National Aeronautics and
Space Administration

Cross-Basin Assessment

NASA Western Water Action Office

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Introduction and Key Findings

The climate in much of the Western U.S. presents substantial water-related challenges for building and sustaining a thriving society and economy. Water is often scarce, and the "when and where" of water availability rarely coincides conveniently with the "when and where" of water needs. While the elaborate water storage and transport infrastructure developed in the West has enabled many to thrive, a shifting climate, increased population and demands, and concern for ecosystem resilience continue to compound water challenges.

Increased knowledge alone will not solve the West's water challenges, but better informed water decision making has the potential to meaningfully improve the lives of the millions of people who call this corner of Earth home, the millions more who are likely to move to the West in the future, and the millions more who rely on its exports. Satellite remote sensing in particular offers a unique vantage point to better understand and plan for the West's water challenges at scales from farm fields to major river basins.

To bridge the potential gap between Earth observation scientists and water decision makers in the Western U.S., NASA's Western Water Action Office (WWAO) works to understand decision makers' needs, maintains a pulse on the latest innovative water-related science, facilitates the coproduction of innovative solutions, and helps to scale those solutions for the greatest possible impact.

Since 2016, WWAO has conducted six Basin-based needs assessments, including one California-focused rapid needs assessment conducted through a literature review. These assessments have generally shared three common elements: a basin characterization study, identifying issues and key water managers in a basin; a multi-day engagement with water decision makers in a basin with a shared goal of identifying use cases for Earth observation support of water decision-making; and a concluding report. The information collected is then used to inform WWAO's decision-making on funding projects with some connection to the use cases.

Having engaged with decision makers across the Western contiguous U.S. through these formal needs assessments and ongoing relationship building and networking, WWAO is now drawing together its individual needs assessment findings to highlight pressing needs across these basins. This work is intended to inform WWAO's own strategic planning as it pursues a new alignment of its resources to create impact under NASA's Earth Science to Action (ES2A) framework, while also serving as a guidepost for participants in all stages of the Earth observation value chain.

Overview of Findings

This assessment considers the results of the six basin assessments in a few different lights. While the amount and nature of the data collected in each of the assessments varied, a methodology was created to query shared characteristics, such as impacted WWAO focus area, state relevance, focus on water cycle pool and flux, and focus on water characteristic and water use. The analysis also considered information provided by WWAO regarding the projects funded in response to the basin assessments.

In order to answer a more difficult question from the data – which use cases span across multiple basins – a cluster analysis was completed to connect use case topic areas by subject matter. These clusters help demonstrate which areas were discussed across the assessments even if the format of the assessments changed or the use cases themselves didn't match up precisely.

The conclusions from this Cross Basin Assessment are varied, and it is likely readers, with different histories and roles in the assessment will interpret the data from their own vantage point – and we hope they do. As we attempt to connect the results of this assessment to other work ongoing with the Western Water Action Office, a few things stand out:

- **Geography.** At least across the Western US, geography does not appear to be a major limiting factor for use cases, especially when considered as clusters. We state in our findings that use case characteristics are *surprisingly evenly distributed* across geographies. Perhaps this shouldn't be a surprise? The relationship between snow, runoff timing, and subsequent water management challenges, for example, is not unique to the Missouri or the Columbia basins. For WWAO's purpose, this suggests the limiting factor is the relationships and trust it takes to launch a scaled product - even across basins - rather than launching a bespoke project for a single basin that can't be applied to more than one basin.

- **No Obvious Winner.** There is no one "cross-basin use case" to rule them all. While certain patterns have emerged across the use case characteristics and clusters, the analysis did not reveal one (or more) obvious cross-basin use cases ripe for immediate scaled implementation. If anything, it revealed that most use cases belong in a group/cluster of related cases, and that together they suggest an ongoing need for continued engagement and collaboration with end users to work out what about them is solvable and scalable.
- **AI/Industry/Manufacturing?** Considering takeaways from ongoing, related analysis of WWAO's work and engagement with end users, a consistent under-representation of private sector organizations (though this changed towards the end of the study period) could have overemphasized present needs in water management. This leap in logic stems in part from our companion study highlighting that emerging uses in manufacturing/industry are on the front of mind for private enterprise. Why did these uses hardly move the needle among the needs assessment audiences? Is it the audience selection? The innovation/culture of manufacturing catching up with the water industry? A question of water source and water use scale that isn't yet threatening the dominant user across the West (irrigation for agriculture, 80% of all uses)?
- **Missing Groundwater.** When we compared the use case clusters to descriptions of WWAO's projects, the project selection fell across the spectrum of clusters: snow, precipitation, runoff and streamflow, etc. The notable exception was groundwater. The two groundwater clusters (representing 15 of the 108 use cases) were not addressed by WWAO's projects. This is worth further investigation. Of the two other unaddressed clusters - both single use case clusters – a "NASA Water Related Data Portal" is compelling (and has been brought up in other forums). "Improved Reservoir Yield Estimates, " from A/W/R, may be worth pursuing as well, and is probably more universal than its initial clustering implies.

We suggest that readers of the Cross-Basin Assessment understand the work as an independent review of the patterns, opportunities, and operative differences in WWAO's basin assessment program up to this point. But it is also meant to be read in conjunction with other work underway to understand WWAO's relationship with other NASA programs (*Preliminary Stakeholder Report)*, the rapidly developing Western water and Earth observation markets (*Market Assessment)*, and the analysis of WWAO and other federal *Research to Operations* practices that can help inform future work (*Impact & Transition Report)*. These four pieces of analysis, taken in conjunction with WWAO's 2024 strategic communications analysis and recommendations, provide a broad basis to make a new strategic plan of action for this critical program at a critical time.

WWAO's Basin Needs Assessment Methodology

Overview

WWAO conducted their literature-review-based Rapid Needs Assessment in 2016, and as of December 2024, WWAO has conducted five basin-specific needs assessments focused on the following USGS water resource regions: the Upper and Lower Colorado (one assessment), the Pacific Northwest, the Rio Grande, the Missouri, and the Arkansas-White-Red. All assessments but the Rapid Needs Assessment were supported by consultant partners. Each needs assessment consisted of:

1. Preparatory efforts (desktop research, a survey, and/or a series of discussions with key stakeholders) to inform WWAO's preliminary understanding of relevant water availability, use, and challenges
2. A workshop at which use cases were developed by stakeholder participants supported by NASA subject matter experts and NASA internal or external facilitators

Consultant partners and pre-workshop efforts associated with each assessment are listed in Table 1.

The 2016 Rapid Needs Assessment was initially authored by WWAO staff and drew on "published assessments, journal articles, white papers, congressional reports, workshop reports, and an informal survey of western water managers". A series of broad management needs within specific conceptual categories were articulated along with associated information needs, potential stakeholders, and timeframes. Draft needs were then refined through a review workshop involving Western water experts from federal and state agencies, academia, and nonprofits (Table 2.

For the basin-specific needs assessments, WWAO used its preparatory efforts as the basis for workshop participant recruitment and proposal of potential topic areas for exploration during the following workshop. Workshop participants were recruited based on their active roles and interests in water management in each particular basin. Represented sectors are indicated in Table 2.

Table 1. WWAO's needs assessment consultant partners and preparatory efforts.

Year	Basin	Consultant Partners	Preparatory Efforts
2016	N/A (Rapid Needs Assessment)	▪ None	▪ Desktop research
2018	Upper and Lower Colorado	▪ JPL A-Team ▪ Arcadis U.S., Inc.	▪ Survey
2021	Pacific Northwest	▪ SPF Water Engineering	▪ Desktop research ▪ 22 discussions
2022	Rio Grande	▪ Daniel B. Stephens & Associates, Inc.	▪ Survey ▪ 19 discussions ▪ Pre-workshop participant webinar

2023	Missouri	▪ SPF Water Engineering ▪ HDR, Inc.	▪ Desktop research ▪ Survey ▪ 22 discussions ▪ Pre-workshop participant webinar
2024	Arkansas-White-Red	▪ HDR, Inc. ▪ Aqua Strategies, Inc.	▪ Desktop research ▪ Survey ▪ 18 discussions ▪ Pre-workshop participant webinar

Table 2. WWAO needs assessment workshop locations and participant information.

Year	Basin	Workshop Location	Total Workshop Participants	Number of Workshop Participants by Sector

				Federal Agencies	***State Agencies***	***Local or Regional Agencies***	***Tribal Agencies***	***Academia***	***Non-profits***	***For-profits***
2016	N/A (Rapid Needs Assessment)	Pasadena, CA	11	5	2	0	0	2	2	0
2018	Upper and Lower Colorado	Not specified	14	1	2	5	0	3	3	0
2021	Pacific Northwest	Portland, OR	27	11	11	1	1	3	0	0
2022	Rio Grande	Virtual (due to Covid-19)	20	6	4	6	1	0	3	0
2023	Missouri	Omaha, NE	25	6	11	1	0	4	2	1
2024	Arkansas-White-Red	Oklahoma City, OK	24	2	7	0	6	4	3	2

WWAO invited participants to confirm or modify the proposed potential topic areas for the workshop, and participants were assigned to or chose which topic area they would focus on for the workshop. Topic area groups were thus formed, and with facilitation from WWAO staff and/or consultant partners, they developed one or more use cases associated with their topic area. A use case template was provided (see Figure A2-1 for a sample), and while the template has slightly evolved between workshops, it has generally captured information related to existing decision making contexts and workflows, present challenges, desired future states, and potential data or information requirements.

After the workshops, the consultant partners compiled use case information, drafted a report, invited feedback and further input from WWAO staff and workshop participants, and revised and finalized the report.

Assessment Differences and Related Challenges

While the general objectives of WWAO's needs assessments have not changed over time, their processes have varied slightly as WWAO has responded to external constraints and adapted based on ongoing learning. Notable shifts include alterations to the structure of preparatory work (Table 1), tweaks to use case templates, increased efforts to ensure consultant partners have relevant subject matter expertise, and the Covid-driven change to a remote workshop for the Rio Grande assessment. It is also possible that user needs could have substantially shifted between the 2016 Rapid Needs Assessment and the 2024 Arkansas-White-Red Assessment.

Past and present WWAO staff have noted that participant recruitment might have had a substantial influence on needs assessment findings. "Getting the right people in the room" is a significant challenge, and WWAO has not always achieved the ideal balance of perspectives it would desire (see Table 2). Even if WWAO succeeded in recruiting representatives from a representative cross-section of the relevant institutions or organizations, it was not always guaranteed that an organization's representative would be situated in the ideal branch and level of the organization to provide the most pertinent contributions at the workshop.

Note on Gaps in Conceptual and Geographic Coverage

WWAO's Rapid Needs Assessment stated that "a subsequent report will examine water quality and water infrastructure needs." This report was not provided to Metropolitan Group (MG), though these topics are certainly addressed in the basin-specific needs assessments.

WWAO's geographic focus is understood to include the U.S. states west of the 100th meridian, but WWAO has not conducted basin-specific needs assessments for all USGS water resource regions encompassing this land. Unaddressed basins include some fully west of the 100th meridian and within the contiguous U.S. (California and Great Basin, though Great Basin assessment planning in progress), fully west of the 100th meridian but outside of the contiguous U.S. (Alaska and Hawaii), and partially west of the 100th meridian and within the contiguous U.S. (Souris-Red-Rainy and Texas-Gulf). While WWAO has not conducted a dedicated basin-specific needs assessment in the California Water Resource Region to generate use cases, it has maintained ongoing engagements with key water stakeholders in the state to keep abreast of needs informally. No relevant Western states in the contiguous U.S. fall completely outside of WWAO's addressed basins, but the following states are at least partially contained within WWAO's unaddressed basins: California, Idaho, Louisiana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, and Wyoming.

Cross-Basin Assessment Methodology

Use Case Characterization

WWAO's basin needs assessment reports (publicly available on the WWAO website) served as a critical starting point for this cross-basin needs assessment, but with over a hundred use cases, slight variations in use case templates, and inconsistent group practices in filling out template content, a common framework was needed to facilitate analysis across all use cases. To that end, in collaboration with the WWAO team, MG developed a common use case characterization framework. Key variables within that framework are summarized in Table 3.

As original use case descriptions often lacked sufficient detail to make unequivocal binary judgements about the relevance of a use case to a given topic, we generally opted for ordinal characterizations of relevance that we applied after reading the use case descriptions in detail (e.g., not likely relevant, possibly relevant, likely relevant, or clearly relevant). Two variable categories employed were water cycle *pool* and *flux* foci. In this context we used "pool" to refer to generalized places where water exists (e.g., groundwater, lakes, and ice and snow) and "flux" to refer to the processes of water moving within or between pools (e.g., precipitation, streamflow, and groundwater withdrawal). To avoid downplaying likely relevant water cycle pools and fluxes, we flagged possible relevance due to adjacency in the water cycle even if a specific pool or flux was not explicitly mentioned (e.g., if groundwater was explicitly mentioned, we assigned "possibly relevant due to adjacency in the water cycle" to groundwater withdrawal). The WWAO focus area relevance variable category refers to the six "focus areas" that WWAO has been using in much of their recent analysis and planning efforts.

Table 3. Key use case characterization variables and levels.

Variable Category	Variables	Possible Labels
USGS water resource region relevance	USGS water resource regions 9 through 20	Unknown, developed to be generically relevant [from the Rapid Needs Assessment], or explicitly relevant
State relevance	All U.S. states at least partially west of the 100th meridian	Unknown, possibly relevant due to workshop geography, implicitly relevant, or explicitly relevant
WWAO focus area relevance	Water availability, water use, water quality, water infrastructure, extreme events, and watershed health	Not likely relevant, possibly relevant, likely relevant, or clearly relevant
Water cycle pool foci	Groundwater, soil moisture, terrestrial vegetation, rivers and streams, canals, lakes and ponds, reservoirs, wetlands, ice and snow, coastal waters, and atmospheric water	Not likely relevant, possibly relevant due to adjacency in the water cycle, or clearly relevant
Water cycle flux foci	Infiltration, groundwater withdrawal, groundwater-surface water exchange, terrestrial vegetation uptake, evapotranspiration, precipitation, irrigation, snowmelt, runoff, streamflow	Not likely relevant, possibly relevant due to adjacency in the water cycle, or clearly relevant
Water characteristic foci	Extent, depth or elevation, volume, flow rate, composition, temperature	Unknown, not likely relevant, or relevant

Water use foci	Non-human, municipal, domestic, agricultural, resource extraction, industrial, hydropower, non-hydropower utilities, water transport, water storage, recreation, emergency management, navigation, and waste management and water treatment	Not likely relevant, possibly relevant, likely relevant, or clearly relevant

WWAO Project Characterization

WWAO provided a list of their funded projects to enable evaluation of a) the progress in addressing use cases that WWAO has facilitated and b) identification and characterization of use cases remaining to be addressed. MG worked with WWAO staff to augment this project list with funding amounts, information on geographies addressed (basins and states), application readiness level (ARL) progress information (where known or estimated), and explicit linkages between individual projects and the use case(s) they address.

Use Case Analysis

To examine how use cases were distributed in terms of relevance to the individual variables listed in Table 3, we created stacked bar graphs showing the numbers of use cases and their varying degrees of relevance to the above variables.

Given WWAO's particular interest in the geographic universality or specificity of use case characteristics, we also generated maps showing the percentages of use cases relevant to both a given variable and a particular basin or state out of all the use cases relevant to that basin or state. Basins not directly assessed by WWAO are overlaid with a diamond pattern, and colors for those basins are related to content from the Rapid Needs Assessment and any incidental mentions of those basins in use cases from other basin assessments.

Cluster analysis

While the above analyses facilitated comparisons of the overall and geographically specific prevalence of individual use case characteristics, they did not consider the use cases holistically (i.e., they only considered one variable at a time), and they did not flag similarities between use cases from different assessments. To address these gaps and facilitate strategic planning around such a large number of use cases, we developed *clusters of use cases* based on all 41 variables in Table 3 other than USGS water resource region relevance and state relevance (including water cycle pool foci, water cycle flux foci, water characteristic foci, and water use foci variables). Ordinal and binary variables were converted to numeric (i.e., yes and no became 1 and 0, and not likely relevant, possibly relevant, likely relevant, or clearly relevant became 0, 1, 2, and 3).

Based on these numeric forms of the variables, we computed a Manhattan distance matrix which yielded a multidimensional distance between each pair of use cases determined by the sum of the absolute differences between the use cases for each variable. As a simplified hypothetical example with only three variables: if a Use Case A registered 1 for variable X, 1 for variable Y, and 0 for variable Z, and a Use Case B registered 0 for variable X, 1 for variable Y, and 3 for variable Z, the Manhattan distance between the two use cases would be 4 (1 plus 0 plus 3).

Based on this distance matrix we then performed UPGMA (unweighted pair group method with arithmetic mean) clustering, a form of hierarchical agglomerative clustering that progressively lumped use cases together based on their multidimensional similarity. This clustering resulted in a dendrogram or tree diagram showing how closely related the use cases were. The dendrogram was then pruned to 10 branches or clusters, each containing one or more use cases, and based on the use case names within each cluster, we assigned a descriptive name to each cluster.

WWAO Project Analysis

We mapped the geographies addressed by WWAO projects based on project-specific relevance to USGS water resource regions and states. To describe the topical focus of each project, we assumed that the project was related to all topics relevant to the use cases that inspired the project. Based on that information, we produced bar graphs showing the numbers and percentages of use cases related to the above variables that have been at least partially addressed by WWAO projects.

Findings from WWAO's Needs Assessments

Use Case Counts and Workshop Topic Areas

WWAO has collected 108 use cases through its needs assessments with per-assessment use case counts ranging from 12 to 26 (Table 4). Concept areas varied across workshops, but grouping workshop-specific concept areas into higher-level categories reveals that some concepts have been consistent areas of emphasis ("water supply and availability" and "agriculture and irrigation"), some have been directly addressed more sporadically ("climate and extremes" and "groundwater"), and others have received increased direct attention in more recent assessments ("water quality," "watershed health," "infrastructure," and "surface water"). All use cases are listed in Table A3-1.

Table 4. Use case counts and concept areas addressed by USGS water resource region.

