply defined and interpreted because institutions measure different aspects according to socio-economic interests; and (4) how disagreements over the temporal scales used to measure water runoff of the Colorado River have broad political, ecological and economic influences and consequences. This is followed by an analysis of the empirical findings and, finally, I present general conclusions of the research.

In the concluding section, I reflect on the practical and political reasons for why standardisation in water quantification is always incomplete and I call for critical analysis of how water data is produced and used. The LPP case indicates that although more water data is needed to make better decisions, data itself is not a definitive route to resolving political disputes. Indeed, the opposite can happen, in that additional value-laden information can be used to lend weight to competing institutional or political positions, and can thus lead to decisions going in even more divergent directions.

CASE STUDY

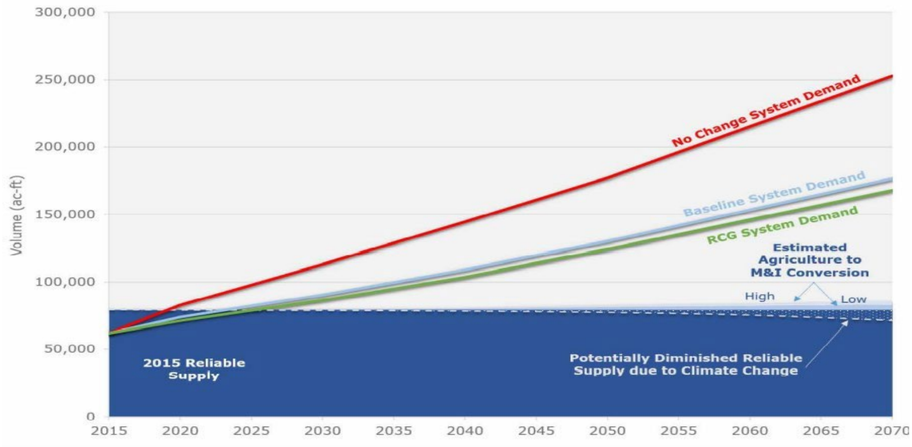
Utah's 2021 Water Resources Plan is an official document that analyses the state's water demand and supply. It argues that it is necessary to build a water pipeline to transport water from the Colorado River (Figure 1) to southern Utah due to the shortages that the latter region will face in the coming years. The report models the future water demand scenarios of Washington County in three colour lines that contrast the region's available water supply (Figure 2). These scenarios suggest that even under the most optimistic scenario, water demand will exceed Washington County's supply in the near future (UDWRe, 2021).

Figure 1. Colorado River Basin showing the Upper and Lower Basins.

Source: Lukas and Elizabeth (2020: 3).

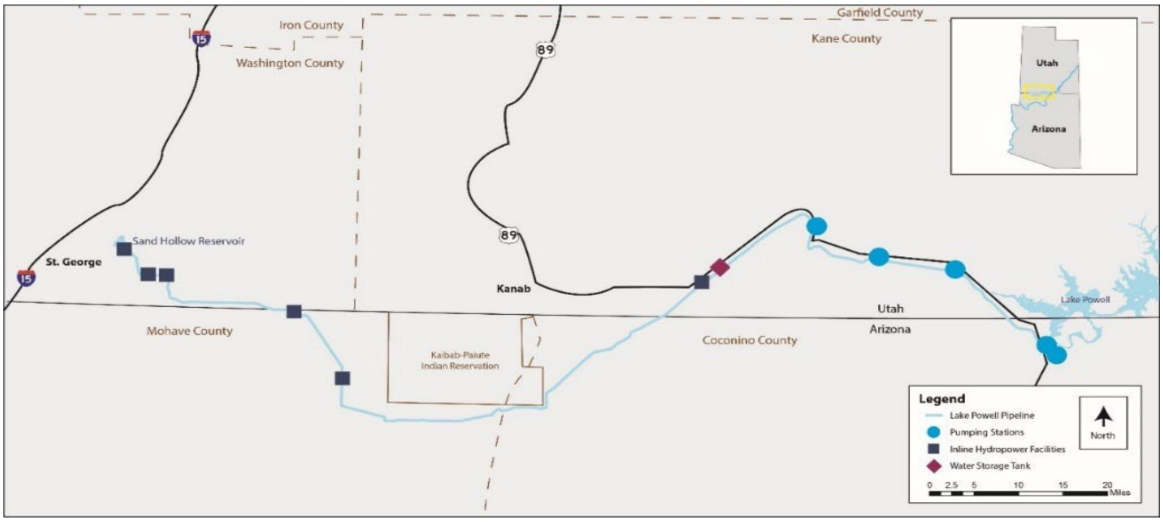
The Utah Division of Water Resources (UDWRe) models indicate that southern Utah's water supply is at risk, suggesting that immediate intervention is required through the construction of the Lake Powell Pipeline (Figure 3). When we evaluate the scientific basis of this project, however, we find some evidence that supports the building of the LPP and some that suggest that this is not advisable. There are also opposing interpretations of the data with regard to current water management. Critics argue that the State of Utah should not build the LPP because it has mismanaged its water resources; they cite as an example the fact that 70% of the diverted water goes to agriculture and, of that, the majority promotes the cultivation of alfalfa, which requires large volumes of water. They argue further that the southern Utah cities such as St George that would benefit from LPP water are higher consumers than those in the rest of the region. Indeed, according to environmental organisations such as the Utah Rivers Council, Washington County is one of the largest water wasters in the country. In their defense, local farmers maintain that the cultivation of alfalfa is ideal for Utah's geographical conditions, and local authorities contend that Washington County leads water conservation in the state.

Figure 2. Water supply and demand for Utah's Kanab/Virgin River Basin.



Source: UDWRe (2021: 82).[1]

Figure 3. Proposed Lake Powell Pipeline route.



Source: Lake Powell Pipeline (2022).

Both critics and defenders of the LPP use ideas about water scarcity to justify their stance. All actors agree that Utah's water access is threatened, as the southwestern United States is continually experiencing periods of drought, and climate projections indicate that climate change will impact the region's water access. The respective sets of actors, however, draw opposite conclusions.

According to critics of the LPP, no water will be available for transporting through this pipeline in the coming years because drought is reducing the flow of the Colorado River. LPP. advocates, on the other

[1] Note: red line = increased water demand from population growth, with no additional conservation efforts and without considering climate change; light blue line = water demand if current conservation strategies are continued in the context of climate change; green line = water demand if compliant with regional conservation goals (RCGs) in the context of climate change; white dotted line = future water supply losses due to climate change; light blue shaded areas = extra water that can be obtained from converting agricultural water to municipal and industrial (M & I) water; dark blue areas = reliable water supply as of 2015.

hand, such as the Washington County Water Conservancy District general manager, argue that the groups that oppose the LPP misrepresent their data and deny that new climate adaptation infrastructure is essential to the state's future. They contend that the pipeline should be built because it will protect Washington County against future droughts, which will increase with climate change. This manager argues that the Virgin River, on which Washington County depends, will be negatively affected by climate change: "Being able to tap into a larger project makes our supply here more reliable and safer. The Colorado River is the most reliable water source in the western United States" (Meiners, 2020).[2]

This research proposes a set of epistemological questions as a way to associate and differentiate the kinds of data that support and criticise the LPP. The paper, inductively, groups four major logical challenges and paradoxes by abstracting common features of the heterogenous data in the LPP controversies (Table 1). This strategy is based on the idea that environmental conflicts encapsulate epistemological problems that are derived from the possibilities and limits of producing and mobilising knowledge. Conceptual tools are thus not simply brought in to this discussion to explain the debates in Utah over water data; rather, I consider this controversy to be a theoretical case.