Basin Assessment	Number of Use Cases Generated	Concept Areas Addressed
N/A (Rapid Needs Assessment)	22	▪ Snow, watersheds, and runoff forecasting ▪ Monitoring groundwater and subsidence ▪ Sub-seasonal to seasonal (S2S) precipitation forecasting

		▪ Soil moisture ▪ Evapotranspiration
Upper and Lower Colorado	13	▪ Snow properties and processes; water-supply forecasts (less than one year) ▪ Evapotranspiration (ET) over land and water; crops and agriculture properties and processes; irrigation type and method ▪ Extreme event prediction and impact; water-supply forecasts (24-plus months); groundwater characterization
Pacific Northwest	14	▪ Agriculture ▪ Water quality ▪ Water supply ▪ Watershed health
Rio Grande	12	▪ Water supply monitoring and forecasting

		▪ Water use and management/agriculture ▪ Climate and extremes ▪ Watershed health and water quality
Missouri	21	▪ Watershed health and management ▪ Water availability ▪ Agriculture and irrigation ▪ Water quality ▪ Water infrastructure
Arkansas-White-Red	26	▪ Watershed health ▪ Groundwater ▪ Surface water ▪ Agriculture, land use, and water quality

		▪ Water infrastructure ▪ Hydroclimate extremes

West-Wide Use Case Characteristics

WWAO has historically employed six focus areas to guide their strategic thinking and communications: water availability, water use, water quality, water infrastructure, extreme events, and watershed health. Use case relevance was distributed fairly evenly across these focus areas (Figure 1).

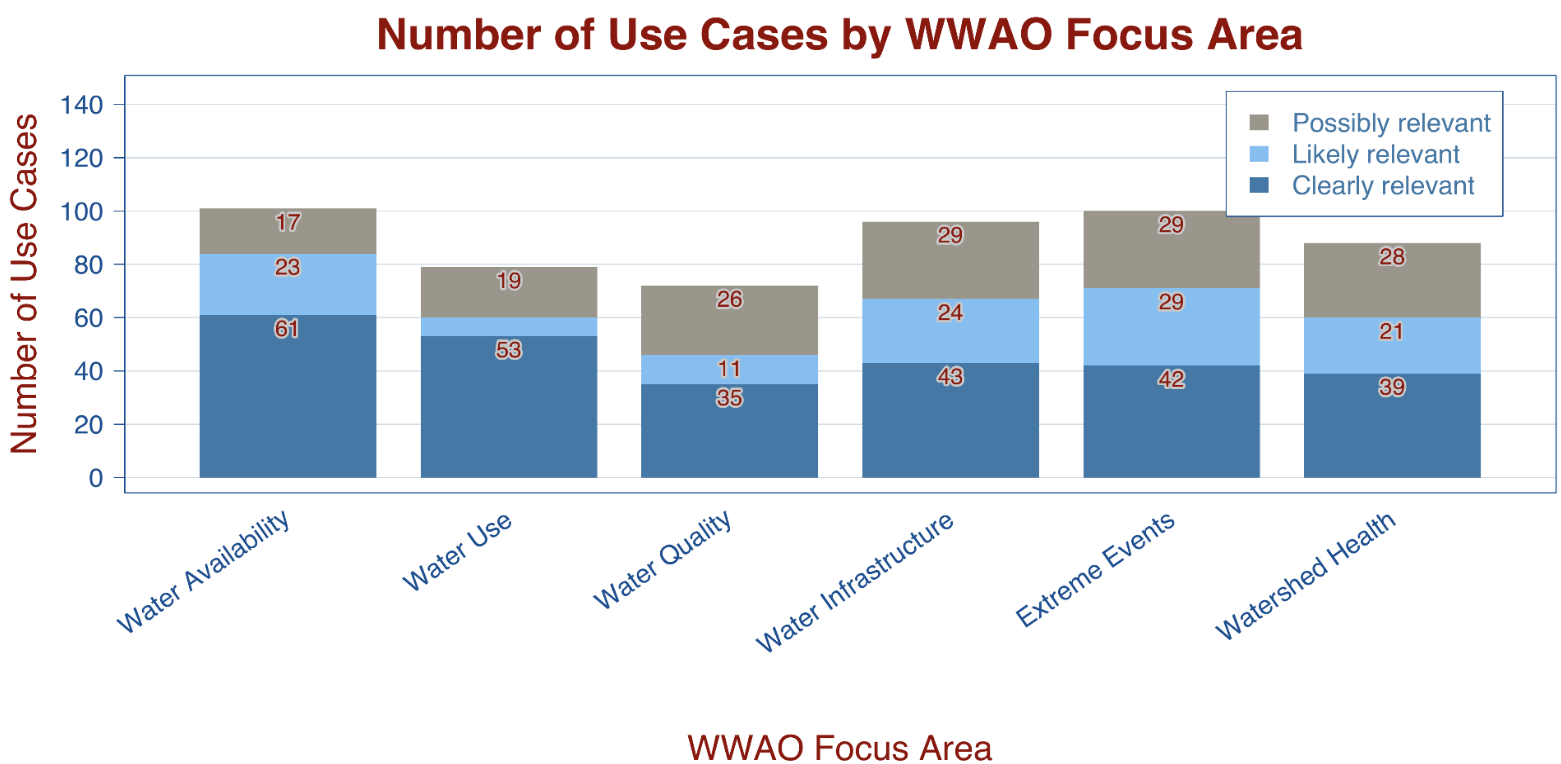

Figure 1. Numbers of WWAO-documented use cases related to WWAO's established focus areas.

All pools of the water cycle have received at least some attention in use cases, though some stand out as strong areas of emphasis (terrestrial vegetation, rivers and streams, and reservoirs), while others have received little direct attention (coastal waters and atmospheric water; Figure 2).

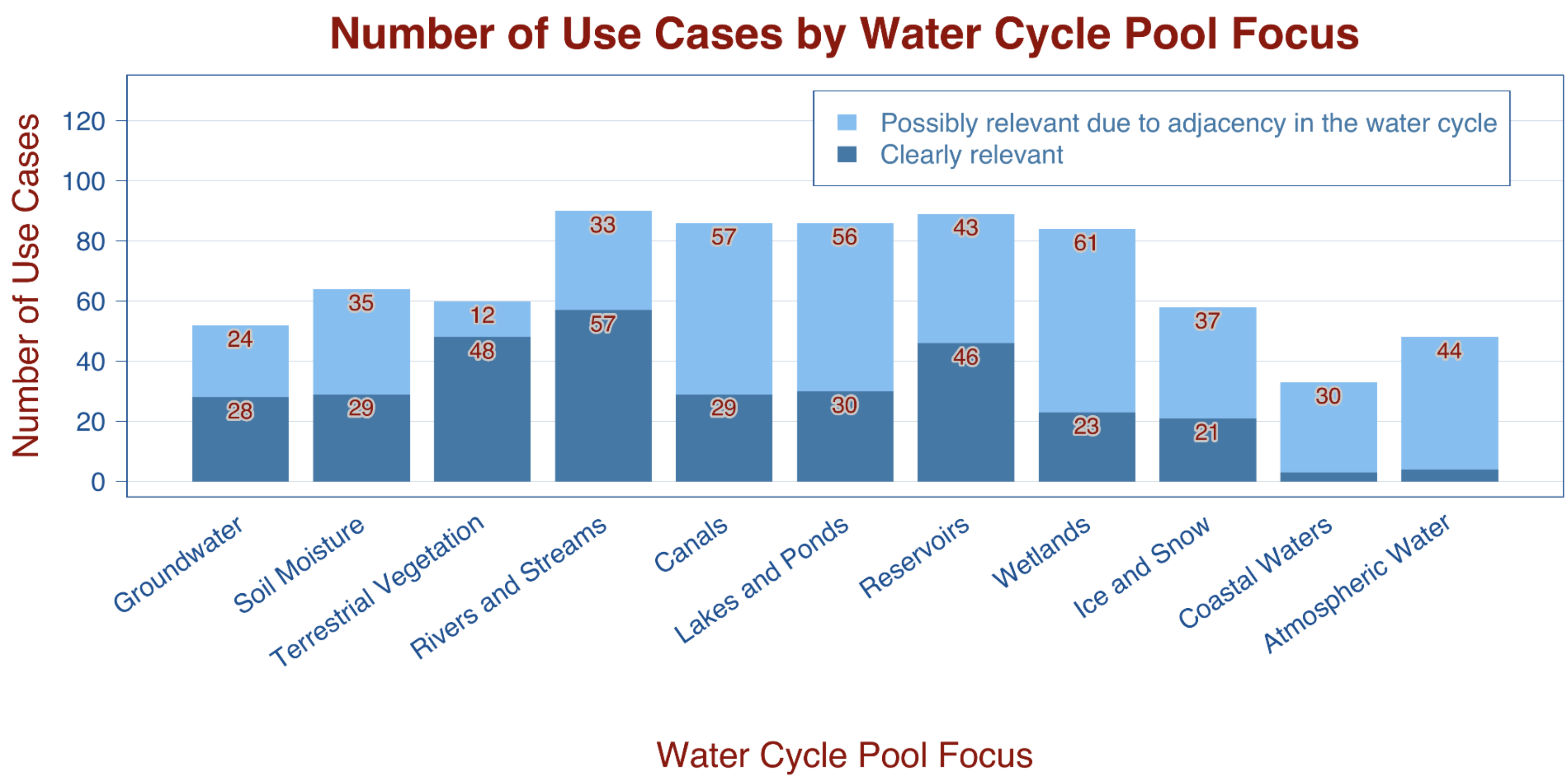

Figure 2. Numbers of WWAO-documented use cases related to distinct pools of the water cycle.

Similarly, all fluxes of the water cycle received at least some attention (Figure 3). Evapotranspiration, precipitation, irrigation, and streamflow were clearly relevant to the most use cases. Interestingly, while groundwater-surface water exchange and terrestrial vegetation uptake were not often clearly relevant, they were often adjacent to pools that were clearly relevant.

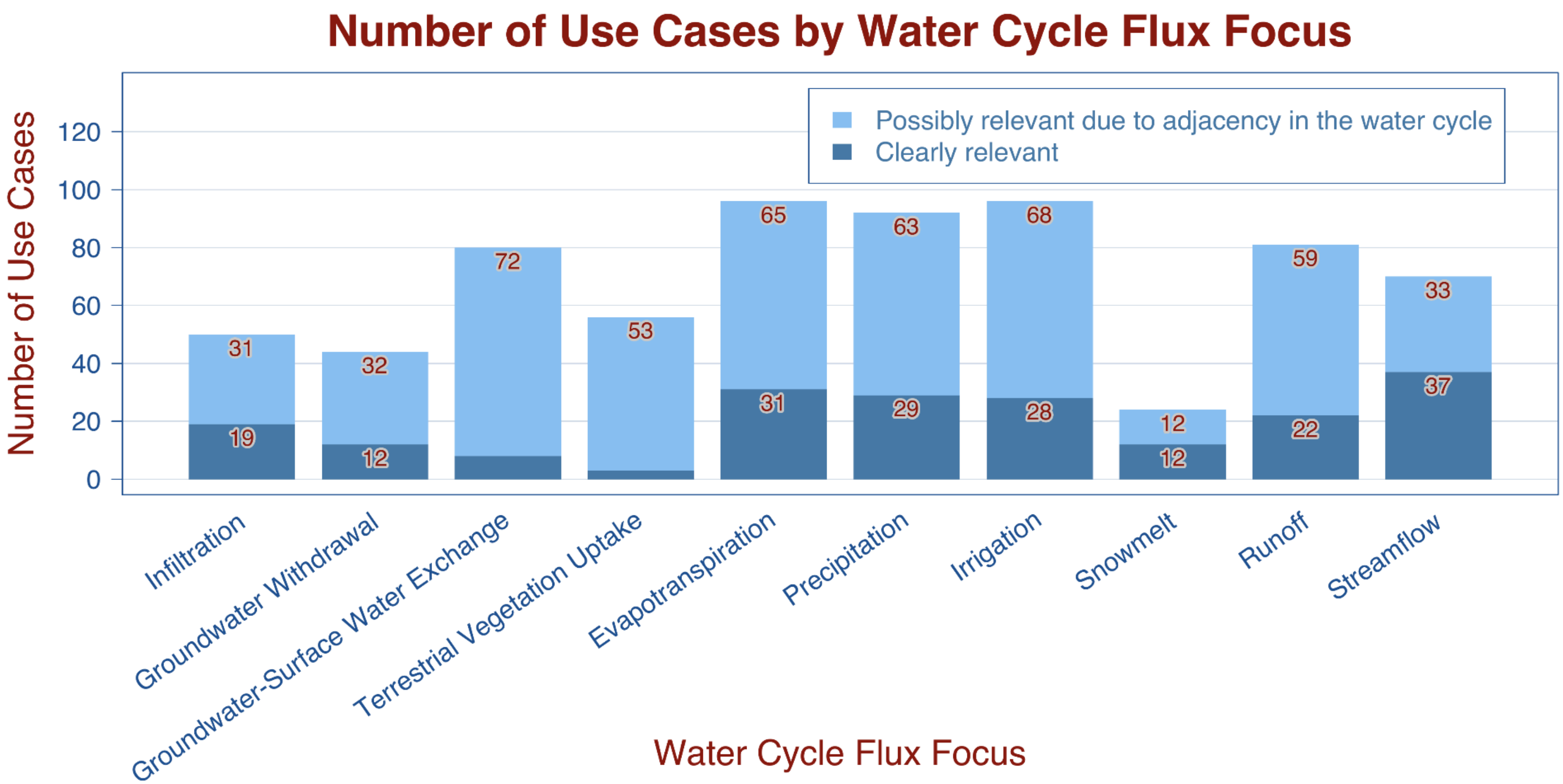

Figure 3. Numbers of WWAO-documented use cases related to distinct fluxes of the water cycle.

Water volume and flow rate were the two water characteristics that were relevant to the most use cases, while extent, composition, and depth or elevation were moderately represented, and temperature received much less attention (Figure 4). In more general terms, use cases focused on water quantity more than quality.

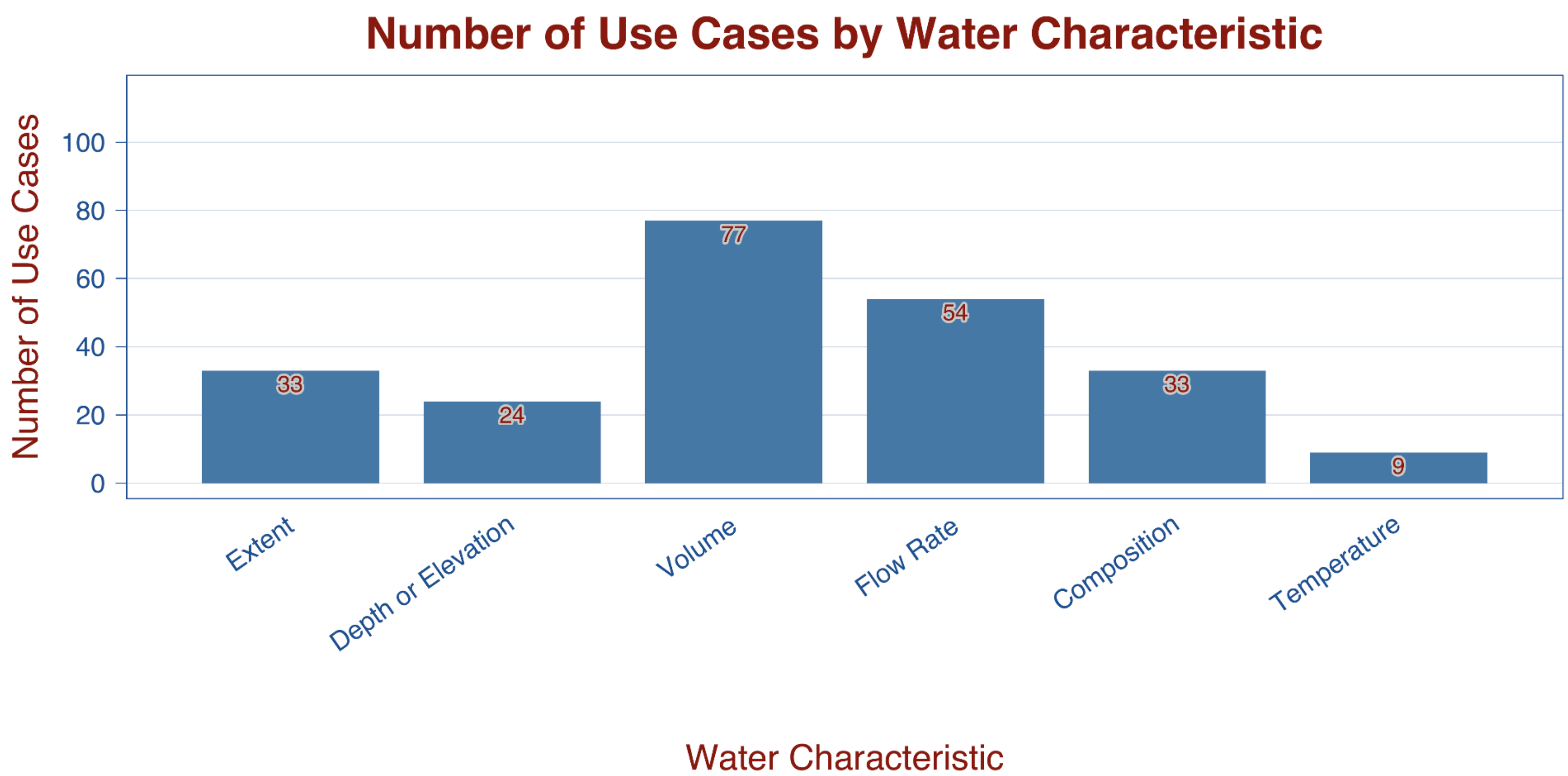

Figure 4. Numbers of WWAO-documented use cases related to measuring distinct characteristics of water.

In terms of water use foci, non-human, municipal, agricultural, hydropower, water storage, and emergency management uses had the most clearly relevant use cases (Figure 5). Domestic use and navigation were much less likely to be at least possibly relevant to use cases than all other use categories.