Table 1. Central aspects of the Lake Powell Pipeline controversy

Temporal scenario of interest	Elements of controversy	Epistemological questions
Current water management	Agricultural production	Value
	Water use in cities	Ranking
Past impacts and risks of future shortages	Drought	Perspective
	Hydrological projections	Delimitation

Source: Author's elaboration.

THEORETICAL REVIEW

There is growing academic interest in researching the politics of water quantification. Recent studies argue that water is not a passive and ahistorical entity; rather, it should be considered as a substance with political materiality because multiple actors seek to tie their interests, knowledge and concerns to how it is quantified (Linton and Saadé, 2024; Molle et al., 2024; Molle and Collard, 2024; Perramond, 2024; Puy and Lankford, 2024). This section explores four arguments that deepen these discussions; they will help elucidate the causes of the divergence in water data in the LPP controversies.

Values create value

Social ideals affect what we measure. Measurement is not the neutral identification of a given value; rather, it is a technical process that grants value to what is being measured. The quantification of a diffuse object clarifies, legitimises and reinforces its social importance (Brighenti, 2017). Water quantification illustrates this idea, since the process of quantification encapsulates values; this is so much so that the answer to the question 'How clean is the water?' is only partially scientific, as water quality thresholds depend, at least to some extent, on the use to which people put it.

The process of quantifying the world is not neutral. Methods of measurement are forms of government; they shape how the power to manage the environment and human populations is distributed to the state, to individuals and communities, and to the market (Anand, 2015; Appel et al.,

[2] To understand the historical context, the implications of the possible construction, and the political games of the LPP, see Perdomo (2024a, 2024b).

2018; Brighenti, 2017; Linton, 2010; Linton and Saadé, 2024; Puy and Lankford, 2024; Schlaudt and Huber, 2015; Vera, 2015). As an example of this, the representation of the hydrologic cycle and the idea of water as a resource are connected to the political interests of nations since, "by institutionalising the quantification of stocks and flows of water on a national scale, the state took a major step in making water available for, and amenable to, management by state agencies" (Linton, 2010: 149).

Multiple interests guide how we compare data to establish a ranking

Quantifying water use is more than just a technical task of collecting and compiling monitored data to identify who uses more and less water. This process, instead, requires asking political and methodological questions such as what is the purpose of comparing data and what is the analytical strategy that will be used to do so. State institutions seek to assess progress and monitor performance in water conservation; they thus make *internal comparisons* that group the regional data within its own environmental, economic, demographic and political conditions. Because environmental organisations seek to critically evaluate states, they use *external comparisons* to integrate data from other states or countries.

Let us think about the number of times per week that people around the world take a shower. Should we compare these figures to denounce countries' water waste and encourage conservation? Or is this an impossible comparison because each region has particular conditions, and thus determining whether people bathe 'a lot' or 'a little' becomes a moral judgment? Is this an apples-and-oranges comparison? Are the differences or similarities between countries of little, or relatively great, importance? No one has been able to answer this question. According to Stirling (2019a), it is impossible, "to derive a single generally definitive answer for this kind of essentially value-laden politics". Professionals learn to omit the philosophical problem of incommensurability due to institutional pressure to find concrete answers to open problems.

We cannot know reality directly, only from perspectives that focus our attention

We see patterns and facts by selecting a contingent analytical totality that connects and makes sense of particular data (Tsing, 2010). In scientific research, the 'natural whole' that gives meaning to particular data is not evident in itself; it is not an empirical reality, but is rather a methodological and conceptual delimitation that researchers produce (Hastrup, 2013). The choice of an analytic context is nevertheless not neutral; its selection is influenced by technological, moral and political factors (Helmreich, 2016; Bond, 2022; Ribot, 2022).

We cannot identify the environment in a panoramic way; rather, we receive partial perspectives that highlight and exclude information. On minor spatial levels, for example, the national delimitation of watersheds in the United States (Omernik et al., 2017) and global climate models (Ditlevsen, 2013) lack resolution and are imprecise. A critical factor that prevents constructing a general view of the environment is what Edwards (2010) calls *computational and data friction*. Computational friction refers to the technical and human obstacles that limit the conversion of data into information that is helpful in making decisions; data friction, on the other hand, refers to factors that restrict the production, management, evaluation and sharing of data. These partial perspectives occur because scientific data is produced with different instruments and for different purposes, because there are multiple ways of assembling it, and because levels of confidence in the data and the research also vary.

Political and technological factors influence the way we delimit the environment

The social world influences how scientists produce knowledge. According to Schlaudt and Huber (2015: 5), it is thus important to study, "the 'invisible infrastructure' of metrology; more generally, it requires a recognition of the contingent, 'history-laden' context in which scientific knowledge is embedded and with which it is entangled in various intricate, often improvised ways". Scientists quantify the environment in diverse ways because – based on different academic protocols and the influence of technological devices

– they learn to evaluate what counts as data and to contextualise it in specific ways (Calkins and Rottenburg, 2017; Mahony and Hulme, 2016; Melsen, 2022).

Technology is not a neutral object for collecting data about water; rather, it is a conceptual filter that affects how water is understood and controlled (Linton, 2010; Rozwadowski, 2010). Tools such as formulas, indexes, lists and pacts, for example, affect decision-making; they create an abstract image of water and ways of managing it by delimiting space for institutional improvisation (Ballestero, 2019). As a final point, researchers also study the environment differently because of the interests and pressures of the institutions in which they work (Saltelli and Giampietro, 2017; Stirling, 2019a).

EMPIRICAL FINDINGS

This section explains how the water consumption of crops and the water use of cities, as well as droughts and river flows are quantified in the Colorado River Basin; it also reviews the essential aspects of the LPP-centred controversy. In the process, it highlights the epistemological challenges of water quantification. Table 2 catalogues the empirical findings.

Table 2. Synthesis of empirical findings.