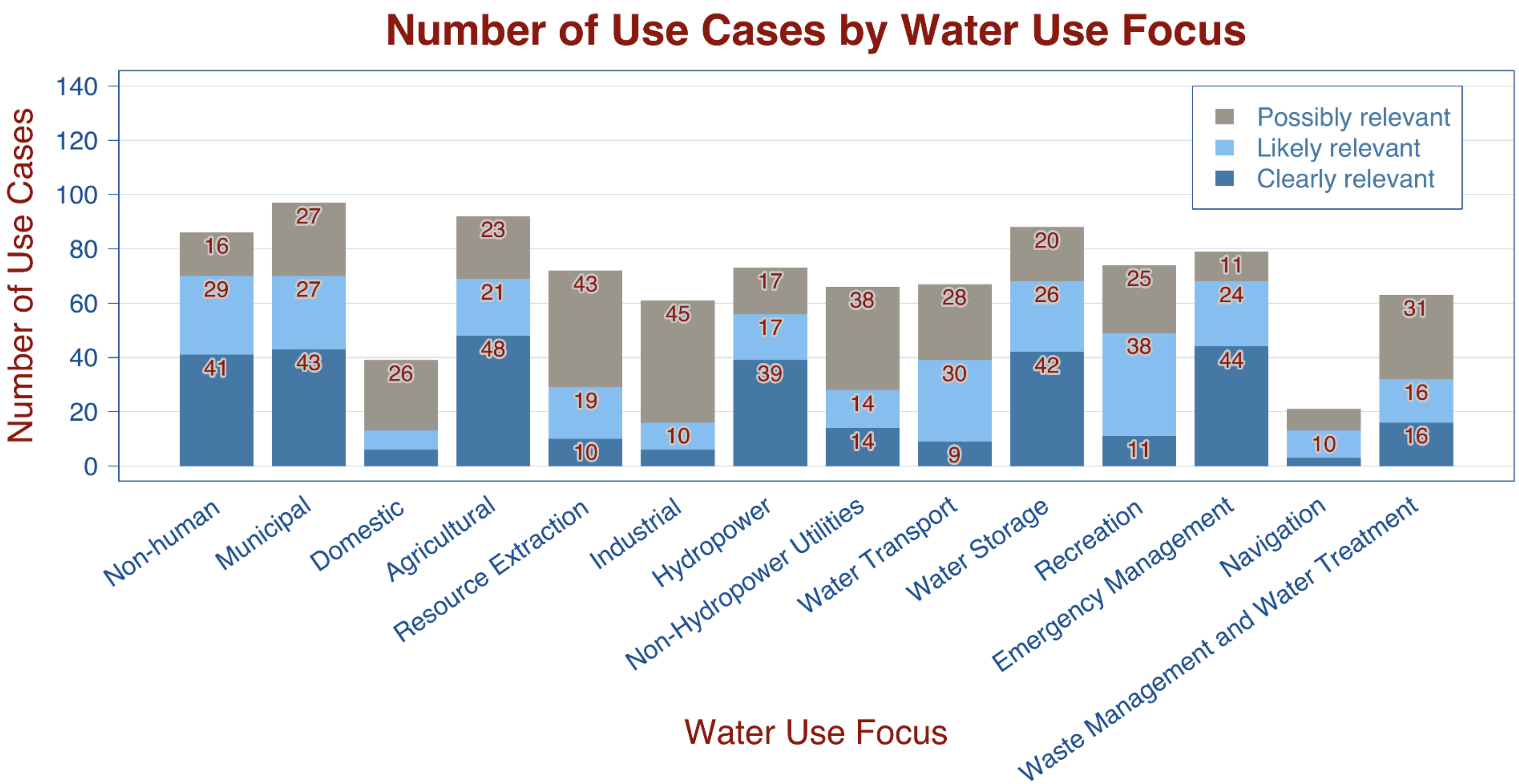

Figure 5. Numbers of WWAO-documented use cases related to distinct types of water use.

Additional Notable Themes

While not always expressed in quantitative terms or captured consistently, calls for higher-resolution data, both spatially and temporally, were present in many use cases. That said, it is prudent to assess whether resources at an appropriate or workable resolution already exist for the suggested use cases.

Use Case Characteristics by Geography

Examining the above variables when segmented by USGS water resource regions and states revealed that inter-variable differences in use case relevance generally outweigh geographic differences (Figures 6 through 10 and A4-1 through A4-7). The West-wide findings described above have relatively little variation by basin or state.

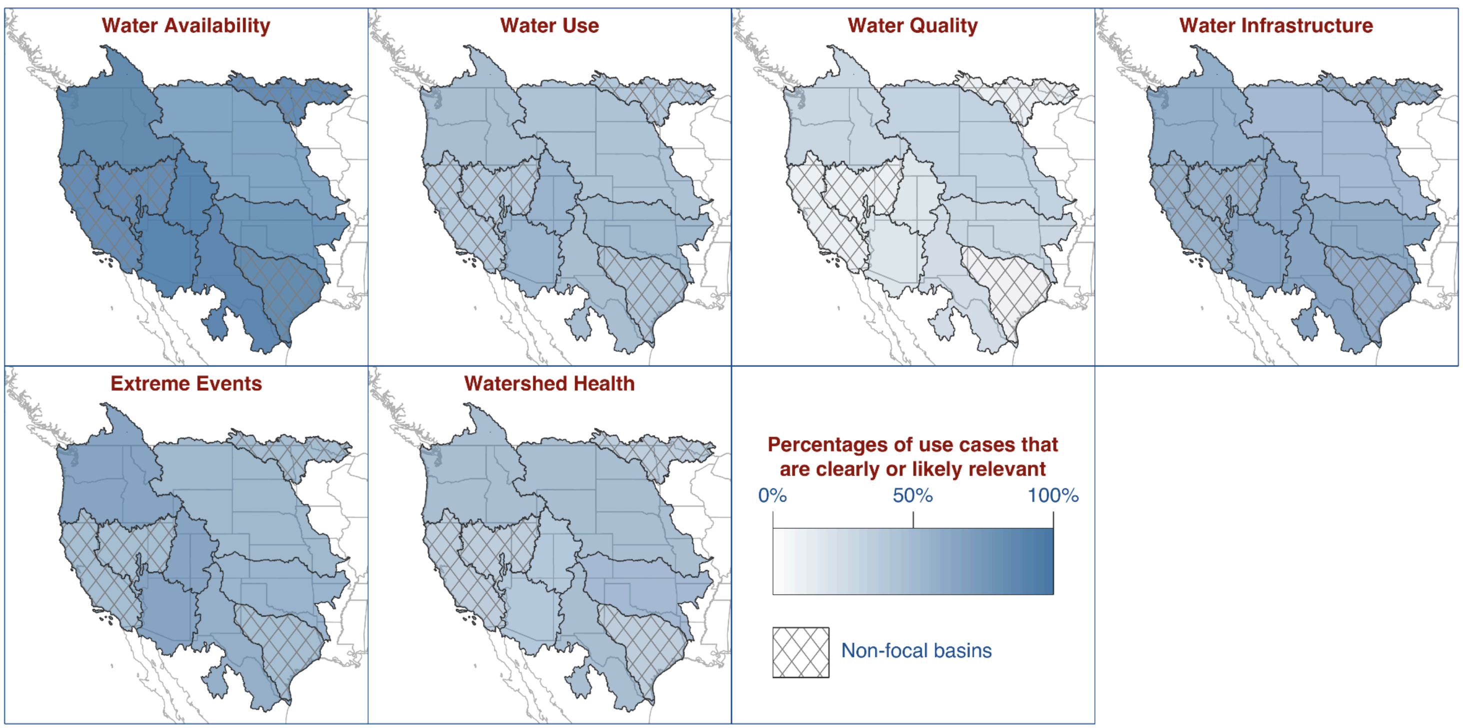

Figure 6. Percentages of WWAO-documented use cases related to WWAO focus areas segmented by use case relevance to Contiguous Western U.S. USGS water resource regions.

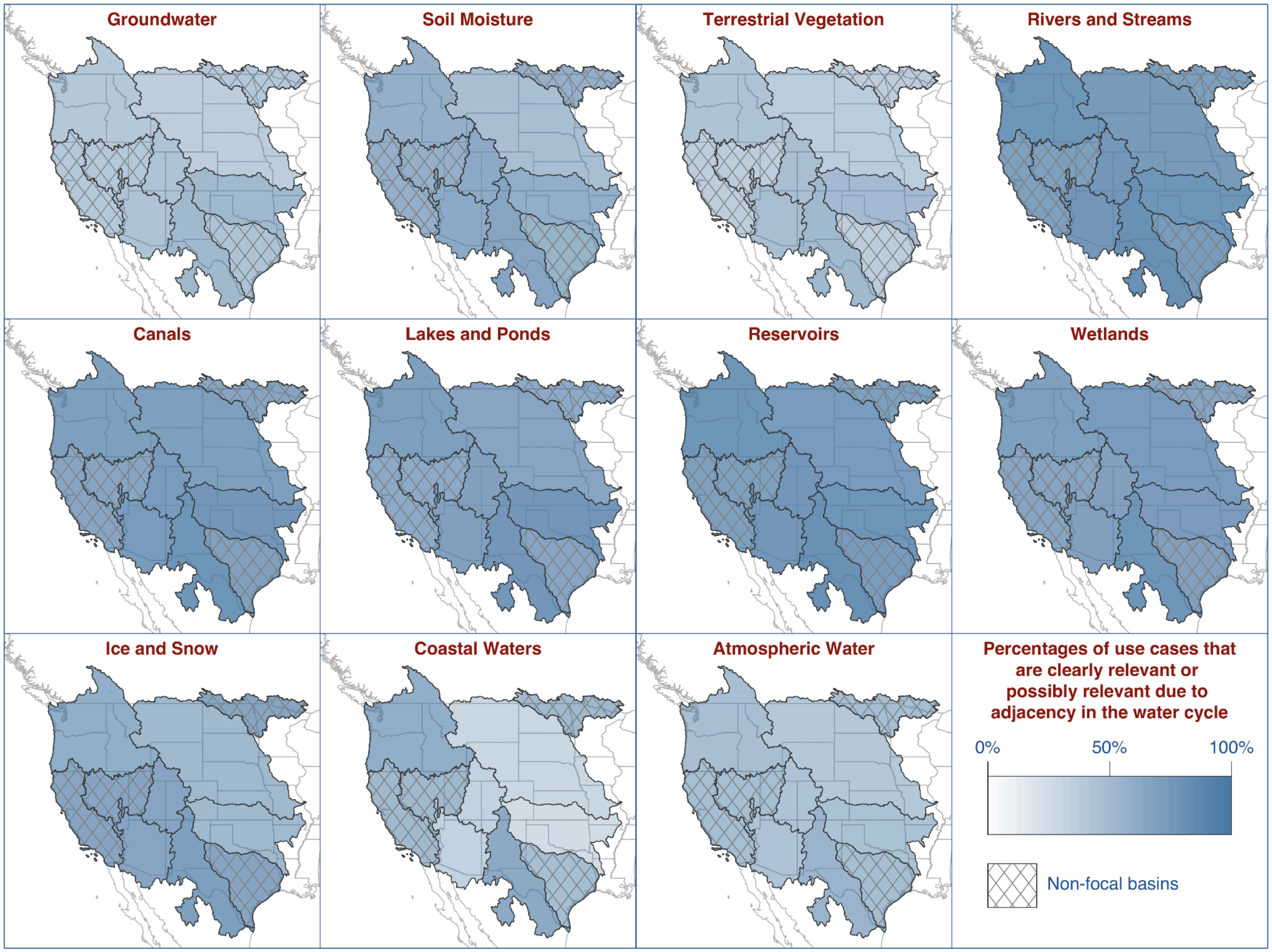
Groundwater
Soil Moisture
Terrestrial Vegetation
Rivers and Streams
Canals
Lakes and Ponds
Reservoirs
Wetlands
Ice and Snow
Coastal Waters
Atmospheric Water
Percentages of use cases that are clearly relevant or possibly relevant due to adjacency in the water cycle
0%
50%
100%
Non-focal basins

Figure 7. Percentages of WWAO-documented use cases related to distinct pools of the water cycle segmented by use case relevance to Contiguous Western U.S. USGS water resource regions.

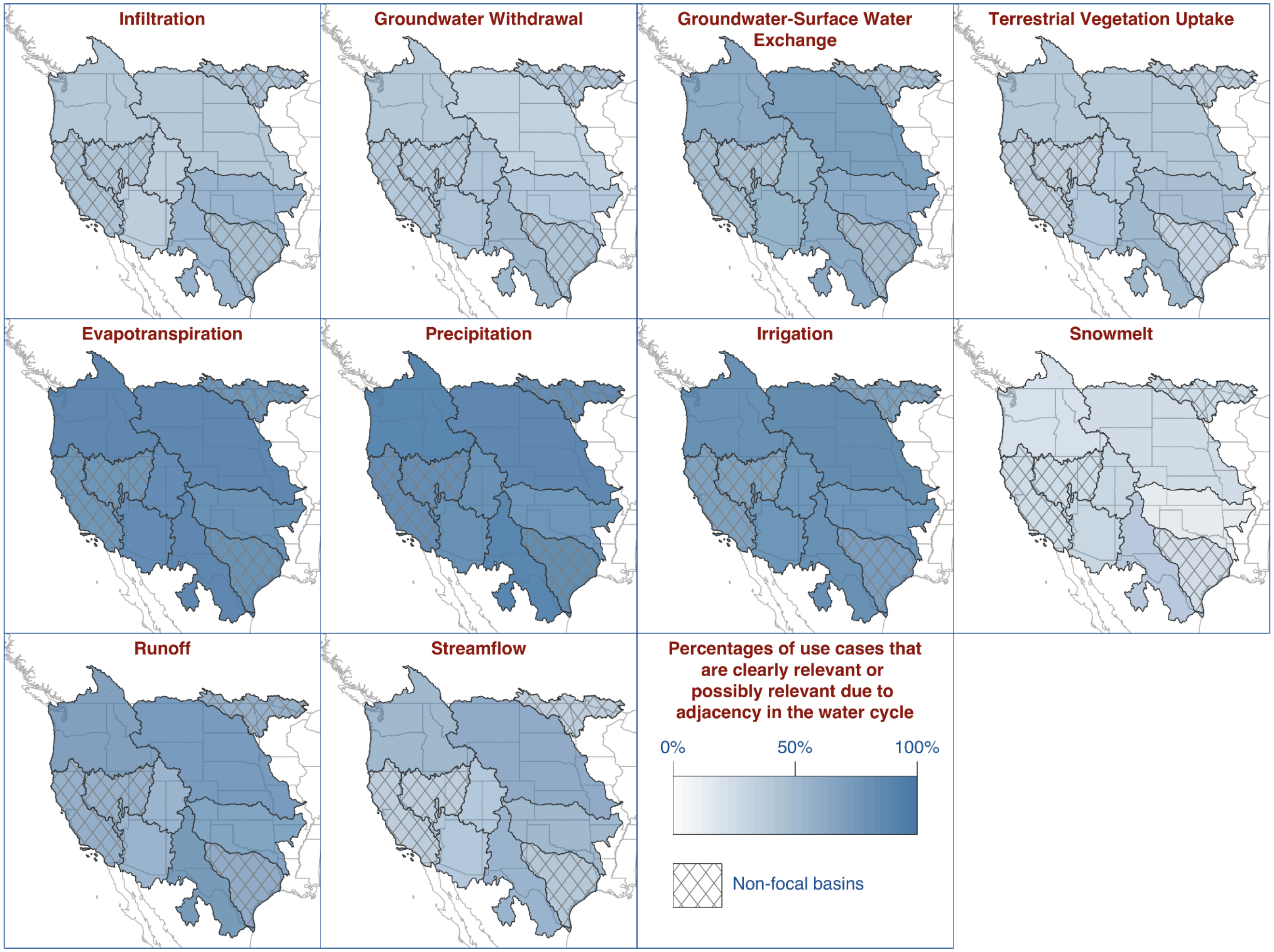
Infiltration
Groundwater Withdrawal
Groundwater-Surface Water Exchange
Terrestrial Vegetation Uptake
Evapotranspiration
Precipitation
Irrigation
Snowmelt
Runoff
Streamflow
Percentages of use cases that are clearly relevant or possibly relevant due to adjacency in the water cycle
0%
50%
100%
Non-focal basins

Figure 8. Percentages of WWAO-documented use cases related to distinct fluxes of the water cycle segmented by use case relevance to Contiguous Western U.S. USGS water resource regions.

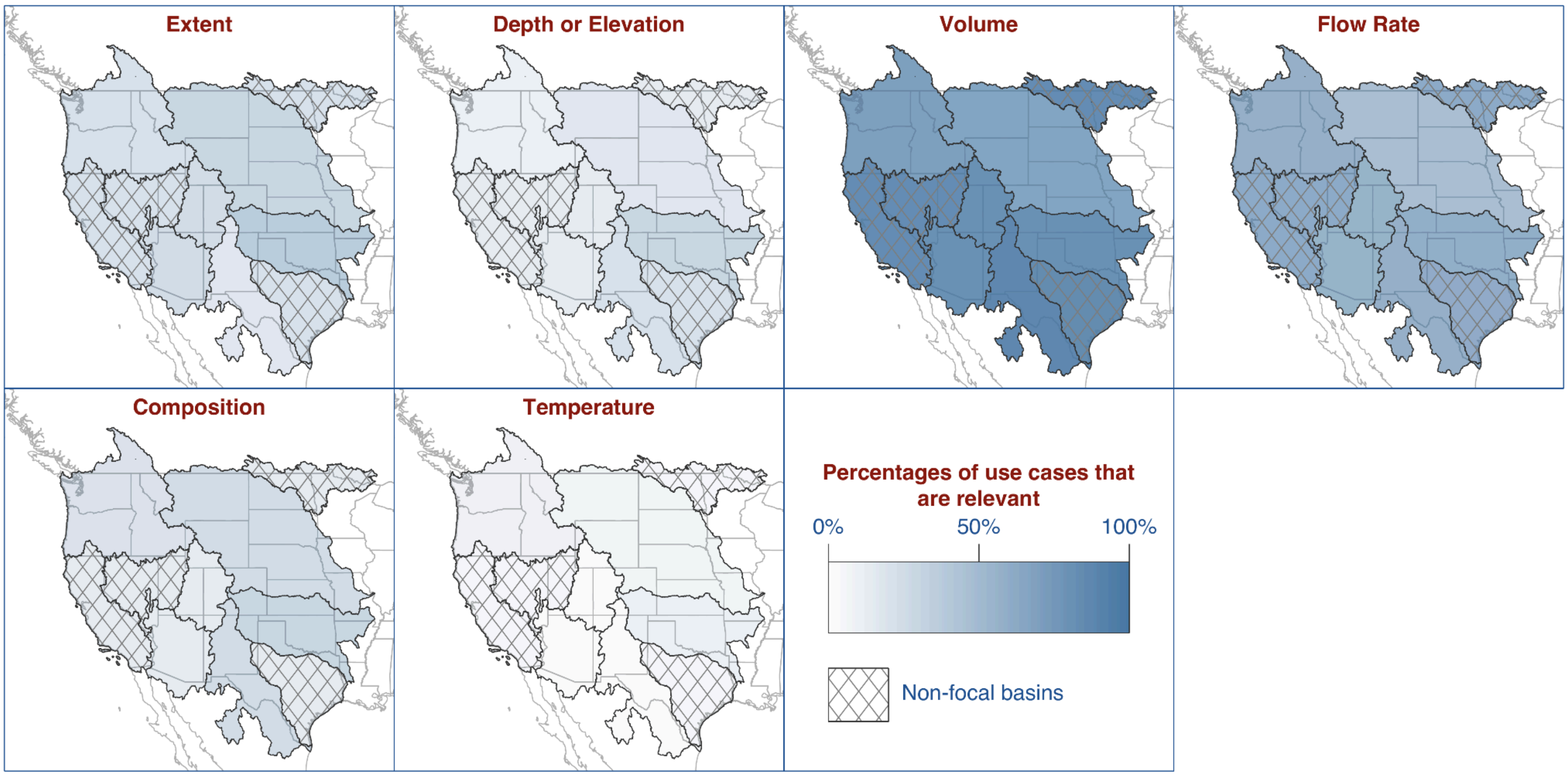

Figure 9. Percentages of WWAO-documented use cases related to measuring distinct characteristics of water segmented by use case relevance to Contiguous Western U.S. USGS water resource regions.

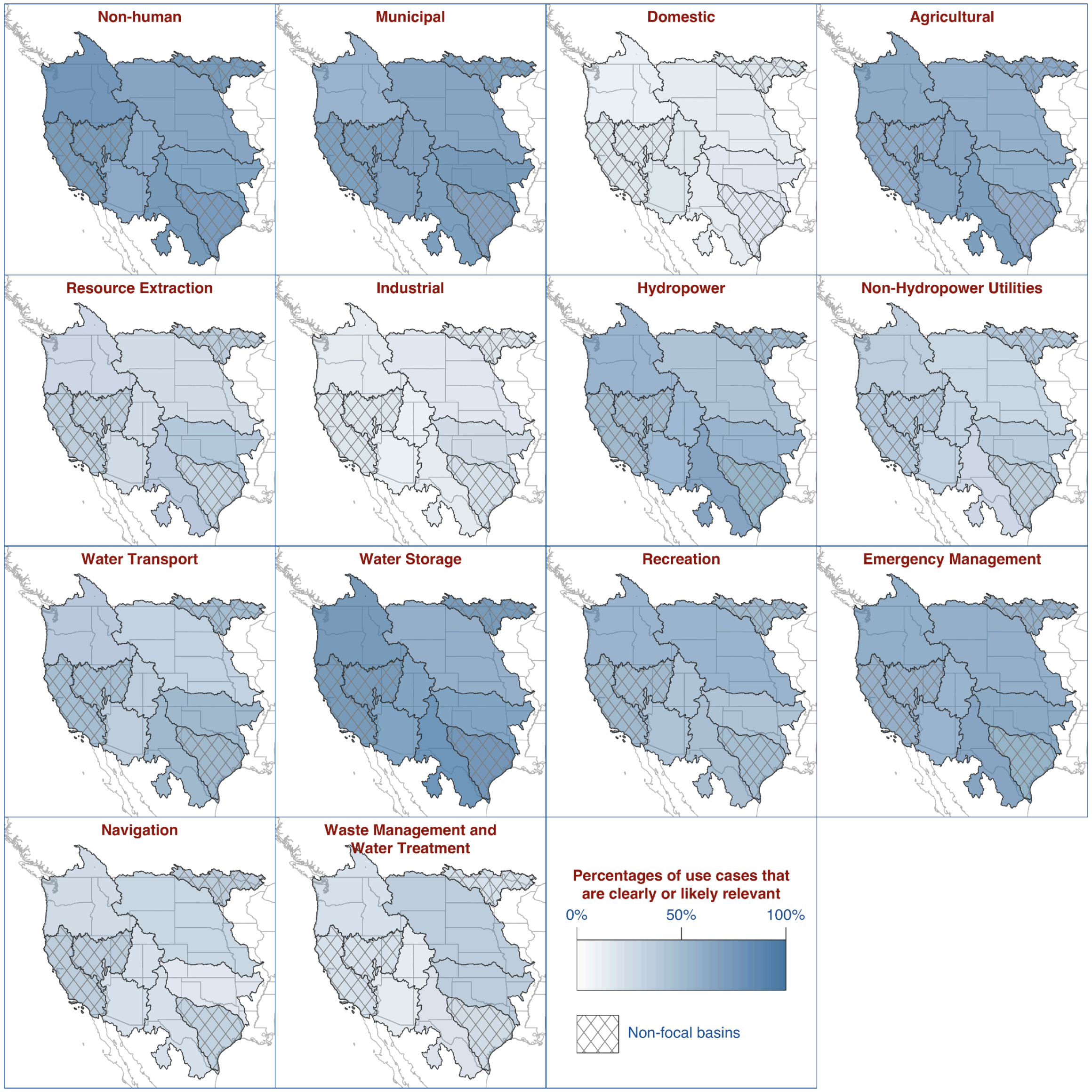

Figure 10. Percentages of WWAO-documented use cases related to distinct types of water use segmented by use case relevance to Contiguous Western U.S. USGS water resource regions.

Use Case Clusters

The ten use case clusters are presented in Table 5, and the specific use cases within each cluster are listed in Table A3-1. The use cases in each cluster were generally conceptually coherent with a few apparent outliers. Some manual modifications to the clusters could likely make them more coherent and strategically useful (e.g., shifting "Improved reservoir yield estimates" to another cluster and combining the groundwater clusters), but we have left the clusters in their raw form for the purposes of this cross-basin analysis. Some commentary on the use case characteristics of each cluster is provided below.

Table 5. Summary information on use case clusters.

Use case cluster name	**Number of use cases**	**Notes**
Snow	4	All contained use cases are from the Rapid Needs Assessment.
Precipitation, drought, and reservoirs	19	—
Water availability	6	—
Runoff and streamflow forecasting	13	—
Groundwater recharge and use	8	—

Watershed health and water quality	27	—
Agriculture, irrigation, and evapotranspiration	22	—
Groundwater storage	7	—
Improved reservoir yield estimates	1	The cluster name is the same as the single contained use case's name.
NASA water-related data portal	1	The cluster name is the same as the single contained use case's name.

Snow

The four use cases in the "snow" cluster were all developed during the Rapid Needs Assessment. They expressed needs related to improved snowmelt (and associated flood) prediction through characterizing the geographical distribution of snow, snow water equivalent, and dust on snow. These use cases generally had likely applicability to non-human, municipal, and hydropower water uses as well as non-hydropower utilities, water transport, water storage, recreation, emergency management, and navigation.

Precipitation, Drought, and Reservoirs

The 19 use cases in the "precipitation, drought, and reservoirs" cluster were developed during the Rapid Needs Assessment (seven) and Colorado (two), Pacific Northwest (two), Rio Grande (two), Missouri (one), and Arkansas-White-Red (five) Needs Assessments. This cluster was less clearly focused than most of the others. Terrestrial vegetation, rivers and streams, and reservoirs were prominently addressed water cycle pools, while infiltration, evapotranspiration, precipitation, and runoff were prominently addressed water cycle fluxes. These use cases generally had likely applicability to non-human, municipal, agricultural, and hydropower water uses as well as water storage and emergency management.

Water Availability

The six use cases in the "water availability" cluster were developed during the Pacific Northwest (one), Rio Grande (two), and Arkansas-White-Red (three) Needs Assessments. They expressed needs related to refining different aspects of water balance, including evapotranspiration and groundwater-surface water interaction. These use cases were possibly or clearly relevant to most water cycle pools and fluxes with snowmelt being one exception. They generally had the greatest likely applicability to non-human, municipal, agricultural, industrial, and hydropower water uses as well as water transport, water storage, and emergency management.

Runoff and Streamflow Forecasting

The 13 use cases in the "runoff and streamflow forecasting" cluster were developed during the Colorado (three), Pacific Northwest (one), Rio Grande (six), and Missouri (three) Needs Assessments. As runoff and streamflow are major fluxes linking various pools of the water cycle, these use cases expressed needs touching on many of those pools. They generally had the greatest likely applicability to non-human, municipal, agricultural, hydropower, and water uses as well as water transport, water storage, recreation, and emergency management.

Groundwater Recharge and Use

The eight use cases in the "groundwater recharge and use" cluster were developed during the Rapid Needs Assessment (one) and Colorado (one), Pacific Northwest (two), and Arkansas-White-Red (four) Needs Assessments. Groundwater was clearly relevant to all but one use case, and rivers and streams, canals, lakes and ponds, reservoirs, and wetlands were also highly relevant. Streamflow was the most relevant water cycle flux, followed by groundwater-surface water exchange, groundwater withdrawal, and infiltration. The use cases generally had the greatest likely applicability to water storage, municipal water use, and hydropower.

Watershed Health and Water Quality

The 27 use cases in the “watershed health and water quality” cluster were developed during the Colorado (one), Pacific Northwest (five), Rio Grande (one), Missouri (11), and Arkansas-White-Red (nine) Needs Assessments. Terrestrial surface water bodies were the focus of most of these use cases with groundwater, soil moisture, ice and snow, coastal waters, and atmospheric water receiving little attention. Streamflow was the only water cycle flux with substantial clear relevance. Use cases addressed both the water composition and temperature aspects of water quality and were applicable to a broad range of water uses.

Agriculture, Irrigation, and Evapotranspiration

The 22 use cases in the “watershed health and water quality” cluster were developed during the Rapid Needs Assessment (seven) and Colorado (six), Pacific Northwest (three), Rio Grande (one), Missouri (three), and Arkansas-White-Red (two) Needs Assessments. The vast majority centered on agriculture, including crop mapping, irrigation, and agriculture-related evapotranspiration. Soil moisture and terrestrial vegetation were the two primary water cycle pools addressed.

Groundwater Storage

The seven use cases in the “Groundwater storage” cluster were developed during the Rapid Needs Assessment (three) and Missouri (one) and Arkansas-White-Red (three) Needs Assessments. They generally centered on characterizing groundwater volume or levels more than those in the “groundwater recharge and use” cluster that focused more on infiltration and groundwater-surface water interaction. The use cases generally had the greatest likely applicability to water storage, municipal and domestic water use, and non-hydropower utilities and emergency management.

Improved Reservoir Yield Estimates

This single use case was developed during the Missouri Needs Assessment. It was broadly applicable to most aspects of the water cycle but focused more on poorly quantified reservoir losses to evaporation and infiltration as opposed to reservoir inputs. The use case was clearly applicable to municipal, agricultural, and hydropower water uses as well as water transport, water storage, recreation, emergency management, and navigation.

NASA Water-Related Data Portal

This single use case was developed during the Missouri Needs Assessment. It was somewhat of an outlier, as it did not address a specific use case, but rather called for the development of a broadly applicable, comprehensive, user-friendly portal for accessing analysis-ready data.

Use Case Status Evaluation and Opportunity Analysis

Geographic Distribution of WWAO Projects

WWAO has funded 29 projects since 2016, and the focal locations of those projects are shown in Figure 11. WWAO's projects have addressed issues relevant to all Western Contiguous U.S. USGS water resource regions. WWAO's active request for information (RFI) concerning potential Missouri Region projects will likely increase the number of projects relevant to that region (and associated states), and the same will likely be true for the Arkansas-White-Red Region if WWAO follows through on its plan to fund projects there.

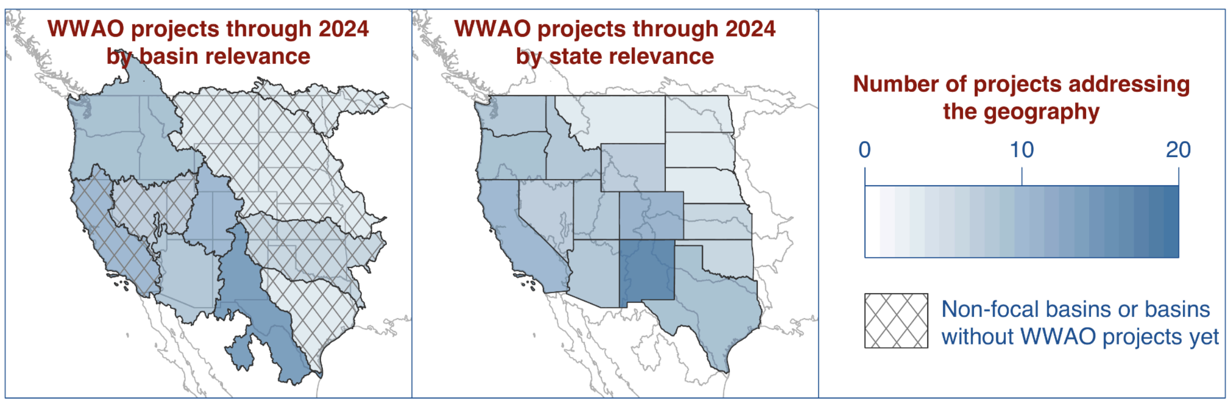

Figure 11. Focal locations of WWAO projects.

In addition to projects with direct relevance to the USGS water resource regions where WWAO has conducted assessments, issued RFIs, and funded targeted work, WWAO has also funded projects with relevance to the four Contiguous U.S. USGS water resource regions for which it has not conducted needs assessments (California, Great Basin, Souris-Red-Rainy, and Texas-Gulf) and two regions for which it have assessed needs but have not yet funded projects directly responding to those needs (Arkansas-White-Red and Missouri).

Conceptual Distribution of WWAO's Projects

21 of WWAO's 29 projects (72%) have been directly inspired by WWAO use cases. Collectively, these projects have at least partially addressed 27 of the 108 WWAO use cases (25%). Numbers and percentages of use cases relevant to WWAO focus areas, water cycle pools, water cycle fluxes, water characteristics, and water uses are shown in Figures 12 through 16. WWAO's projects have touched on between 17% and 50% of use cases relevant to each use case characteristic.

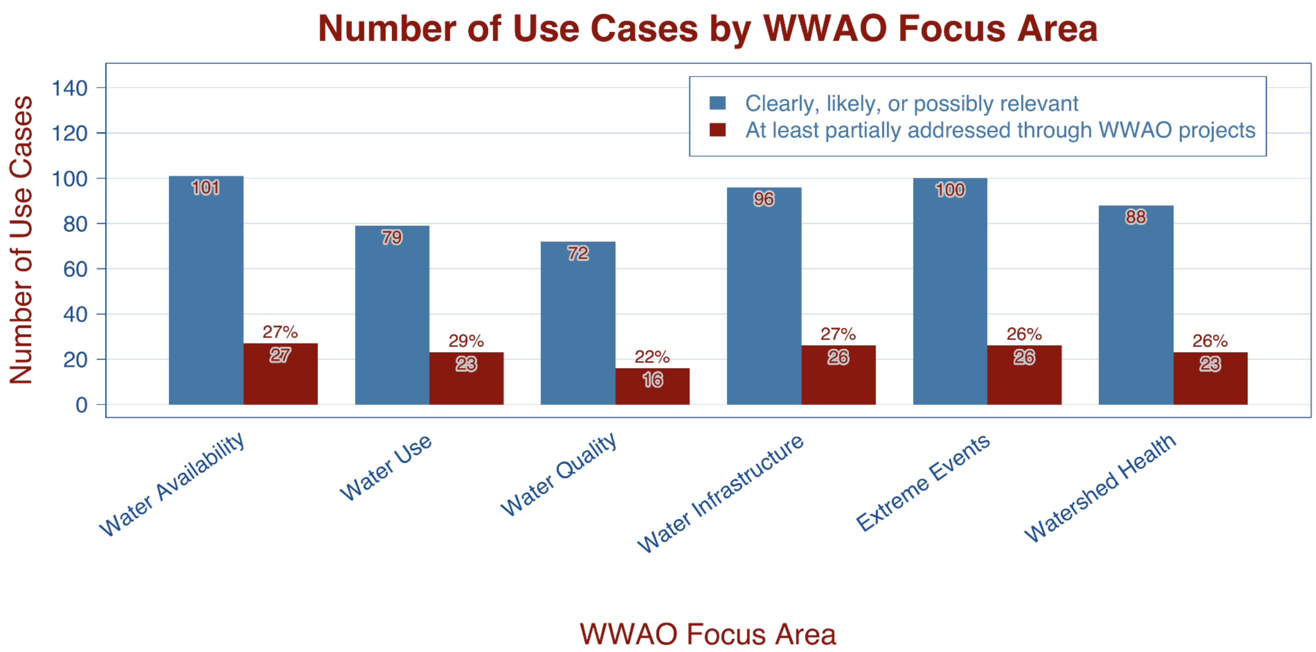

Figure 12. Numbers of WWAO-documented use cases (total and at least partially addressed) related to WWAO's established focus areas.

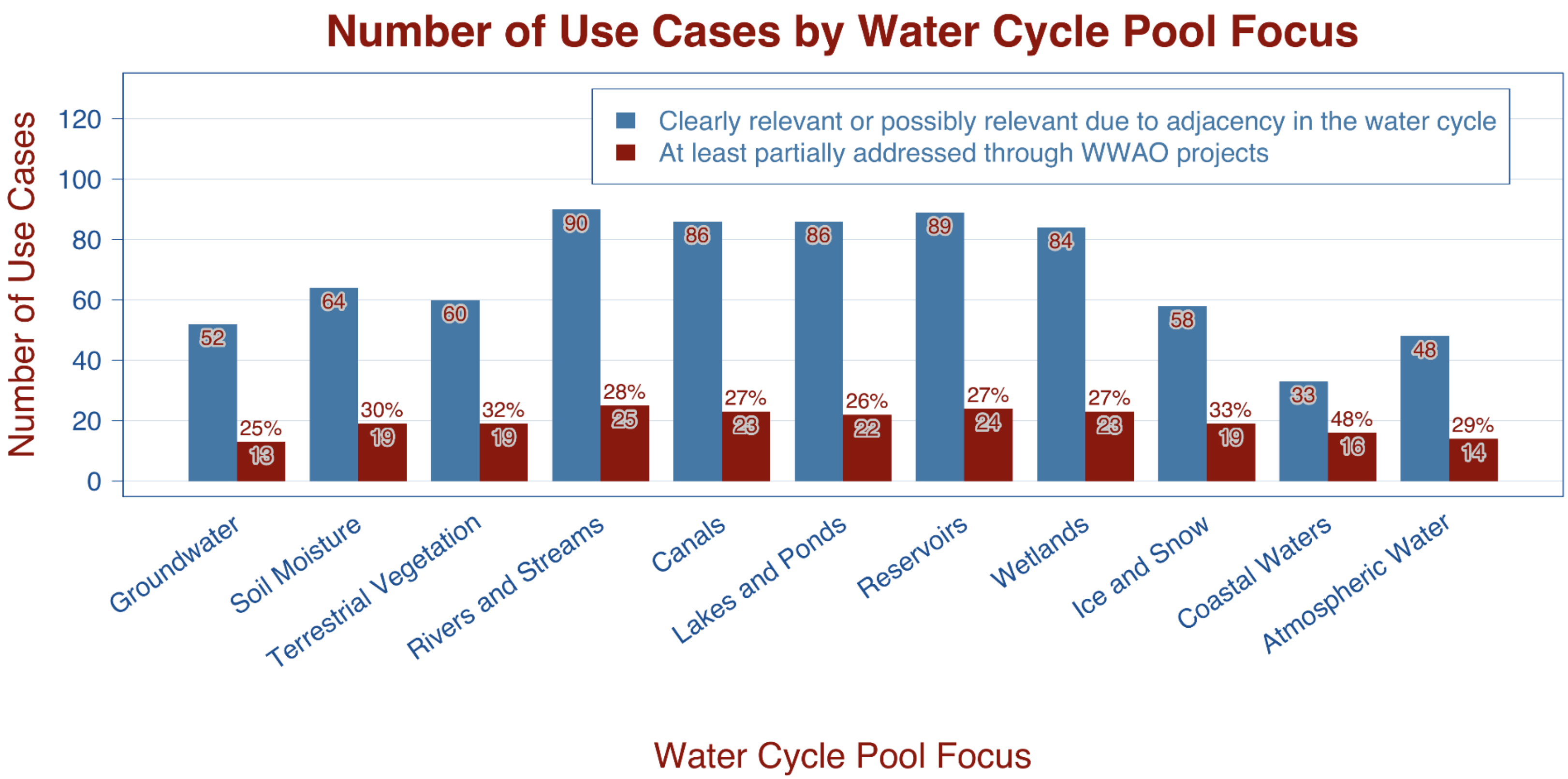

Figure 13. Numbers of WWAO-documented use cases (total and at least partially addressed) related to distinct pools of the water cycle.