Epistemological question	Type of data	Types of conflict	Positions and interests
Value (What is the water's worth?)	Water consumption of crops; for example, 68% of the water diverted in Utah for agriculture is used to cultivate alfalfa	Different ideas on the most efficient use of water affect the selection of water metrics and are defended with economic, environmental and political criteria	*Farmers and agricultural agencies* (seeking to defend their historical access to water rights and the current distribution system): Alfalfa is an ideal crop for Utah's geographical conditions *Environmentalists and critics* (wishing to transform the state's water policy to focus on environmental sustainability): Alfalfa consumes enormous amounts of water, so it does not make sense to grow it in arid regions like Utah
Ranking (Where do we stand comparatively?)	Water use by cities and states; for example, Utah consumes 169 gallons (640 litres) of water per capita per day	Fights over whether water figures can be compared; moral arguments about who and where more is consumed and the assertion that their consumption is thus wrong	*Conservationists* (wanting to prevent the construction of new infrastructure projects like the LPP): Water consumption in Washington County and Utah is higher than in other cities and states *State agencies* (hoping to garner the support of citizens and legislators for the construction of water infrastructure): Consumption is less than, or incomparable to, that of other states
Perspective (From which angle or level do we look at things?)	Environmental indicators of drought; for example, low Surface Water Supply Index at Virgin Basin: – 0.31	Institutions do not represent droughts in a general way; their socio-economic interests determine what data they seek to obtain, what information they use,	*Federal agencies* (wanting to identify climate anomalies in order to alert and support states): National maps are a general representation of environmental conditions *State agencies* (wanting to protect the socio-economic interests of the State of Utah): National maps are not helpful for decision-making on a regional and local

		and what maps they produce	scale; other indicators are thus required to respond to the contextual conditions of Utah
Delimitation (What are the boundaries of the datasets that we consider?)	River flow; for example, 18 or 30 years of data from reservoir levels at Lake Powell	Selecting particular time frames creates different river flow projections; these are of profoundly different political, ecological and economic interest and have different consequences	*Federal scientists and agencies* (aiming to model the river within the scientific and regulatory frameworks of federal agencies): Data from the last 30 years of the flow of the Colorado River must be considered to identify future trends *University researchers* (whose aim is to critically evaluate modelling strategies in order to identify realistic hazard and sustainability scenarios): Only data from the last 20 years should be considered because the 1990s were anomalously wet

Source: Author's elaboration.

Water efficiency according to whom?

Critics of the construction of the LPP contend that alfalfa is one of the largest water wasters in the region; they argue that it does not make sense to build this water pipeline if Utah is not committed to water conservation in agriculture. Activists claim that 70% of the water diverted in the state is for agriculture; about 68% of this water is used to cultivate alfalfa, a crop that is not even for local consumption but rather goes mainly to feed livestock in Asia. Locally, this crop has a low economic impact, constituting only about 0.2% of the state's annual gross domestic product (Maffly and Eddington, 2022). Alfalfa uses large amounts of water but has the lowest agricultural return on water consumption. In the context of drought in southwest Utah and the rapid increase of its population, academics and political leaders wonder if, given the threat of scarcity, the water of the region should not be put to more efficient use, and thus a higher value, by being prioritised not for agriculture but for cities, industries and ecosystems.

Figure 4. Alfalfa field in Utah

Source: Maffly and Eddington (2022).

Advocates of alfalfa claim that this plant is the most valuable agricultural crop in Utah because it is ideal for the region's environmental conditions (Figure 4). It is resilient to global warming, they claim, because it survives periods of drought due to its deep roots, thereby also reducing erosion. Irrigation of alfalfa crops recharges groundwater and the cultivation of this plant adds nitrogen, keeps carbon and nutrients in the soil, requires little fertiliser, and can grow at high latitudes where it is difficult to grow other plants due to the cold and the reduced growing season. Since alfalfa is a nitrogen-fixing plant, farmers can plant different crops in what were alfalfa fields to take advantage of the nitrogen-rich soil. Alfalfa also survives intentional water cuts, so depending on the region and the season, the water no longer needed for irrigation can be sold to the city. This crop can grow throughout the year, uses degraded recycled water, and encourages bird, insect and mammal diversity. Utah's dry climate means that alfalfa grows and is harvested more efficiently and with higher quality in the state than in other regions. Because of its high nutritional value, alfalfa is essential to animal feed and to the milk and meat economy and boosts secondary economies. It also creates the financial opportunities that allow rural communities in Utah to persist (Podmore, 2022).

Proponents of alfalfa justify the value of this crop through its units of measurement. According to Putnam (2015), "[i]t's not so much how much water is used, but how much crop is produced per unit water that is important – also known as water-use efficiency. In that category, alfalfa shines". The value of the crop depends not only on the quantity harvested but also on the "quality per acre", that is, the nutritional content that, in this case, is favoured by Utah's geographic conditions (Maffly, 2023). What is interesting about these arguments is that the way proponents quantify it does not describe but gives value to alfalfa. In this way, public perceptions are influenced by the indicators selected to measure alfalfa's performance.

Alfalfa's water consumption is highlighted through comparisons with other crops, but there are actually multiple ways to compare it. At public events in Utah on the future of the Colorado River, for example, farmers in favour of cultivating alfalfa contend that it is unfair to claim that it consumes the most water resources in the region since its annual water consumption is the same as that of the crops that farmers grow throughout the year due to the change of seasons.

Political positions as comparative strategies

States, industries and communities require accurate water data to improve management and design strategies to prepare for potential hazards. An evaluation of Utah's water data reveals extensive difficulties with its rigour. In 2015, the Legislative Auditor General found that there was no adequate data because of the training and communication problems of institutions. They also found that municipalities erroneously report that they are making use of all their water rights because they fear losing them if they do not use them. The report thus concluded that Utah lacks reliable data with which to make future water demand projections (Legislative Auditor General, 2015).

Set against this panorama of doubt on the rigour of water data in Utah, the figures on water conservation performance are central to the polarisation around the LPP. Washington County authorities claim that their county leads in water conservation in the state. Utah Rivers Council representatives, meanwhile, argue that Washington County is one of the highest per-person water consuming regions in the United States. Can both of these facts be true? Can Washington County be a regional conservation leader but still consume and waste more than most of the country? Is the evidence contradictory, or is it that the emphasis is on one fact rather than the other?

According to the U.S. Geological Survey, in 2015 Utah was the second-largest state in per-person domestic water use, consuming 169 gallons (640 litres) per day (USGS, 2018), a fact which the Utah Rivers Council claims is evidence of the state's water wasting. Critics suggest that this high consumption is rooted in Utah's lack of political commitment to conservation; other states in the region allocate more economic incentives to, for example, replacing traditional lawns with drought-tolerant plants that require less water. Other reasons given by critics for Utah's high water consumption include that: the doctrine of prior appropriation discourages conservation in the state; low water prices give rise to overconsumption; and there are not enough meters in the state's secondary water systems. Within the region, Washington

County could be considered the most dramatic case of overconsumption, with its inhabitants using even more water than residents of large cities such as Las Vegas (Utah Rivers Council, 2022).

In their defense, Utah's representatives claim that there is increasing investment in secondary system meters and in programmes to encourage water-efficient landscaping. New laws have also been whereby farmers will not lose their allotted water rights if they conserve water or if, for some other reason, they do not use their entire allocation in a given year. The Utah Division of Water Resources (UDWRe, 2021) argues that the low price of water is due to the geographical specificities of the region; they also insist that it is a mistake to compare Utah to other regions because each state measures water differently and operates under particular environmental conditions. This last argument is deeply philosophical: Utah authorities defend their water figures on the basis of their incommensurability with those of other states.