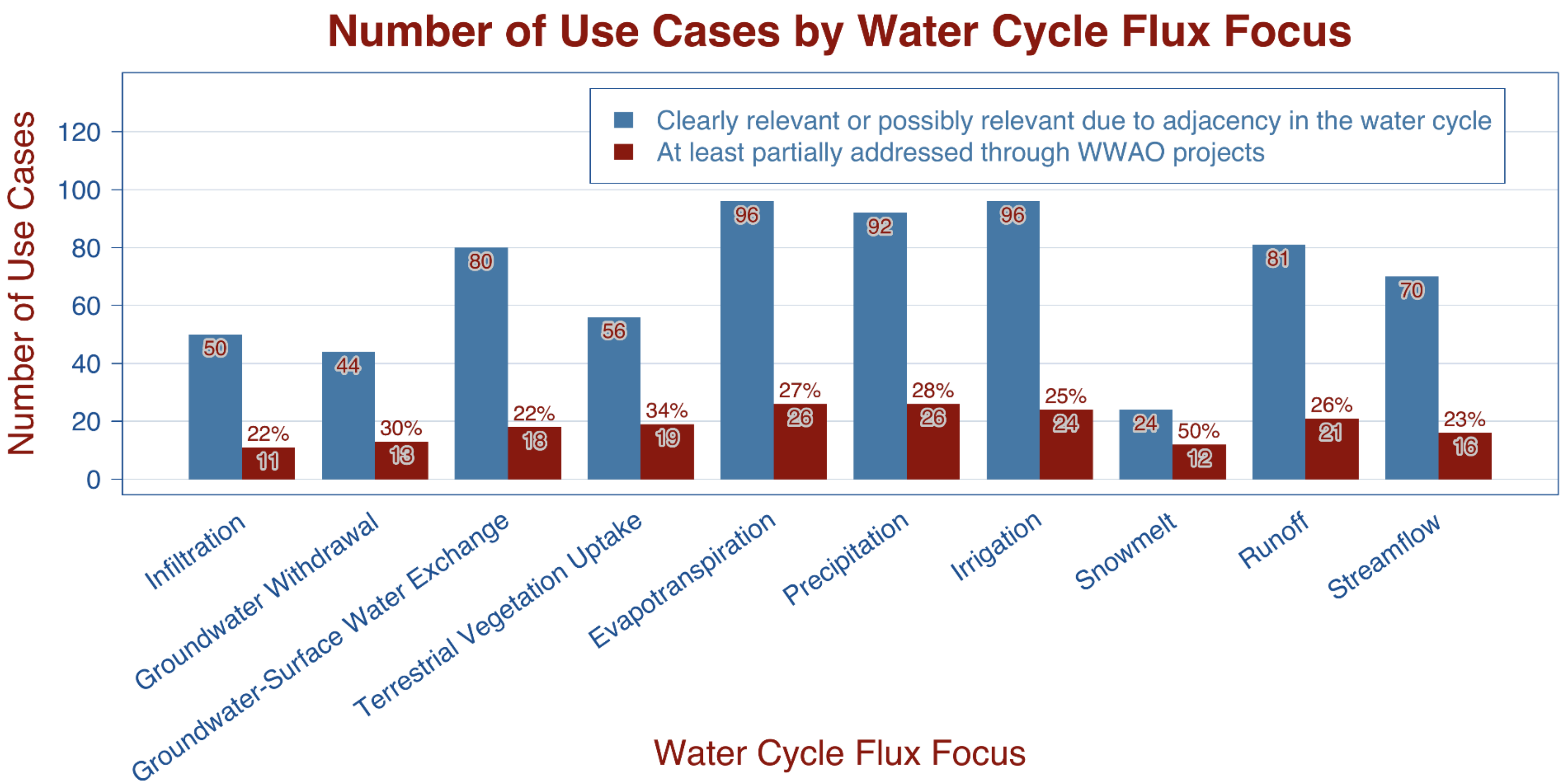

Figure 14. Numbers of WWAO-documented use cases (total and at least partially addressed) related to distinct fluxes of the water cycle.

Number of Use Cases by Water Characteristic

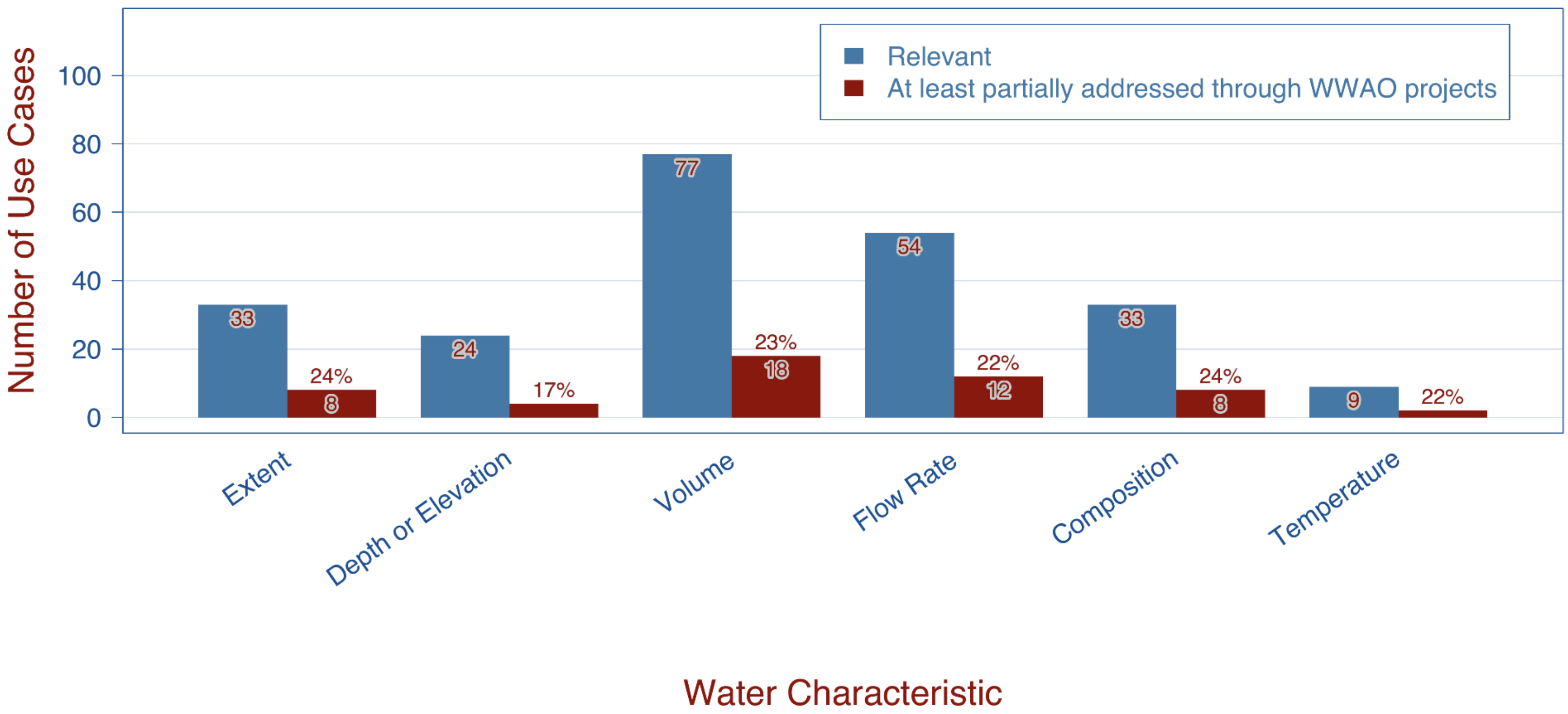

Figure 15. Numbers of WWAO-documented use cases (total and at least partially addressed) related to measuring distinct characteristics of water.

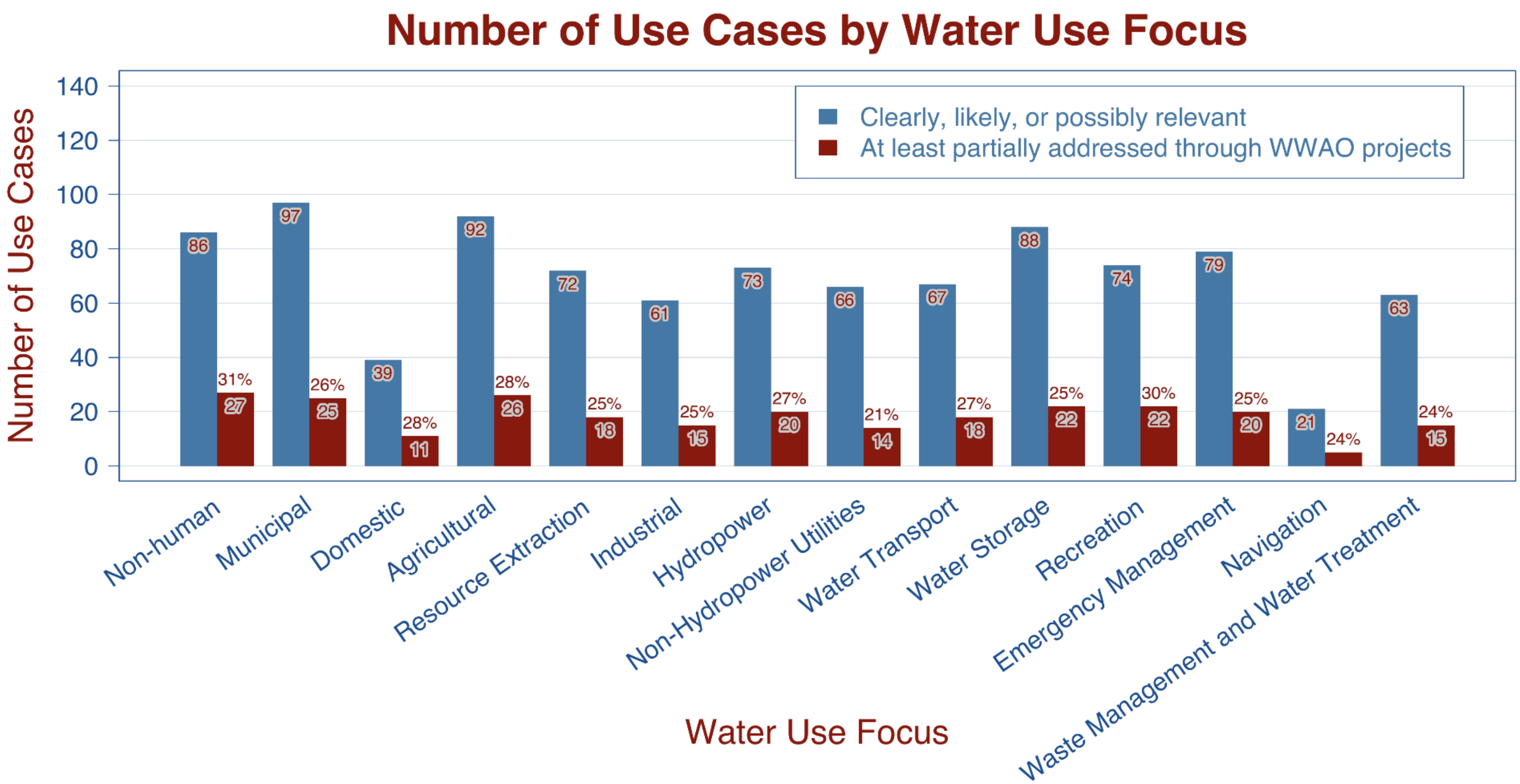

Figure 16. Numbers of WWAO-documented use cases (total and at least partially addressed) related to distinct types of water use.

WWAO's Projects by Use Case Clusters

Examining WWAO's at least partially addressed use cases by the use case clusters described above reveals a slightly different picture (Figure 17). The two clusters with single use cases have not been addressed by WWAO projects, nor have the two groundwater clusters (the groundwater-relevant use cases touched by WWAO projects that are shown in Figure 13 fell into other clusters, highlighting the value of looking at the use case data multidimensionally).

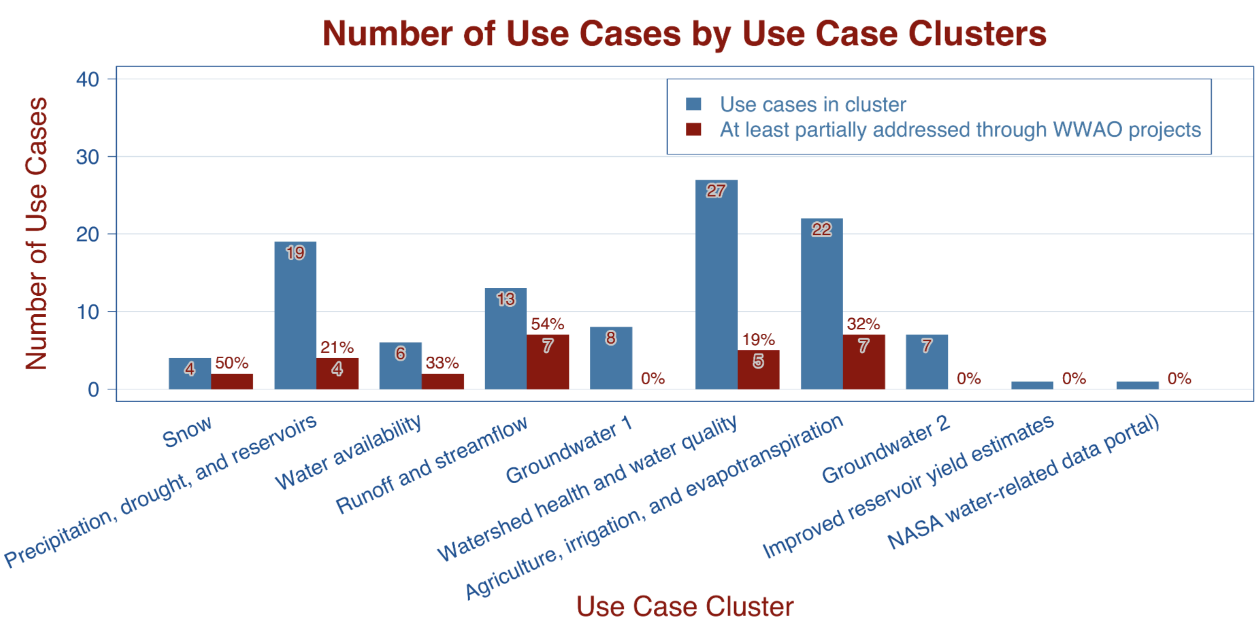

Figure 17. Numbers of WWAO-documented use cases (total and at least partially addressed) in each use case cluster.

Conclusions and Recommendations

WWAO's 108 collected use cases paint a clear picture of water-related Earth observation needs across much of the Western Contiguous U.S. While there were some gaps in WWAO's assessment coverage and challenges in placing use case data from various assessments in a common analytical framework, the broad geographic and conceptual coverage of WWAO's use cases makes them a strong basis for innovation and scaling of Earth observation solutions for water management in the Western U.S.

Use case characteristics related to water cycle pools and fluxes, water measurement characteristics, and water uses were surprisingly evenly distributed in geographic terms, with few basins or states standing out with a unique need or lack of needs. More than geography, water measurement characteristics exhibited distinctly varying prevalence in use cases—measures of quantity (volume and flow rate in particular) received notably more attention than measures of water quality.

WWAO has made strong progress in addressing collected use cases with 25% of use cases at least touched by 1 of WWAO's 29 funded projects (and projects yet to be initiated for the Missouri and Arkansas-White-Red Regions). While WWAO's projects touch on all considered water cycle pools and fluxes, water measurement characteristics, and water uses, clustering of use cases revealed that use cases in two groundwater clusters have not yet inspired WWAO projects.

WWAO has many strategic choices to make in how it goes about addressing use cases, both newer ones, and those for which WWAO projects have already made some progress. This analysis revealed few gaps in WWAO's project portfolio, but labeling each use case and project with application readiness levels would facilitate more detailed analysis of WWAO's achievements to date and opportunities for further innovation and scaling. There is also a clear need for estimating the feasibility and potential impacts of addressing each use case (or at least clusters of use cases) so that WWAO can maximize its potential impacts. **WWAO is well positioned to positively transform the lives of those who study, manage, use, benefit from, and appreciate water in the Western U.S.** Well-reasoned decisions grounded in the information WWAO has gathered will help ensure WWAO delivers on its potential.

List of Acronyms

ARL – Application Readiness Level

ES2A – Earth Science to Action

MG – Metropolitan Group

NASA – National Aeronautics and Space Administration

RFI – request for information

UPGMA – unweighted pair group method with arithmetic mean

USGS – United States Geological Survey

Western U.S. – Western United States

WWAO – Western Water Action Office

Appendix I: Sample use case template from the Arkansas-White-Red workshop

	Use Case Title	Descriptive Title Here (e.g. "Improved ET for Groundwater Management")
Must Haves	**Current State or Water Management Challenge**	Describe the decision(s), current process, and data/models used to support decision making, or describe the water management challenge(s) where lack of information is inhibiting progress.
	Desired Result	Describe desired improvements to the decision-making process or the water management challenge described above.
	Need/Gap	Describe the information needed to achieve the desired result (e.g., consumptive use, snow water equivalent, streamflow, vegetation health, forecast, etc). Note: needs should be agnostic to specific solutions.
	Information Requirements	To the extent possible, describe the required characteristics of the data needed to improve the decision, e.g., spatial resolution, temporal resolution, accuracy, latency, and data formats. Include necessary modifications to existing models.
	Partner Potential	Identify the primary organization that would partner with WWAO to develop/implement a potential project to address the need (should it be selected). Provide name(s) and contact information. Primary partner: <Contact Info/Phone number here> Other interested parties: <Contact info and phone numbers>
	Affected area or community	Indicate if the need or challenge described above varies in significance across different communities or regions (e.g., urban, rural, underserved communities). Further explanation may be provided if necessary.
Supports WWAO Needs Prioritization	**Description/Decision Context**	Describe the decision to be made, how the decision is made, and who makes the decision with as much detail as possible, including information about what data are used to inform the decision-making process and who is currently responsible for producing and/or interpreting the data.
	Obstacles to Addressing the Need	Describe obstacles (e.g., technical, institutional, cultural, financial, etc) to addressing the need.
Supports WWAO Project Development and Partnering	**Current Workflow**	Describe the flow of information from a set of inputs to models (as appropriate) to outputs (e.g., monthly reports, graphs, etc.) that are used to make the decision.
	Potential Data Sources	Identify potential information sources that could aid in addressing the decisions or challenges described above. These sources may include but are not limited to NASA data.
	Participants	Describe the primary participants who are impacted by this need.

Figure A2-1. WWAO's use case template from the Arkansas-White-Red workshop.

Appendix II: Full List of Use Cases

Table A3-1. All 108 WWAO use cases sorted by source workshop and including use case cluster names.

Source Workshop	Use Case Name	Use Case Cluster Name
Rapid Needs Assessment (RNA)	Improved understanding of how the snowpack is evolving in western U. S. mountain basins during the snow season to anticipate and plan for runoff anomalies	Precipitation, drought, and reservoirs
RNA	Incorporate information about dust on snow as images, with an indication of how the current year compares to past years and the average for dust	Snow
RNA	Development of interactive snow analysis products to characterize basin- distributed snow- covered area and snow water equivalent	Snow
RNA	Support flood control through assessment of springtime flood risk in the Great Plains states by broad-scale monitoring of snowpack	Snow
RNA	More accurate seasonal predictions of the timing and magnitude of snowmelt in mountainous regions and their impacts to western water supply	Snow

Source Workshop	Use Case Name	Use Case Cluster Name
RNA	Need to prevent the six undesirable effects of groundwater use	Groundwater recharge and use
RNA	Improved understanding of available groundwater volume	Groundwater storage
RNA	Improved understanding of how aquifers can be used for water storage	Groundwater storage
RNA	Earthquakes	Groundwater storage
RNA	Improved forecasts including accurate probability estimates over the range of interest that allows water manager to properly manage reservoirs	Precipitation, drought, and reservoirs
RNA	Regional scale observations of extreme precipitation	Precipitation, drought, and reservoirs
RNA	More reliable precipitation forecasts to inform water supply and flood control operations at reservoirs where atmospheric river events frequently and predictably occur	Precipitation, drought, and reservoirs
RNA	Increase the skill S2S precipitation forecasting for western water management	Precipitation, drought, and reservoirs

Source Workshop	Use Case Name	Use Case Cluster Name
RNA	Understanding of watershed conditions for reservoir operations	Agriculture, irrigation, and evapotranspiration
RNA	Integration of soil moisture observations to advance the National Soil Moisture Network	Agriculture, irrigation, and evapotranspiration
RNA	Irrigation planning	Agriculture, irrigation, and evapotranspiration
RNA	Mapping irrigated lands as well as crop type and fallowed land	Agriculture, irrigation, and evapotranspiration
RNA	Improved estimates of field- scale evapotranspiration (ET) to quantify consumptive water use, especially for irrigated agriculture to improve irrigation scheduling, and for estimating the volume of interstate water transfers, for example, in the Colorado River basin	Agriculture, irrigation, and evapotranspiration
RNA	Accurate estimates of riparian zone ET are needed to properly and soundly apportion river water for human and environmental needs	Precipitation, drought, and reservoirs
RNA	Accurate estimates of ET for assessing rangeland health	Agriculture, irrigation, and evapotranspiration

Source Workshop	Use Case Name	Use Case Cluster Name
RNA	Monitoring evaporative losses over reservoirs and rivers	Precipitation, drought, and reservoirs
RNA	Identify illegally irrigated lands	Agriculture, irrigation, and evapotranspiration
Colorado	Timely streamflow predictions at sub-basin level	Runoff and streamflow forecasting
Colorado	Improved forecasts of snowpack, runoff, water demand, evapotranspiration	Runoff and streamflow forecasting
Colorado	Irrigation management	Agriculture, irrigation, and evapotranspiration
Colorado	Irrigation mapping	Agriculture, irrigation, and evapotranspiration
Colorado	Consumptive use for calculating water budget	Agriculture, irrigation, and evapotranspiration
Colorado	Reservoir evaporation	Precipitation, drought, and reservoirs
Colorado	Crop mapping	Agriculture, irrigation, and evapotranspiration

Source Workshop	Use Case Name	Use Case Cluster Name
Colorado	Crop monitoring	Agriculture, irrigation, and evapotranspiration
Colorado	Augmenting groundwater quantification	Groundwater recharge and use
Colorado	Mitigation of wildfire impacts on watershed supply	Agriculture, irrigation, and evapotranspiration
Colorado	Augmentation of state-level drought planning and response	Precipitation, drought, and reservoirs
Colorado	State-level drought planning	Runoff and streamflow forecasting
Colorado	Long-term water resource planning: predicting changes in the Sierra Nevada or Rocky Mountain snowline, snowpack distribution, and streamflow forecasts	Watershed health and water quality
Pacific Northwest	Crop mapping	Agriculture, irrigation, and evapotranspiration
Pacific Northwest	Evapotranspiration/consumptive use	Water availability

Source Workshop	Use Case Name	Use Case Cluster Name
Pacific Northwest	Irrigation	Agriculture, irrigation, and evapotranspiration
Pacific Northwest	Cyanobacteria	Watershed health and water quality
Pacific Northwest	Stream temperature	Watershed health and water quality
Pacific Northwest	Turbidity	Precipitation, drought, and reservoirs
Pacific Northwest	Evapotranspiration	Agriculture, irrigation, and evapotranspiration
Pacific Northwest	Groundwater recharge and storage	Groundwater recharge and use
Pacific Northwest	Snow water equivalent	Runoff and streamflow forecasting
Pacific Northwest	Streamflow monitoring	Watershed health and water quality
Pacific Northwest	Habitat management	Watershed health and water quality

Source Workshop	Use Case Name	Use Case Cluster Name
Pacific Northwest	Land use and land cover	Precipitation, drought, and reservoirs
Pacific Northwest	Surface groundwater interaction	Groundwater recharge and use
Pacific Northwest	Stream temperature dynamics	Watershed health and water quality
Rio Grande	Improving streamflow forecasting	Runoff and streamflow forecasting
Rio Grande	Integrated data/information system and modeling	Runoff and streamflow forecasting
Rio Grande	Groundwater-surface water interaction and groundwater level monitoring	Water availability
Rio Grande	Vegetation changes and impacts to water supply/quality	Precipitation, drought, and reservoirs
Rio Grande	Channel geomorphology and sedimentation	Precipitation, drought, and reservoirs
Rio Grande	Fallow-field monitoring to support water conservation	Agriculture, irrigation, and evapotranspiration

Source Workshop	Use Case Name	Use Case Cluster Name
Rio Grande	Quantification of conveyance losses	Water availability
Rio Grande	Improved water supply forecasts to support basin-wide planning and farm management	Runoff and streamflow forecasting
Rio Grande	Identifying the strongest influences on streamflow	Runoff and streamflow forecasting
Rio Grande	Identifying the impact of soil moisture deficits	Runoff and streamflow forecasting
Rio Grande	Identifying tipping points for irreversible change	Watershed health and water quality
Rio Grande	Impacts of wildfire events	Runoff and streamflow forecasting
Missouri	Identification of habitat corridors, habitat complexes, and connections	Watershed health and water quality
Missouri	Measure channel characteristics to identify changes in watershed health	Watershed health and water quality
Missouri	Identification of temperature changes and riparian habitat in headwater streams	Watershed health and water quality

Source Workshop	Use Case Name	Use Case Cluster Name
Missouri	Refining harmful algal bloom satellite data to capture smaller waterbodies and near-shore areas	Watershed health and water quality
Missouri	Evaluating contributing factors to evaluate wetland sustainability	Agriculture, irrigation, and evapotranspiration
Missouri	Measurement of surface water storage and elevation	Precipitation, drought, and reservoirs
Missouri	Improved runoff forecasting	Runoff and streamflow forecasting
Missouri	Improved reservoir yield estimates	Improved reservoir yield estimates
Missouri	Improved consistent and temporal coverage of soil moisture and temperature at depth	Runoff and streamflow forecasting
Missouri	Improved spatial and temporal analyzed evapotranspiration information from remotely sensed data, enhance OpenET	Agriculture, irrigation, and evapotranspiration
Missouri	Understanding spatial and temporal change in groundwater/aquifer levels	Groundwater storage

Source Workshop	Use Case Name	Use Case Cluster Name
Missouri	Soil health/carbon sequestration	Agriculture, irrigation, and evapotranspiration
Missouri	Improved temperature measurements for protection of aquatic life	Watershed health and water quality
Missouri	Detection of metals in water bodies	Watershed health and water quality
Missouri	Determining impact of land cover/land use changes to water quality	Watershed health and water quality
Missouri	Monitoring water quality	Watershed health and water quality
Missouri	Identification of land-applied biosolid	Watershed health and water quality
Missouri	Methods to develop automated wetland delineation	Watershed health and water quality
Missouri	Improve river forecasting through collection and application of more refined model inputs	Runoff and streamflow forecasting
Missouri	Infrastructure condition assessment	Watershed health and water quality

Source Workshop	Use Case Name	Use Case Cluster Name
Missouri	NASA water-related data portal	NASA water-related data portal
Arkansas-White-Red (AWR)	Water Availability	Water availability
A-W-R	Aquifer Recharge/Improving Natural Groundwater Recharge Estimates	Water availability
A-W-R	Water Supply Systems	Watershed health and water quality
A-W-R	Watershed Health 2.0	Watershed health and water quality
A-W-R	Improving Groundwater Withdrawal Estimates	Groundwater storage
A-W-R	Monitoring Groundwater Levels	Groundwater storage
A-W-R	Improving Density and Coverage of Surface Water Elevation and Discharge Measurements to Enhance Groundwater-Surface Water Exchange Estimates	Groundwater recharge and use
A-W-R	Refine Water Balance in Surface Water Basins	Water availability

Source Workshop	Use Case Name	Use Case Cluster Name
A-W-R	Early Detection and Warning System for Harmful Algal Blooms (HABs)	Watershed health and water quality
A-W-R	Water Quality Measurements	Watershed health and water quality
A-W-R	Identify Land and/or Water Contamination in Early Stages (Rural)	Watershed health and water quality
A-W-R	Water Use Efficiency	Agriculture, irrigation, and evapotranspiration
A-W-R	Quantify Irrigation Water Use	Groundwater recharge and use
A-W-R	Evaluate Land Management Practices	Watershed health and water quality
A-W-R	Riparian Zone Mapping	Watershed health and water quality
A-W-R	Invasive Species Mapping	Agriculture, irrigation, and evapotranspiration
A-W-R	Impervious Cover	Precipitation, drought, and reservoirs

Source Workshop	Use Case Name	Use Case Cluster Name
A-W-R	Fuel Loads and Burn Mapping	Precipitation, drought, and reservoirs
A-W-R	Impact of Subsidence on Infrastructure on Tribal and Rural Lands	Groundwater storage
A-W-R	Failures of Wastewater Infrastructure Leading to Unpermitted Discharges into Streams	Watershed health and water quality
A-W-R	Watershed Hydrology Information for Infrastructure Needs Assessment	Groundwater recharge and use
A-W-R	Information Needs for Dam Risk Assessment, Flood Emergency Planning, and Flood Response	Precipitation, drought, and reservoirs
A-W-R	Stream-related Risks to Infrastructure	Watershed health and water quality
A-W-R	Identification of Available Water Supply Under all Climatic Conditions (including hydrologic extremes)	Groundwater recharge and use
A-W-R	Rapid Detection of Drought and Drought Impacts	Precipitation, drought, and reservoirs

Source Workshop	Use Case Name	Use Case Cluster Name
A-W-R	Drought-Flood Whiplash Likelihood and Area Identification	Precipitation, drought, and reservoirs

Appendix III: Supplementary Tables and Figures

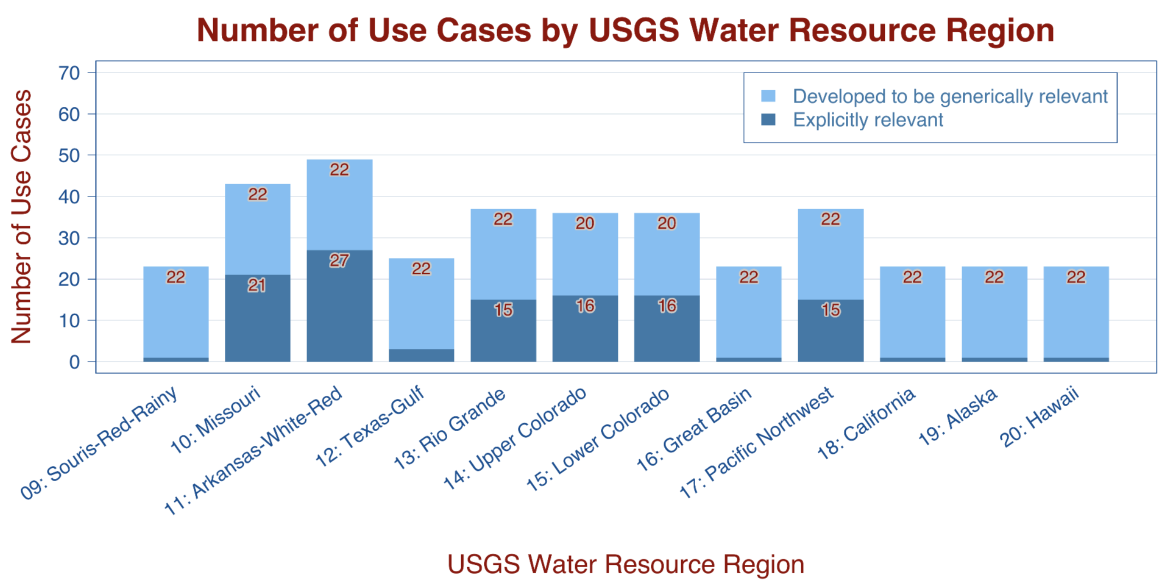

Figure A4-1. Numbers of WWAO-documented use cases related to each USGS water resource region in the Western U.S.

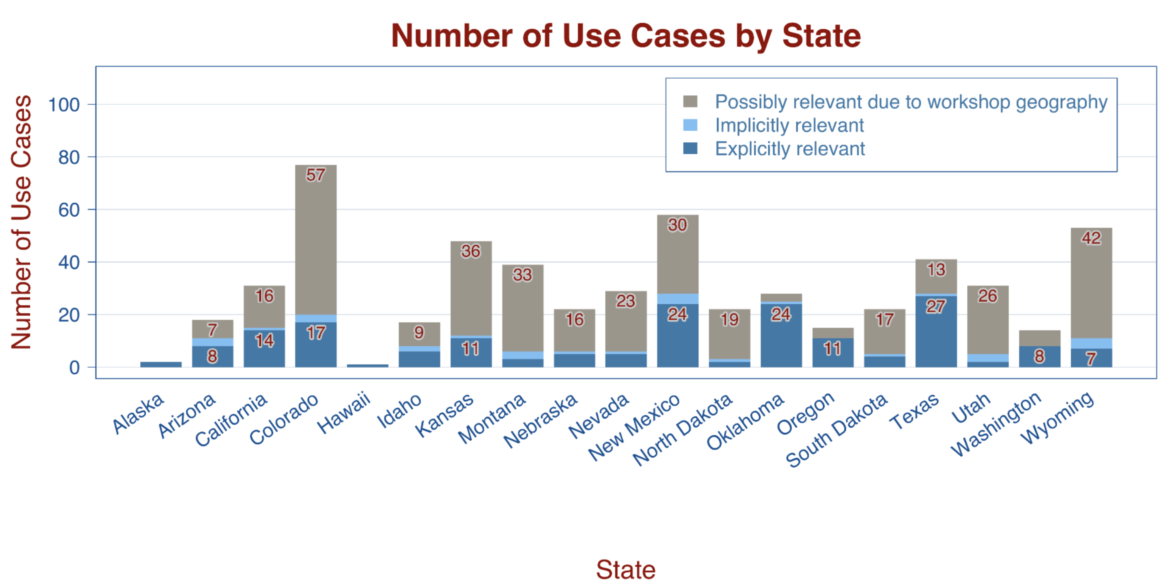

Figure A4-2. Numbers of WWAO-documented use cases related to each state in the Western U.S.

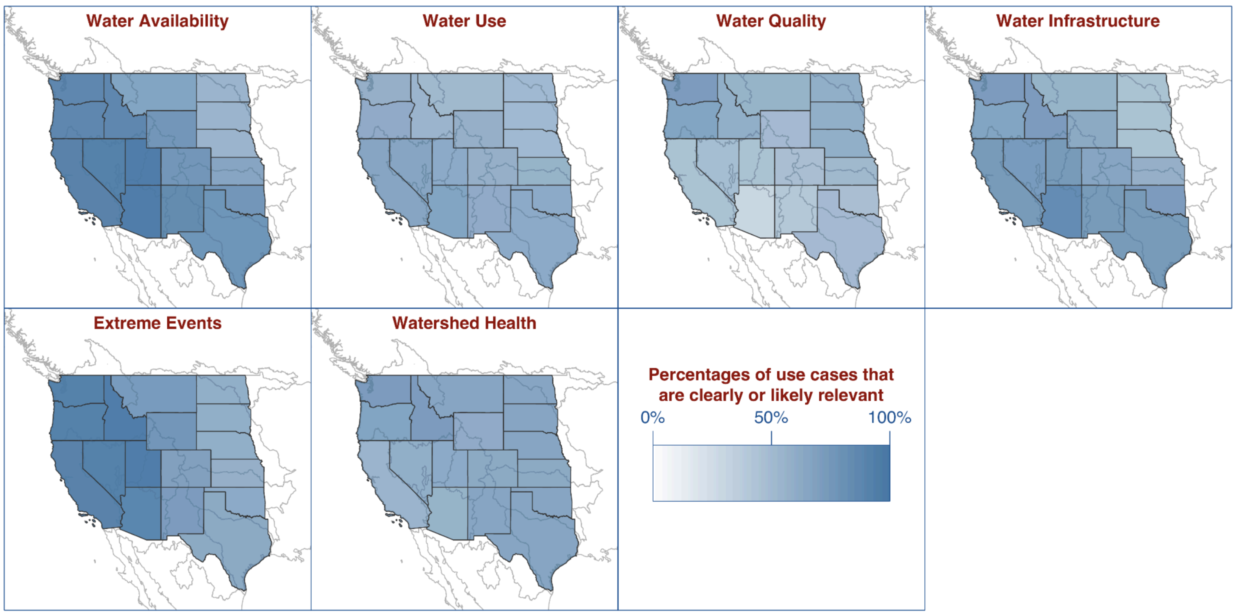

Figure A4-3. Percentages of WWAO-documented use cases related to WWAO focus areas segmented by use case relevance to Contiguous Western U.S. states.