Inquiring into the process whereby the U.S. Geological Survey establishes figures on water use, we find that, "[d]ata in this report may have been derived from reported, estimated, or calculated means using different sources and methods and, therefore, will have varying levels of accuracy" (USGS, 2018: 5). States use different methods to report water data because of the absence of a standardised system at the national level. Members of the Utah Geological Survey (2018) reflect on the comparative difficulties of this:

> If Utah water is used to generate electricity sold to California, should the water be legered against the producing state or consuming state? Conversely, California grows many crops that are shipped to Utah, and in this case, some of California's water is shipped to Utah in fruits and vegetables. This may be a reason the USGS does not highlight per capita total use in its report.

This last argument highlights that water is not only consumed locally; it is also redistributed by commerce, which is referred to in the academic literature as 'virtual water'. The previous idea is not entirely convincing as the amount of water contained in the crops exported to Utah is minimal compared to the amount of water used for irrigation in California; nevertheless, it is mobilised as an argument by a state agency.

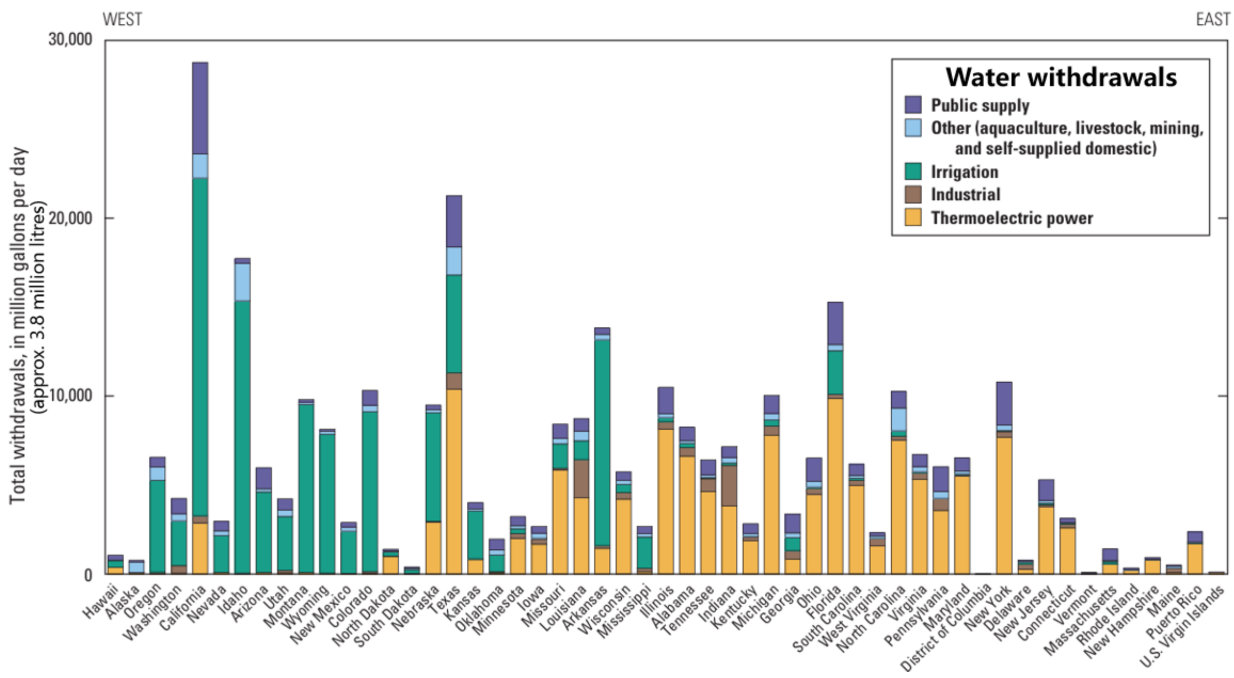
On the national scale, Utah's water withdrawals seem lower than those of the country's other western states. Water consumption also looks different if it is calculated on the basis of a state's total consumption, its overall per capita use (which may vary seasonally), or its per capita 'public' use (domestic, commercial and industrial) (Figure 5). Due to the open possibility of making all kinds of comparisons, it has been warned that, "[a]lthough state rankings are good for creating attention-grabbing headlines that inspire water-use awareness, they have little to no scientific merit" (Utah Geological Survey, 2018).

If we compare states through aggregated regional data, we cannot see state-level variability; however, each state and county has complex variables that affect water use. Examples of this include: environmental variables (access to water sources, soil moisture, precipitation, evapotranspiration), technological variables (reservoir capacity, irrigation canals, public and private supply networks, water reuse infrastructure, measurement systems), demographic variables (seasonal variations in population due to tourism), economic variables (types of companies such as golf courses and hotels, industries such as agriculture), and institutional variables (water laws and conservation incentives). According to Utah's water authorities, their water measurements are not designed for direct comparison with other states; they contend, however, that internal (within-Utah) temporal comparisons of water data can be used to assess state-level advances or setbacks in the achievement of conservation goals. According to the UDWRe (2021: 17),

> Utah's water use is often compared to that of other western cities and states that don't use the same calculation method or even collect the same data. The result can be an "apples to oranges" comparison (For example, the city of St. George compared to the entire State of Nevada or New Mexico or the State of Utah

compared to cities such as Tucson, Las Vegas, and Albuquerque). It's more relevant to compare current numbers against past performance and ensure the State sees improved conservation and efficiency.

Figure 5. Water withdrawals by state.



Source: Adapted from USGS (2015: 12).

There are concerns that difficulties in making comparisons are an excuse to hide water overuse in Utah. In public comments on the 2021 Utah Water Plan, members of an environmental organisation called Conserve Southwest Utah stated that, "there are ways of dealing with this apples-to-oranges situation, but Utah refuses to work to normalise the comparisons preferring to say we can't be compared" (UDWRe, 2022). It is worth mentioning, however, these critics do not detail how to solve the problem of data incommensurability. In the same report, members of another environmental organisation called Western Resource Advocates disagree with Utah's idea that states should not compare gallons per capita per day (GPCD) because of the specificity of the secondary water use system and tourism; they argue that, on the one hand, states do not report systems that they do not have, and, on the other hand, tourism is common in the western part of the US and Utah's high water use is in fact residential. The director of the Utah Rivers Council acknowledges the challenges of comparisons but wonders if this is not an excuse to avoid talking about wasting water.

Let us take a closer look at the problems of measuring GPCD. According to water authorities, GPCD is calculated differently in different states depending on total demand, water use, and consumptive use. The first strategy is used in California, the second in Utah, and the third in Arizona and Southern Nevada. Each approach has different variables, producing different results. How the population is counted also has an important impact on the GPCD, and there are multiple ways to calculate it. According to the UDWRe (2021: 17), Utah's water use looks high relative to other states because the GPCD is measured differently across the country:

> Some cities and states only report certain types of water use and/or may apply a credit for water that is returned to the system. Or, some cities and states may only report single-family residential potable water use and exclude multi-family residential use, commercial, institutional, industrial, secondary and/or recycled water. Utah accounts for all water use types (potable, secondary, and recycled water) by all industries

(residential, commercial, institutional, and industrial) and doesn't apply credits for flows returned to the system. This comprehensive process may give the false impression that Utahns use more water than people in other states.