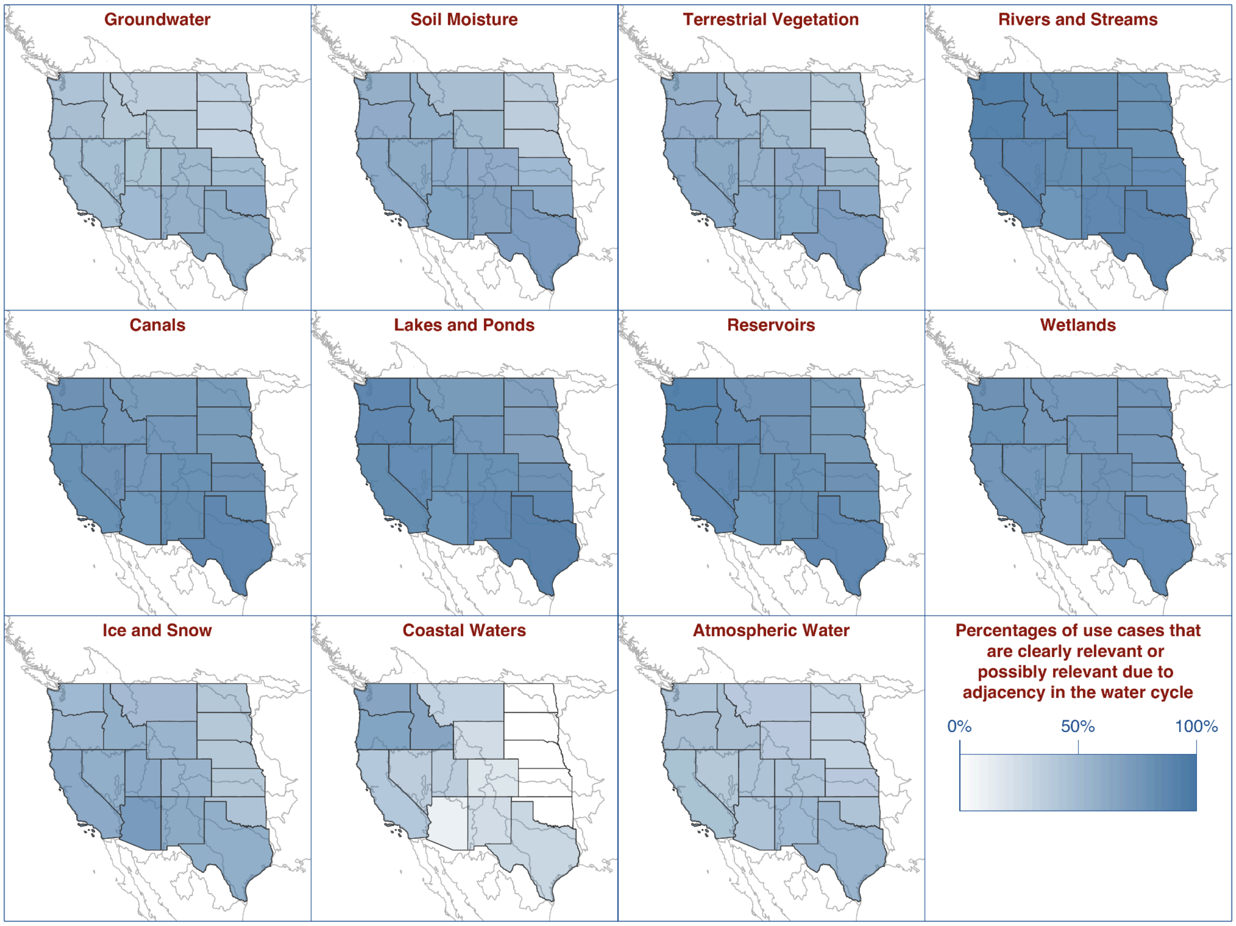

Figure A4-4. Percentages of WWAO-documented use cases related to distinct pools of the water cycle segmented by use case relevance to Contiguous Western U.S. states.

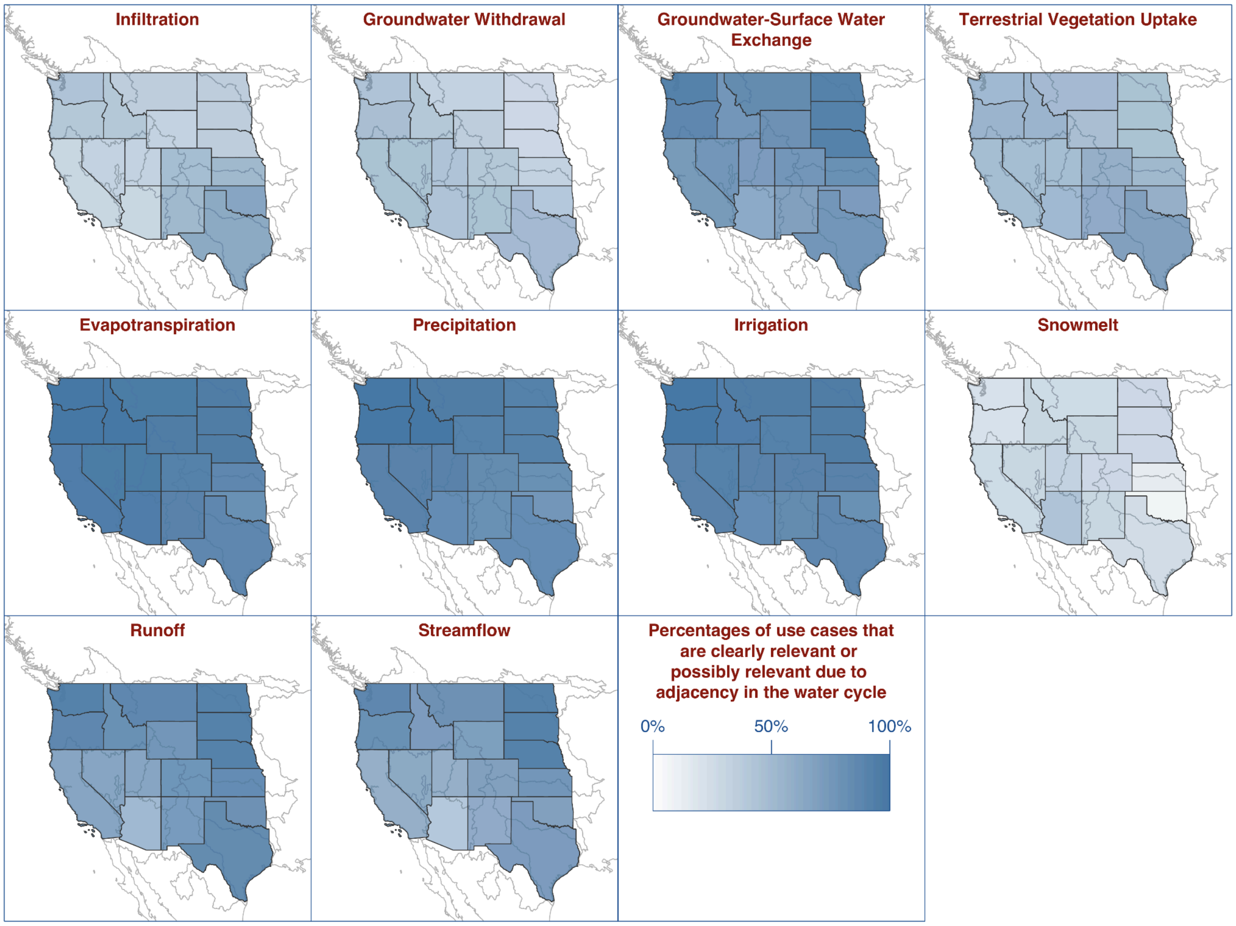

Figure A4-5. Percentages of WWAO-documented use cases related to distinct fluxes of the water cycle segmented by use case relevance to Contiguous Western U.S. states.

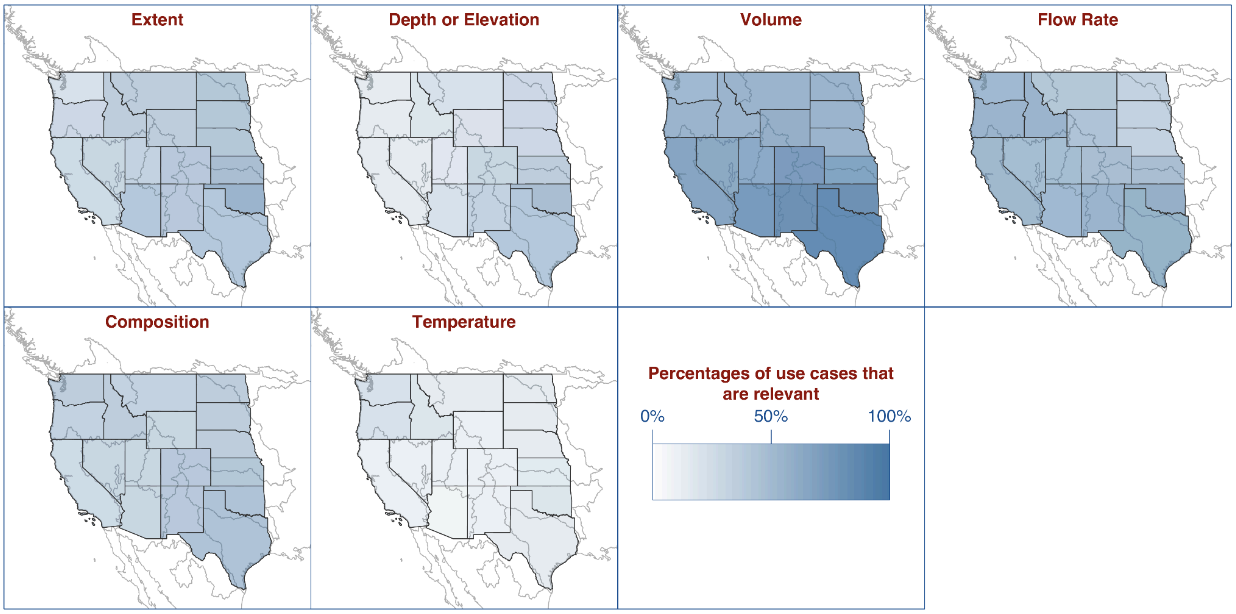

Figure A4-6. Percentages of WWAO-documented use cases related to measuring distinct characteristics of water segmented by use case relevance to Contiguous Western U.S. states.

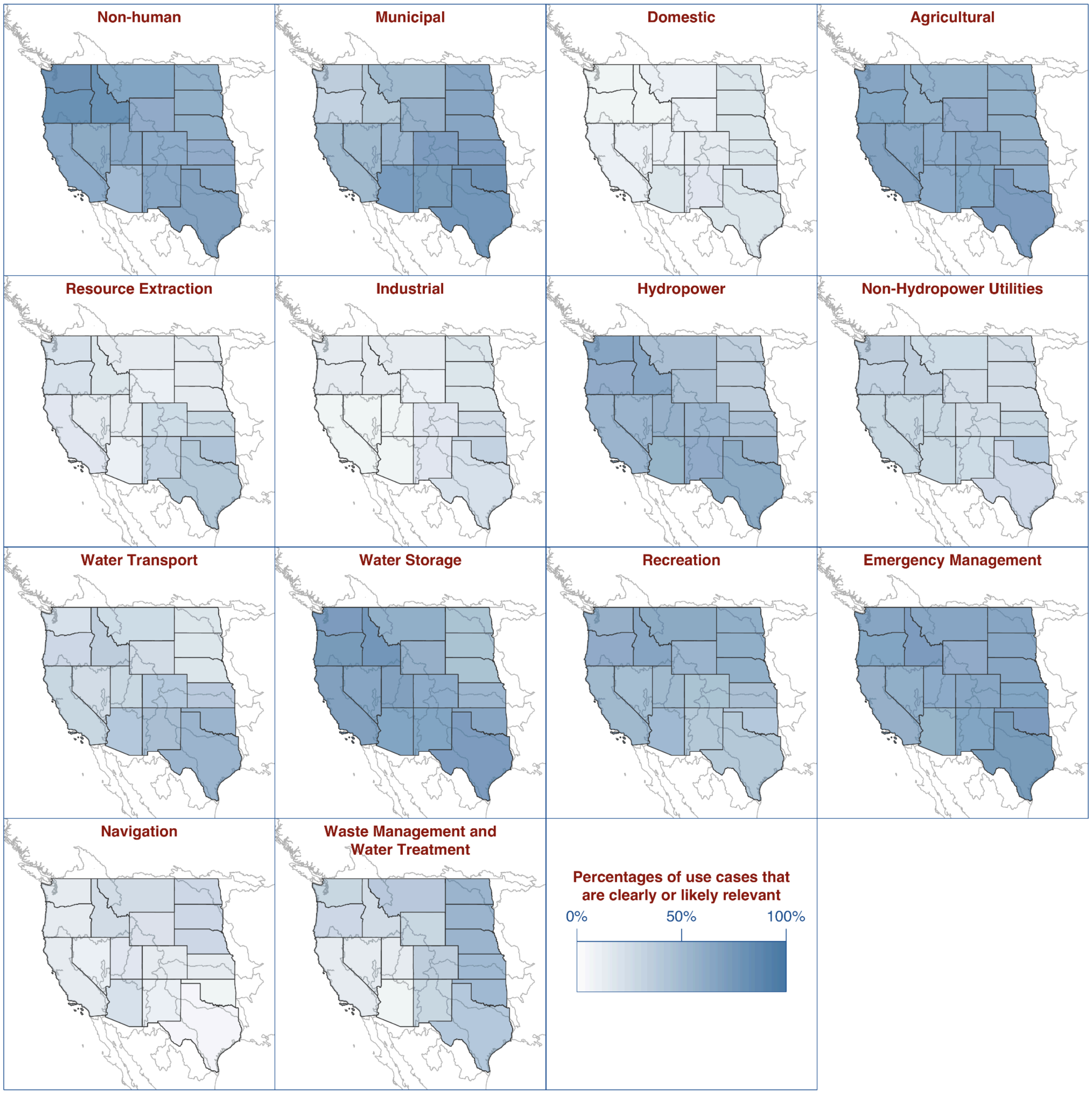

Figure A4-7. Percentages of WWAO-documented use cases related to distinct types of water use segmented by use case relevance to Contiguous Western U.S. states.

Appendix IV: Great Basin Needs Assessment (2026)

While some of the findings from the May 2025 Great Basin needs assessment dovetailed nicely into existing problem statements (*see* Appendix V, below), there are some elements of the Great Basin that stand out as unique compared to other basins in the west. The following slidedeck highlights some of the most salient convergences with earlier findings and divergences as well, as well as potential opportunity areas.

2025 Great Basin Needs Assessment Workshop

Divergence and Convergence - Cross-Basin Analysis

January 2026

WWAO Needs Assessment Overview

- Between 2016-2024 WWAO conducted **six basin needs assessments:**
  - Rapid Needs Assessment (not basin specific)
  - Upper and Lower Colorado Basin
  - Pacific Northwest Basin
  - Rio Grande Basin
  - Missouri Basin
  - Arkansas-White-Red Basin

- These needs assessments produced **108 use cases** that generally fall into five clusters:
  - Groundwater
  - Watershed health
  - Agriculture, Irrigation, and Evapotranspiration
  - Precipitation, Drought, and Reservoirs
  - Runoff, Streamflow, and Water Availability

Western Water Action Office

WWAO Needs Assessment Overview.

- March 2025 - WWAO conducts a Cross-Basin analysis and finds:
  - **Themes**: challenges identified in each cluster found across multiple basins
  - **Opportunity Zones**: strategic areas where NASA's scientific capabilities can be directly applied to bridge the critical gaps identified by water managers
- November 2025 - WWAO completes a **final needs assessment for the Great Basin**
  - 17 additional use cases are developed
- The Great Basin Needs Assessment finds areas of convergence with other needs assessments, while uncovering **unique needs and opportunities** in the Great Basin.

Western Water Action Office

Great Basin Needs Assessment Use Cases

Water Infrastructure and Measurement
- Understanding Changing Snowpack and SWE to Locate New Resilience Efforts Like Reservoirs.
- Closing the Delta Between Diversion Rights and Actual Diversions.
- Characterizing/Measuring Reservoir Capacity Across the Great Basin

Groundwater & Surface Water Interaction
- Understanding and Mapping Spatio-Temporal Connectivity Between Aquifers and Surface Water.
- Irrigation, Agriculture, and Their Interface with Surface and Groundwater.
- Balancing Water Supply and Use by Humans and Nature

Western Water Action Office

Great Basin Needs Assessment Use Cases

Watershed Health and Water Quality

- Post Disturbance Restoration for Ecosystem/Watershed Health
- Improved Access to Information for Rangeland Management and Forecasting
- Identifying Point and Nonpoint Source Pollution in Water

Hydro Climate Extremes, Variability, And Risk

- Better Drought Definition and Decision Framework
- Monitoring Wildfire Impacts on Air Quality, Water Quality, and Snow
- Impacts of Drying of Terminal Lakes, Dust, Air Quality, and Albedo
- Flood Risk Characterization and Prediction

Western Water Action Office

Great Basin Needs Assessment Use Cases

Agriculture/Irrigation and Water Availability/Budget

- Gaps in Mid-Elevation Snow Monitoring
- Monitoring Inventory and Flow of Springs/Small Streams in the Great Basin
- Water Budget and Scenario Planning for Farmers
- Water Budget for Irrigation Water Suppliers

Western Water Action Office

Areas of Convergence - Agriculture & Irrigation

Theme Statements from the Cross-Basin Analysis:

- “We don’t know how much water crops are actually using.”
- "We need integrated, localized data to support smart scheduling."

Great Basin Alignment:

- **Use Case: Closing the Delta Between Diversion Rights and Actual Diversions**
  - Decisionmakers lack real-time data to reconcile "paper rights" with actual wet water diversions. This mirrors the cross-basin need for defensible, field-scale consumptive use data
- **Use Case: Water Budget and Scenario Planning**
  - End-users explicitly requested tools to "play around with water budget scenarios," aligning with the cross-basin theme that piecemeal data is insufficient; producers need synthesized, planning-grade tools.