In 2022, Utah's water districts supported a bill to calculate state's consumptive use per capita because not all used water is lost; although some is depleted, part of the water returns to the river system. The bill sought to reduce Utah's per capita usage numbers relative to other states. According to directors of the water districts, "We're getting a lot of comments from federal agencies and other state agencies – [in] Nevada, Arizona, Colorado – saying 'you guys don't deserve Colorado River water, you don't do a good job using what you've got'" (Larsen*,* 2022).

The controversy surrounding this bill is that state agencies could not openly communicate the state's water use to the public. Many states are anxious about releasing all their water data because they do not want public scrutiny or to be judged by comparisons, a real risk they try to avoid. In early 2023, Utah lawmakers rejected a bill to publicise data on the amount of water used by the state's golf courses, arguing that it could unfairly focus public attention on these industries and lead to the drawing of erroneous conclusions (Maffly, 2023b).

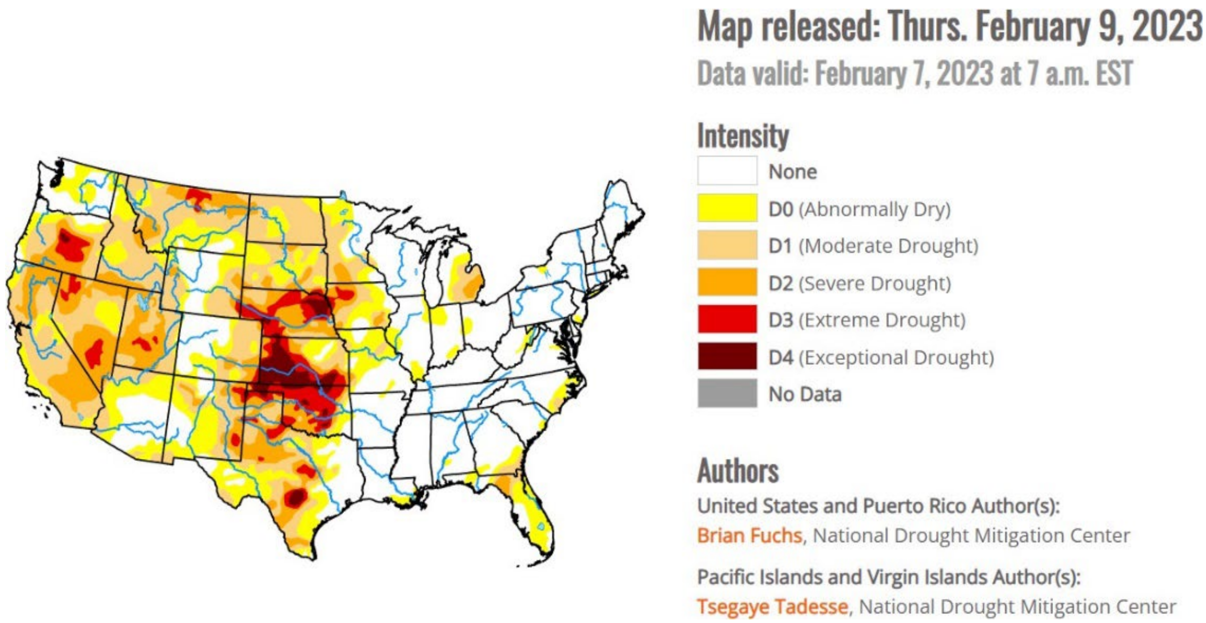
Drought as an analytical perspective

Identifying a drought does not generate controversy because drought maps tend to be considered neutral descriptions of a natural phenomenon. People usually agree that a drought exists but they can disagree about the degree of alarm and the actions that are called for; in the case of Washington County, for example, there can be different opinions as to whether it should accelerate or prevent the construction of the LPP. This section of the paper argues that drought is a fraught, multiply defined and variously interpreted term because institutions measure different aspects of the drought according to their socio-economic interests. Drought maps thus create coarse representations or localised and limited metrics by aggregating heterogeneous local data.

Drought is commonly understood as an extended period of water scarcity that, at the same time, deviates only temporarily from 'normal' conditions as established from the long-term average. In academic terms, there is no universal definition of drought because each region has specific environmental conditions and low rainfall is therefore not necessarily a determining factor (Wilhite and Glantz, 1985). Distinctions have thus been made between different types of droughts. According to the nature of its impact, drought is categorised as hydrological (water supply), meteorological (precipitation), agricultural (crop health and soil moisture), socio-economic (transportation, energy production, and supply of commodities), or ecological (natural systems) (National Integrated Drought Information System, n.d). Institutions do not ignore the difficulties of studying droughts, and U.S. Drought Monitor (USDM) officers recognise the complexity of categorisation and comparison of the different indicators for dryness. The map in Figure 6 considers diverse kinds of data such as temperature, precipitation, soil moisture, streamflow, vegetation health and reservoir levels; together, these compose a 'big picture' of the country's environmental patterns but they do not allow for identification of local conditions (U.S. Drought Monitor, n.d).

Utah does not rely entirely on the U.S. Drought Monitor because regional particularities do not fit into this map (UDWRe, 2023). A national map is not necessarily applicable at the state level because each type of drought has different indicators that are selected according to the interests of state institutions. Rising temperatures and reduced river flow may, for example, affect fisheries, causing a hydrological and ecological drought; however, this may not necessarily affect farmers' crop irrigation, so the same period will not be considered an agricultural drought and farmers may thus not be interested in implementing conservation strategies. As another example, recharging the water of reservoirs with melting snowpack can prevent a hydrologic or agricultural drought while, in the same period, there may be a reduction in rainfall that calls for the declaring of a meteorological drought.

Figure 6. Drought map of United States.



Source: U.S. Drought Monitor (2023).

Each institution has different interests when it comes to identifying the dangers of drought and the actions called for. Whether an institution works with wildlife and fisheries, agriculture, or energy production determines which indicators of drought they evaluate and which solutions they propose. The institutions in charge of the operations of hydroelectric energy production, for example, are concerned with studying and taking actions concerning hydrological drought; their function does not involve researching and designing strategies for an agricultural drought. In the same way, the institutions in charge of agriculture are concerned that there is enough water for crops and not about what actions should be taken to address ecological drought. In short, the specific interests of an institution cause it to quantify the environment in a particular way, thus creating different indicators, data and risk scenarios.

The U.S. Drought Monitor (USDM) assembles heterogeneous data to compose a national picture of environmental conditions of the United States. This map is helpful for the federal government because it allows the identification of national climatic 'anomalies' to trigger disaster declarations and direct support from the Department of Agriculture. This representation, however, is produced at the cost of reducing the map's resolution at regional and local scales, what Edwards (2010) refers to as data friction. The same happens in statewide projections of water demand. The Utah Division of Water Resources (UDWRe, 2021) warns that state water projections cannot be used to identify local problems because their models lose accuracy at higher spatial resolutions.

Regional models are not necessarily a more realistic representation of environmental conditions than national ones. Local data in Utah does not automatically serve to map local conditions. For environmental data to be considered regional and valuable, it must be connected and compared in a logical regional framework. In this case, the State of Utah does not use the U.S. Drought Monitor; rather, it uses the Surface Water Supply Index (SWSI), which operates as an analytical tool for drought monitoring and the Drought Response Plan. The SWSI aggregates Utah's average streamflow and reservoir storage data to identify the region's water availability. The levels of this index trigger different state-coordinated responses. The first and second phases of the Drought Response Plan begin when specific SWSI indices change, but the third phase is activated only with the governor's Proclamation of a drought emergency (UDWRe, 2023) (Figure 7).

Figure 7. Surface Water Supply Index used in Utah

Feb 1, 2022 | Surface Water Supply Index (SWSI)

Basin or Region	Reservoir Storage[1] (KAF)[2]	Apr-July Forecast (KAF)[2]	Forecast + Storage (KAF)[2]	SWSI[3]	Percentile[4] (%)	Similar Years
Bear	546.0	110.0	656.0	-0.48	44	[1989, 2014]
Woodruff Narrows	12.8	105.0	117.8	-0.68	42	[1981, 2007]
Little Bear	10.7	30.0	40.7	0.4	55	[2008, 2016]
Ogden	32.2	71.0	103.2	-2.03	26	[1990, 2002]
Weber	93.6	210.0	303.6	-3.59	7	[2015, 2021]
Provo	756.9	80.0	836.9	-3.3	10	[2003, 2016]
Western Uintas	155.9	105.0	260.9	1.26	65	[2006, 2016]
Eastern Uintas	19.8	52.5	72.3	-2.62	19	[1990, 2004]
Blacks Fork	10.5	81.0	91.5	-0.62	43	[2006, 2018]
Smiths Fork	5.5	26.0	31.5	1.04	62	[1985, 1997]
Price	17.8	32.0	49.8	-1.65	30	[1989, 1994]
Joes Valley	21.5	41.0	62.5	-3.2	12	[2002, 2003]
Ferron Creek	3.7	28.0	31.7	-2.03	26	[1989, 1992]
Moab	1.0	4.0	5.0	0.69	58	[1991, 1996]
Upper Sevier	37.9	32.8	70.7	-2.81	16	[1990, 1992]
San Pitch	0.0	13.8	13.8	-2.23	23	[1990, 2003]
Lower Sevier	55.4	36.0	91.4	-3.2	12	[2016, 2021]
Beaver River	5.4	22.0	27.4	-1.26	35	[2001, 2014]
Virgin River	29.3	46.0	75.3	-0.13	48	[2008, 2016]

[1] End of Month Reservoir Storage; [2] KAF, Thousand Acre-Feet; [3] SWSI, Surface Water Supply Index; [4] Threshold for coloring: >75% Green, <25% Red

Source: National Water and Climate Center (NWCC, 2022). Note: KAF = 1000 acre-feet (approximately 1.2 million cubic metres).

The SWSI also has data friction since it applies only to homogeneous environmental conditions, being reliable only in mountainous regions that depend on snowmelt runoff. Neither temporal comparisons nor historical reconstructions of droughts can be made, because every time its inputs are transformed the entire index must be recalculated. It also does not consider evaporation and soil moisture. It is thus not helpful in identifying ecological and agricultural droughts. The UDWRe (2007: 6) recognises these problems as stemming from the fact that SWSI indices are,

> dependent upon frequency distributions for selected stream gages and reservoir storage facilities and thus must be recalculated when gages are discontinued, changed, new storage reservoirs are constructed, and after extreme events. As a result, it is difficult to maintain a long-term SWSI time series, and only about half of the Utah basins have a series that goes back further than 1980.

The SWSI's comparative limits create a fleeting and specific but practical understanding of Utah's water supply changes that serves to alert and protect the socio-economic interests of the state. It is not that drought is clearly perceived from the regional perspective and blurs at the national level, rather that different patterns are visible and obscured at each scale. In the case of the USDM, adding highly heterogeneous national data reduces its ability to match the data, and this data friction leads to local inaccuracies in the maps. On the other hand, the inability of the SWSI to compare its data with a more extensive data series limits its capacity for spatial and temporal comparison and for evaluating multiple characteristics of droughts.

Drought does not describe a universal or particular phenomenon in the world; it is the term for multiple intellectual, technical and political attempts to contextualise environmental hazards by grouping heterogeneous data and generalising its patterns. As evidence of this, using the SWSI for decision-making in Utah shows that the understanding of environmental changes is influenced by the infrastructure that states have in place. Hydrological drought in Utah is not simply a natural phenomenon; rather, its assessment depends on comparing changes in reservoir storage, which are influenced not only by climatic factors but also by technical decisions and regional policy on when and how much water to distribute in the Colorado River Basin.

At public debates on water management in Utah, journalists, activists and politicians tend to present drought maps as neutral representations of the environment. They ignore the fact that the categories of these graphs are not descriptive but rather are analytical categories that are configured by researchers in order to respond to the particular interests of institutions. In the case of the State of Utah, for example, hydrological drought is prioritised over ecological drought. Drought maps do not account for the world as it is; instead, they are perspectives that focus our attention on social concerns.

Methodological limits of rivers

The way the Colorado River is quantified is relevant for the LPP in two ways. First, the annual variability of the Virgin River, on which Washington County depends, is so high that scientists have not been able to establish what the impact of climate change might be. For this reason, the inferences and uncertainties about the Virgin River's future are linked to the general knowledge of the Colorado River; in this way, the Colorado River's measurements determine the viability of the LPP. Second, there are widespread disputes over the Colorado River's figures. The State of Utah says that while it currently uses 1.1 million acre-feet (Maf) (about 1.4 billion cubic metres), it has not used all of its river rights, so it could develop another 300,000 acre-feet (af), implying that the LPP can be built (Lake Powell Pipeline, 2022). Criticising this argument, the Utah Rivers Council (2021) argues that every year the Upper Basin states (Figure 1) use 500,000 af more water from the Colorado River than agreed upon in the region, if the historical reduction of its flow is considered. Fleck and Castle (2022), on the other hand, point out that these states are taking less than their total legal allocations.

Upper Basin states claim that it is more difficult for them to undertake water cuts because they depend on the variable flow of the Colorado River, which limits its use to the point where agriculture is forced to consume less water in dry years. According to Fleck et al. (2022), statistical data from the Bureau of Reclamation proves precisely the opposite, since the Upper Basin states consume much more water in dry seasons. Due to the data discrepancy in the basin, they argue that the challenge of having reliable information is due to the fact that,

> [t]he basin's water accounting is hampered by uncertainties and gaps in a number of areas, including accurate estimates of evaporation from some major reservoirs, volume of use of tributary water within the river's Lower Basin region, and questions concerning the methodology for estimating consumptive use (…). It should be noted that there are several different methods of calculating consumptive use of water and that the US Bureau of Reclamation's calculations, on which these numbers are based, are not uniformly accepted by the Colorado River Basin States (Fleck and Castle, 2022).

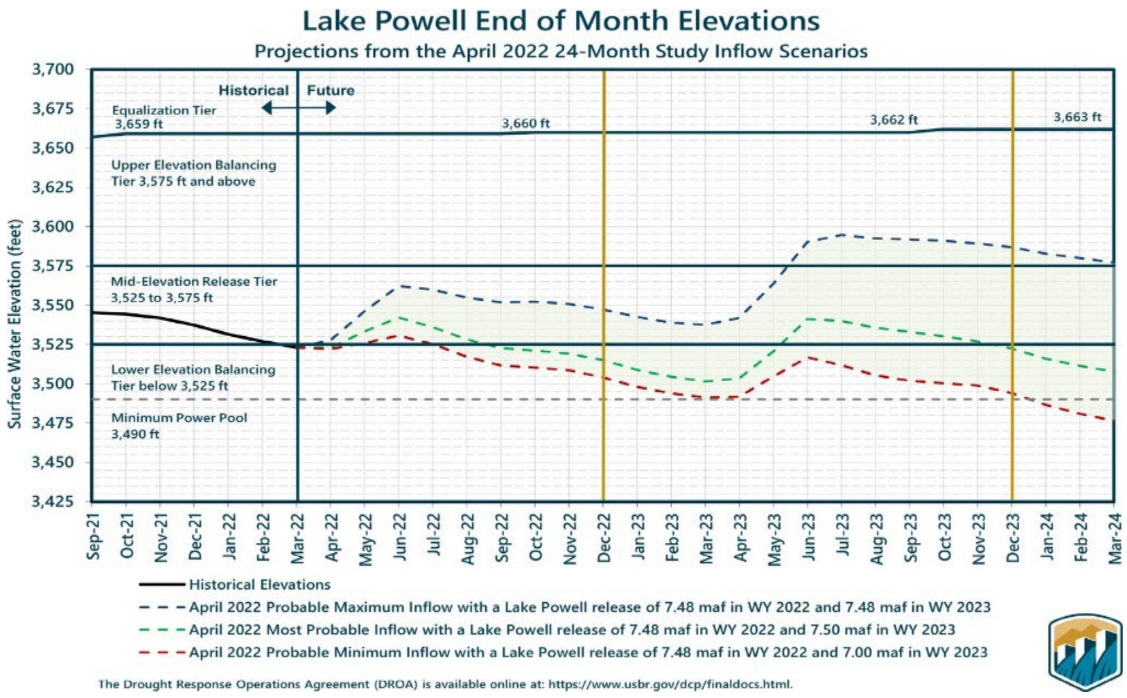
In the public comments on Utah's 2021 Water Resources Plan, the Utah Rivers Council argues that the UDWRe (2022), "is overestimating the Colorado River's annual flows by using the all-time average instead of the twenty-year average. This has led to the Division overestimating Utah's allocation of Colorado River Water". This environmental organisation contends that more water is being measured in the river, which wrongly justifies the construction of the LPP. To understand this polemic, we must ask: How much data is necessary to reconstruct and project a river flow – 18 years? 30 years? This question is important because the start and end time of the measurements changes the average river flow, affecting the water rights distribution in the basin.

The Colorado River Compact, developed in 1922, is the legal agreement between the basin states that manage the river; at that point, only 18 years of river flow measurements were considered. The technical decision to use only the last 18 years of data generated the impression that there was more water in the system than actually existed, because that period was an anomalous wet period in a long time series (Kuhn and Fleck, 2021). The current predictions of the river elevation at Lakes Powell and Mead by the

Bureau of Reclamation through the 24-monthly study scenarios (24MS) are made with data from 1991 to the present. This model projects the probable and most-probable maximum inflows of the river, as well as the probable minimum inflow (Figure 8). Scientists critique the use of data from the last decade of the 20th century, claiming that it should not be integrated into the projections of the Bureau because those years were abnormally wet and that data thus generates a bias in climate models that prevents understanding the rapid reduction of the river (Wang et al., 2022).

Although the first use of records from the river covers fewer years than the second (18 and more than 30, respectively), using short or long time series data can generate the idea that there is more water than is available in the system; this has the power to configure a particular sense of environmental control or risk for the basin states and the federal government. Due to global climate change, it is increasingly difficult to determine how many years of data are needed for climate reconstruction and projection. Scientists around the world are currently debating whether 30 years is a reliable sample because, every year, increasingly extreme weather events generate anomalous data peaks that transform historical averages, creating new controversies about what data should be selectively prioritised or excluded.

Figure 8. Projections of Lake Powell surface water elevation.



Source: Bureau of Reclamation (2022).

Due to the previous controversies about river measurements, we must ask what drives scientists to measure river flows over different time frames. Evaluating the input data of the Colorado River models is relevant because the results influence how the basin's dams are operated. Social expectations and institutional pressures affect the parameters of these models since the Bureau of Reclamation does not carry out projections of the river and its possible response actions outside the current policies. As it is put by Allhands (2022),

> Few major players like publicly talking about the possibility of little to no Colorado River water because they fear it will be perceived as a tacit embrace of that future, as if modeling for an 11 million acre-foot river (or less) means they're ready to throw out decades of water law and appropriations.

Scientific models have premises that are not always visible, such as the Water Supply and Demand for the Kanab/Virgin River Basin in Utah (Figure 2). The problem with the hydrological projections in Utah's Water Resources Plan (UDWRe, 2021) is that it assumes that the water consumed will increase proportionally to population growth. This is controversial for several reasons. Multiple social, economic and technological factors will inevitably transform the region's water demand and there is no way to predict them. Assuming exponential growth in water demand uncritically naturalises current water management. It takes the status quo for granted, thus avoiding a critical reflection on the structural causes of Utah's water supply problems. Water projections are also highly uncertain; in Figure 8, for example, the projected elevation of Lake Powell for the summer of 2023 was inaccurate due to severe winter weather in late 2022. Hydrological projections are intellectual exercises that can give indications to policy-makers but they cannot give final answers.

ANALYSIS OF EMPIRICAL FINDINGS

In Utah's controversies over alfalfa cultivation multiple metrics had been used to measure the water consumption of this crop, the reasons being that: (1) water does not have a single intrinsic value and there thus are various ways of using and quantifying it; (2) all metrics exclude information and are therefore incomplete; and (3) different premises and interests influence the production and interpretation of water-related data. In the same way that knowledge about water is profoundly influenced by the values of those who have an interest in it, the quantification of alfalfa's environmental impact and economic benefit is also highly subjective. The metrics used are influenced by social ideas about the legitimate use of water and, consequently, by different notions of scarcity and sustainability.

The controversy surrounding the use of water for crops and cities reveals that our way of thinking is based on a logical-moral framework. Comparative strategies justify moral judgments, and moral judgments, in turn, justify comparative strategies. Although the LPP controversies could be considered a case of cherry-picking the Tower of Babel of water data, it is much more complex than that. The selective search for data to legitimise a point of view is possible because the philosophical problem of incommensurability has no solution. Comparing is always an exercise in doubt due to the multiplicity of aspects that can be shared by two things or can differentiate between them. Agencies, scientists and activists, however, cannot get stuck in epistemological discussions; they must simplify reality in order to act. Stirling (2019b) argues that this is normal in everyday governance, but this simplification is usually hidden and its implications for decision-making are not usually discussed.

The LPP's controversies show that the legitimacy of comparisons depends on their logical consistency and on the institutional power that authorises them, since they serve communities with moral ideals and particular objectives. Within institutions, comparisons are disciplined to link data with particular interpretations, but this is not always possible. In science, each piece of data is obtained by a specialist community with a limited practical and political purpose. Contradictions in water data emerge when this data is used outside of its authorized context, thus leading to different interpretations. This happens with the water figures of Utah's crops and cities. Indeed, comparisons are valid depending on the context, but an analytical context can be delineated both scientifically and politically and so it will always be in dispute.

Social criteria guide the different strategies for measuring water scarcity, playing a role in identifying the various kinds of droughts. Values affect how we frame the environment, and in this way they influence what we can see. There is no way to have a total vision of the Colorado River's future; there are only partial points of view that are guided by political interests and scientific traditions. Scientific models have attached the ideas of responsibility, danger and benefit to the social world in which they were developed. Hydrological modelling is not affected only by scientific criteria, since institutions' economic and political calculations also influence its parameters. How the Colorado River's future is modelled, for example, depends on what kind of data is and is not considered, whether or not ecosystems' needs are considered relevant, and whether or not future tribal development water rights are included and quantified in the models. In this way, political agendas affect technical decisions.

Although the LPP controversy has historical particularities, it is not an isolated case; its dynamics reveal worldwide characteristics. Environmental conflicts consist of a struggle in which various actors seek to frame the spatial and temporal limits of a problem using scientific, political and economic criteria. This process is not neutral: in its analytical delimitation, causes are highlighted or omitted, a specific idea of risk is created, impacted populations are made visible or excluded, responsibilities are distributed, and a sense of urgency is established. How an environmental conflict is defined, "affects the way possible solutions are developed and appraised" (Kraft and Vig, 2019). In the case of Utah, activists, scientists and state officials used multiple ways of framing current water management practices and future threats; they do so by selecting different methods and data to criticise or legitimise responses to water supply problems, such as the construction of large infrastructure projects.

CONCLUSION

There is conflicting water data worldwide that generates political controversies and hinders decision-making in territorial planning. This research analysed the causes of this divergence based on the contradictory data that support and criticise the construction of the LPP. By considering water figures as epistemological questions, this paper contributes a new analytical strategy to the existing literature on the politics of water quantification.

In the LPP controversies, we find different epistemologies of water that exercise a selective influence over ways of knowing and quantifying water. To support this argument, I first described the influence of social interest in the selection of metrics to quantify alfalfa water consumption; second, I characterised the debates around comparing cities' water use; third, I analysed the problems of perspective in identifying droughts; and, finally, I identified the controversies in the historical delimitation of the Colorado River's water flow.

These four cases illustrate that there is no data that is perfectly objective, comparable and non-contested. Academics tend to be aware that primary data collection and reporting are socially shaped; however, they tend not to acknowledge this publicly in order to avoid public misunderstandings of the situation and fuelling scientific skepticism. Politicians, journalists and activists tend to recognise that data is socially shaped only in order to criticise their opponents' justifications; they do not always recognise this quality in their own figures.

Why, how, and by whom data is defined, monitored, reported, selected, compiled, modelled, interpreted and used influences the production of results. The LPP controversies show that there are judgment calls to be made in producing water data since someone, guided by their scientific traditions, political positions and institutional guidelines, must decide what aspect they are trying to identify (water consumption, future river flows, etc); they must also decide what is the goal (economic growth, water conservation, etc) and what is the proper metric, comparative strategy (internal or external), and scale of analysis (where and when).

Although activists and policy leaders hope that data can solve disputes, more water data does not always unify conclusions and solve environmental conflicts because results can take different directions if actors have different interests and assumptions that influence their bodies of evidence. For this reason, controversies cannot be simplified just to the rational debate over the 'correct' metric, comparison, map or model. Each methodological strategy for quantifying water has political implications that obscure assumptions, and goals that are tied to numbers. This research highlights that a particular range of perceptions is generated by the use of a particular metric, the choice of a comparative strategy, the selection of an analytical perspective, and the delimiting of a time frame to quantify water. These perceptions create a specific sense of risk and ownership that gives value and legitimises and criticises the uses of water.

Due to the divergence in water data surrounding the LPP, we can ask: Wouldn't it be better if there was a common way to value, compare, frame and delimit water throughout the country and the world? Could a unified way of quantifying water definitively resolve the controversies over the LPP? Activists and policy leaders promote the idea that better data is the way to end conflict. This is partially true because, globally, adequate data can facilitate governments' coordinated response to environmental conflicts and climate events. Standardisation is nevertheless always incomplete for practical and political reasons.

People are unlikely to measure water similarly since different mandates from state and federal agencies affect water data collection and interpretation, as well as communication of results. Each agency produces different data because it has different interests, scientific questions, technological capabilities, and funding possibilities. The diversity of methods and water data is not entirely due to political reasons but because, for example, institutions have different periods in which to carry out their research and may only be interested in particular aspects of water based on their guidelines. The data from the agencies in charge of water quality, agriculture, water rights, fisheries, wildlife, etc. are not always aligned, not because they are biased but because they respond to different institutional imperatives.

Standardisation is a way to achieve a monopoly over scientific authority (Vera, 2015) and is an act of territorial control (Schlaudt and Huber, 2015). In the case of the United States, due to its federal political structure, no central agency defines and monitors national standards. There are thus different ways of quantifying water, as observed in the LPP's controversies. By measuring water for their own purposes, activists, institutions and states struggle to attain the political and scientific authority to know and administer a territory. Total standardisation of water data is impossible because metrics are about power, identity and social creativity; that is, they are about the ability to make and justify decisions autonomously, delimit a territory and community of interest, and imagine the world's limits in their own particular way.

Finally, studying the disputes in water quantification related to the LPP allows us to ask an essential question: How do agencies and activists deal with the divergence of water data? Reflections on the political uses of ignorance challenge the idea that power is based only on knowledge (Anand, 2015; Graeber, 2015; Mathews, 2005). Extending these ideas makes it possible to consider that interest groups do not necessarily avoid uncertainties about water data. Politicians, water authorities, scientists and activists know they cannot have an entirely objective knowledge of water use and future projections. Collective uncertainty is thus the terrain in which they all fight to influence public opinion. In this competition, decision-making authority is obtained by acting with conviction and overlooking comparative and scale problems. Actors simplify or omit the epistemological limits and political factors in water measuring in order to present their figures as neutral for greater communication clarity and to speed political stance-making.

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