Areas of Convergence - Groundwater

Theme Statement from the Cross-Basin Analysis:

- “Groundwater and surface water are deeply connected—but managed separately.”

Great Basin Alignment:

- **Use Case: Understanding and Mapping Spatio-Temporal Connectivity Between Aquifers and Surface Water**
  - The Great Basin needs assessment highlights the struggle to manage withdrawals in the Humboldt and Walker River basins where groundwater pumping depletes surface allocations. This validates the wider WWAO finding that legal frameworks often lag behind hydrologic reality.

Areas of Convergence - Snowpack and Runoff

Theme Statement from the Cross-Basin Analysis:

- "Snowpack and soil moisture are under-monitored—but central to everything."

Great Basin Alignment:

- **Use Case: Gaps in Mid-Elevation Snow Monitoring**
  - The Great Basin assessment identifies a critical data void below SNOTEL sites. This aligns with the Cross-Basin observation that current in-situ networks fail to capture spatial variability, particularly in transition zones.

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Areas of Divergence - The Unique Great Basin

The "Hydro-Air" Crisis – Water Management for Air Quality

The Unique Challenge: In most basins, "water quality" refers to algae or chemicals in the water. In the Great Basin, water shortages can create air quality problems.

Use Case: Impacts of Drying of Terminal Lakes, Dust, Air Quality, and Albedo

Specific Need: Monitoring "dust chemistry," "optical depth," and "visibility data."

Why it differs: Other WWAO use case clusters focus on water for consumption or habitat. This adds a "Public Health/Air Quality" dimension to water management not seen in other assessments.

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Areas of Divergence - The Unique Great Basin

The "Wet Winter" Wildfire Paradox

The Unique Challenge: Standard models assume drought drives fire. The Great Basin sees the opposite: precipitation drives fuel growth (invasive grasses), which creates fire risk in grasslands, especially after a dry spring or early summer.

Use Case: Monitoring Wildfire Impacts on Air Quality, Water Quality, and Snow

Specific Need: Data models that capture "fuel loads generated by precipitation" rather than just drought stress.

Why it differs: This inverts the standard "Precipitation & Drought" logic found in other basins, requiring a fundamental shift in how risk is modeled.

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Areas of Divergence - The Unique Great Basin

Inventory vs. Monitoring – The Search for "Lost" Water

The Unique Challenge: Other basins monitor known water assets as they move across the landscape and are used. The Great Basin has "lost" water sources that must be re-discovered.

Use Case: Monitoring Inventory and Flow of Springs/Small Streams

Specific Need: An inventory of ephemeral and perennial springs using high-resolution imagery to detect "wetness anomalies."

Why it differs: This is a "discovery" use case, whereas the existing Groundwater use case cluster focuses on the quantification of known aquifers.

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Opportunity Zone 1 – Dust & Health Monitor

Opportunity Zone Identified in Cross-Basin Assessment: Monitor algae and mine leaks.

New Great Basin Opportunity Zone: Deploy hyperspectral and atmospheric sensors (e.g., EMIT, PACE) to monitor exposed lake beds.

Action: Correlate water surface extent with aerosol optical depth and dust chemical composition to issue public health warnings for communities downwind of terminal lakes.

Opportunity Zone 2 – Spring Discovery

Opportunity Zone Identified in Cross-Basin Assessment: Improve resolution of groundwater models.

New Great Basin Opportunity Zone: Develop "Wetness Anomaly" detection for inventory creation.

Action: Use high-resolution NISAR or thermal data to identify small, unmapped springs and seeps in arid rangelands that serve as critical biodiversity anchors.

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Opportunity Zone 3 – Scenario Planning Tool

Opportunity Zone Identified in Cross-Basin Assessment: Deliver daily ET data.

New Great Basin Opportunity Zone: Move from "Data Delivery" to "Scenario Planning."

Action: Create tools that allow producers to input "what-if" scenarios (e.g., "If I plant alfalfa vs. soy with X acre-feet of water..."). Great Basin farmers specifically requested the ability to "test" decisions before planting, moving beyond passive data consumption.

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Opportunity Zone 4 – Mid-Elevation Snow Monitor

Opportunity Zone Identified in Cross-Basin Assessment: Basin-wide SWE products.

New Great Basin Opportunity Zone: Target the "Transition Zone" Blind Spot (<500m resolution).

Action: Develop specific snow products for the "toe slope" and mid-elevation zones (below SNOTEL) which are uniquely critical in the Basin's north-south mountain ranges. This requires distinguishing north/south facing slope melt rates at a finer scale than general basin models.

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Appendix V: Use Case Clusters (2026 Update)

This appendix consolidates information across the various assessments into "problems to be solved" from the end user's perspective, as opposed to technical hurdles to be achieved (e.g., higher spatial/temporal resolution). Each use case cluster is supported by at least two use cases from the assessments, which are described below the description of the problem to be solved.

Focus Area 1: Subsurface Storage & Groundwater Management

Key Themes

Groundwater acts as an essential buffer for surface water shortages across the West, but local water management entities frequently lack the precise tracking data, subsurface observations, and modeling tools required to handle the resource sustainably. These cross-cutting use cases illustrate how cross-system integration might resolve core administrative blind spots where data is sparse, episodic, or otherwise restricted.

Use Case Clusters

- **Quantifying exact groundwater pumping volumes and aquifer depletion trends remains highly uncertain due to a heavy reliance on unmetered or unverified self-reporting systems.**
    - *Informed by:* **Arkansas-White-Red 2024 Report** (Focus Area B, Use Case B-1), where basins face severe water balance modeling limitations because actual irrigation pumping values are unrecorded or loosely inferred based on seasonal crop harvests.
    - *Informed by:* **Great Basin 2026 Report** (Focus Area B, Use Case B-2), which documents that missing regional well measurement networks prevent water managers from confirming field-level agricultural consumption metrics.
    - *Informed by:* **Rio Grande 2022 Report** (Focus Area B, Use Case B-1), which notes that volumetric water conservation monitoring is limited because ground-truthing relies on inconsistent, non-standardized field entries.
- **Physical well-monitoring networks are too sparse and updated too infrequently to track peak seasonal agricultural drawdown or support continuous localized modeling arrays.**
    - *Informed by:* **Arkansas-White-Red River Basin 2024 Report** (Focus Area B, Use Case B-2), which addresses the reality that most monitored wells lack automated data loggers and are manually checked only once or twice a year.

  - *Informed by:* **Rio Grande River Basin 2022 Report** (Focus Area A, Use Case A-3), detailing how continuous budget cuts have forced agencies to scale back instrumentation, leaving heavy data gaps along narrow river corridors.
  - *Informed by:* **2016 Rapid Needs Assessment Report** (Section 4.1.2), which emphasizes that regional in-situ sensors lack the spatial coverage necessary to trace sudden aquifer declines across vast public and private landscapes.
- **Determining the precise spatio-temporal connectivity between aquifers and surface water bodies is critical for State Engineers who must regulate water rights as a single, connected hydrologic system.**
  - *Informed by:* **Great Basin 2026 Report** (Focus Area B, Use Case B-3), which highlights how groundwater pumping inadvertently reduces neighboring river flows for senior rights holders, causing severe legal contention.
  - *Informed by:* **Columbia River Basin 2020 Report** (Section 4.3.2), outlining how baseline reconnaissance models are stuck using 1960s methodology (assuming recharge strictly equals discharge) due to a complete lack of high-resolution spatial metrics.
  - *Informed by:* **Arkansas-White-Red River Basin 2024 Report** (Focus Area B, Use Case B-4), where existing methods to model river-aquifer exchange rely on spatially coarse assumptions that fail to characterize ephemeral channels.
- **Emerging industrial water demands and extensive deep-earth pumping create severe management friction with adjacent agricultural, tribal, and municipal groundwater users.**
  - *Informed by:* **Great Basin 2026 Report** (Focus Area B, Use Case B-3), where expanding critical mineral extraction (such as water-intensive lithium mining) directly threatens ancient spring flows and tribal reservation connectivity.
  - *Informed by:* **Arkansas-White-Red River Basin 2024 Report** (Focus Area B, Use Case B-5), which outlines how massive multi-well arrays irrigation pumping across regions like the Llano Estacado outpaces natural replenishment while planning models operate on conservative assumptions that treat recharge as zero.

Focus Area 2: Climate Volatility & Hydroclimate Extremes

Key Themes

Shifting climate trajectories in the Western United States generate severe non-stationary fluctuations in water supply, making planning frameworks based entirely on historical stationary averages obsolete. Practitioners require predictive data tools that anticipate extreme environmental anomalies, flash landscape degradation, and sudden variations in water storage parameters to manage municipal allocations and emergency responses effectively.

Use Case Clusters

1. **Operational monitoring systems lack the integrated tools necessary to handle compound "drought-flood whiplash" cycles, where severe post-drought ground parching or fire damage directly amplifies immediate flash runoff and severe erosion.**
   - *Informed by:* **Arkansas-White-Red River Basin 2024 Report** (Focus Area F, Use Case F-3), which details how extreme drought drops regional vegetation cover, accelerating flash runoff and sediment erosion when rainfall occurs.
   - *Informed by:* **Great Basin 2026 Report** (Focus Area A, Use Case A-2), where rapid, unpredicted swings between multi-year drought dry downs and sudden heavy pluvial water years exceed the adaptive boundaries of historical infrastructure design.
2. **Broad, regional scale drought classification indices fail to reflect real-world operational conditions, resulting in economic or regulatory penalties for local livestock and land managers.**
   - *Informed by:* **Great Basin 2026 Report** (Focus Area A, Use Case A-1), where standard drought portrayals (like the U.S. Drought Monitor) enforce land restrictions on public grazing parcels even when localized seasonal rains have produced adequate forage.
   - *Informed by:* **Arkansas-White-Red River Basin 2024 Report** (Focus Area F, Use Case F-2), which outlines how lagging, coarse indices fail to catch the immediate, real-time onset of rapid "flash droughts" or track localized plant moisture deficits.
3. **Water resource planners struggle to distinguish temporary, cyclical weather droughts from permanent, long-term regional aridification when structuring long-range storage and municipal zoning standards.**
   - *Informed by:* **Great Basin 2026 Report** (Focus Area A, Use Case A-3), which notes that extreme seasonal drying cycles are shifting historical ecological baselines, leaving planners uncertain about whether trends represent temporary shortage or long-term climate trajectories.
   - *Informed by:* **2016 Rapid Needs Assessment Report** (Introduction), which states that the fundamental physical processes by which water resources are managed across western mountains were designed to track short-term seasonal changes rather than account for shifting long-term climate dynamics.

Focus Area 3: Agricultural Consumption, Crop Mapping & Evapotranspiration

Key Themes

Agricultural irrigation represents the vast majority of water consumption in the Western United States, yet water right operators and districts routinely manage allocations using coarse paper logs or outdated temperature-based math. Transitioning to sustainable water accounting requires field-scale, low-latency imagery that can map crop distributions, verify active irrigation methods, and track actual evapotranspiration (ET) over vast terrains.

Use Case Clusters

1. **The absence of standardized, field-scale actual evapotranspiration (ET) metrics forces state engineers and irrigation districts to administer water markets and water rights transfers using crude approximations.**
    - *Informed by:* **Columbia River Basin 2020 Report** (Focus Area 4.1.2), which outlines how fragmented ET calculation methods across state boundaries complicate shared hydrologic models and fuel legal conflict over active water transfers.
    - *Informed by:* **Great Basin 2026 Report** (Focus Area B, Use Case B-2), where regulators require highly precise actual depletion data to handle water valuation and prevent the permanent dry down of terminal lakes.
    - *Informed by:* **Colorado River Basin 2018 Report** (Appendix IV, Use Case B-3), which documents how state agencies are hampered by the fact that upstream water-rights users rely entirely on unverified self-reported consumption totals.
2. **Inconsistent spatial and seasonal crop type tracking requires water management agencies to expend massive, costly staff resources on physical "windshield surveys."**
    - *Informed by:* **Columbia River Basin 2020 Report** (Focus Area 4.1.1), documenting that while manually driving rural roads captures crop status, neighbor states lack the personnel to maintain continuous spatial data over cross-border sub-basins.
    - *Informed by:* **Colorado River Basin 2018 Report** (Appendix IV, Use Case B-5), where local water suppliers must run land surveys up to three times a year because broad county-scale data fails to separate crop varieties or track fallowed field boundaries.
    - *Informed by:* **2016 Rapid Needs Assessment Report** (Section 4.2.1), which notes that a primary stakeholder priority is an operational ET product capable of automatically resolving individual agricultural field footprints across entire states.
3. **Individual agricultural producers encounter major time and technological barriers when attempting to integrate open-source water budget models into real-world farming practices.**
    - *Informed by:* **Great Basin 2026 Report** (Focus Area C, Use Case C-3), which addresses how water data is decentralized across multiple interfaces, lacking the simplified, mobile-friendly user experience (UX) required for daily decision-making.

- *Informed by:* **Missouri River Basin 2023 Report** (Focus Area C, Use Case C-2), which details how information delays (such as multi-week latency loops in daily timestep files) limit a grower's ability to use models for immediate irrigation scheduling.
- *Informed by:* **Columbia River Basin 2020 Report** (Focus Area 4.1.3), where data adoption by smaller farms depends entirely on delivery format, noting a 70 percent spike in user engagement once information was delivered via an automated daily email system.

Focus Area 4: Water Infrastructure & Operational Measurement

Key Themes

Aging water storage structures, unmonitored canal networks, and rigid historical safety manuals severely limit water utility performance across western basins. Transitioning to proactive infrastructure monitoring requires automated terrain mapping, high-frequency radar verification, and centralized data pipelines to prevent unpermitted system failure and limit water loss.

Use Case Clusters

1. **Small and medium-sized reservoirs located in remote or rural areas completely lack active ground sensors or bathymetric records, which distorts runoff capacity estimates.**
    - *Informed by:* **Missouri River Basin 2023 Report** (Focus Area B, Use Case B-1), where remote stock ponds, prairie potholes, and mountain lakes are un-gauged, meaning their retention capacity is missing from flood-preparedness forecasts.
    - *Informed by:* **Great Basin 2026 Report** (Focus Area D, Use Case D-1), where managing flash floods and overtopping events is hampered because local managers must estimate storage capacity using physical surveys taken when reservoirs are frozen.
    - *Informed by:* **Colorado River Basin 2018 Report** (Appendix IV, Use Case B-4), where state models use static parameters that fail to evaluate how climbing regional temperatures accelerate evaporative loss across reservoir surfaces.
2. **Watermasters and ditchriders distribute regional supplies without real-time tracking data on canal velocities or field wetness, creating an operational gap between legal paper water rights and physical wet water diversions.**
    - *Informed by:* **Great Basin 2026 Report** (Focus Area D, Use Case D-2), which details how a lack of field-level diversion data forces system operators to allocate water using phone logs and anecdotal impressions, driving resource hoarding.
    - *Informed by:* **Arkansas-White-Red River Basin 2024 Report** (Focus Area D, Use Case

D-2), where groundwater and surface water availability models are hampered by gross approximations of local use.
   - *Informed by:* **Rio Grande River Basin 2022 Report** (Focus Area B, Use Case B-2), detailing how the lack of automated, digitized inflow/outflow metrics makes it difficult to parse out crop water consumption from structural seepage along unlined earthen canals.

3. **Tribal and rural communities completely lack integrated remote tracking systems to rapidly isolate wastewater infrastructure failures or spot early-stage unpermitted effluent leaks into public streams.**
   - *Informed by:* **Arkansas-White-Red River Basin 2024 Report** (Focus Area E, Use Case E-2), which addresses how local health authorities must handle wastewater treatment plant breakdowns using word-of-mouth citizen complaints after rivers are already heavily contaminated.
   - *Informed by:* **Missouri River Basin 2023 Report** (Focus Area D, Use Case D-5), mapping how un-monitored sludge deposits and concentrated animal feeding operations create chronic, hidden seepage fields that leak organic pathogens into local shallow groundwater tables.
   - *Informed by:* **2016 Rapid Needs Assessment Report** (Section 4.1.2), which details how land subsidence from drawing down underlying aquifers directly threatens the physical integrity of surface water aqueducts and levee walls.

Focus Area 5: Runoff, Headwater Stream Dynamics & Snow Architecture

Key Themes

Runoff efficiency and alpine snowpack structures are undergoing complex environmental changes due to shifting baselines and wildfire impacts. Operational water managers require spatially continuous snowpack, soil moisture, and channel geomorphology metrics at a sub-basin scale to optimize reservoir storage goals and protect downstream communities.

Use Case Clusters

1. **Traditional mountain monitoring arrays fail to measure the mid-elevation zones where early seasonal melting, volatile rain-on-snow events, and initial runoff partitioning take place.**
   - *Informed by:* **Great Basin 2026 Report** (Focus Area C, Use Case C-1), which maps the

critical information gap below high-altitude SNOTEL sites but above valley-floor shores, distorting early spring water budget calculations.

- *Informed by:* **Rio Grande River Basin 2022 Report** (Focus Area A, Use Case A-1), which documents that rain-snow transition bands lack adequate in-situ sensing density, forcing managers to calculate river compact deliveries based on incomplete data.
- *Informed by:* **2016 Rapid Needs Assessment Report** (Section 4.1.1), which outlines the systemic regional challenge of moving rain-to-snow transition zones migrating upslope across western mountain ranges.

2. **Hydrologists cannot easily characterize streamflow permanency, low-flow base volumes, or temperature dynamics in un-gauged headwaters, which hinders regulatory land-use permitting.**
    - *Informed by:* **Columbia River Basin 2020 Report** (Focus Area 4.3.4), where standard regression models for un-gauged channels introduce high statistical uncertainty, creating an urgent operational need for a binary "wet/dry" stream channel indicator.
    - *Informed by:* **Missouri River Basin 2023 Report** (Focus Area A, Use Case A-3), outlining how state fish and wildlife departments must manage fishing closures, evaluate timber harvest buffers, and schedule reservoir releases using raw professional judgment due to a lack of local headwater temperature sensors.
3. **Historically calibrated streamflow simulations cannot capture complex, modern environmental feedbacks, such as forest management alterations or regional dust deposition darkening winter snowpacks.**
    - *Informed by:* **Western Snow Conference 2025 Report** (Use Case #4), which addresses how forest thinning and canopy removal for wildland fire mitigation strips away shade, unexpectedly accelerating direct-solar snowmelt.
    - *Informed by:* **Rio Grande River Basin 2022 Report** (Focus Area A, Use Case A-1), showing how soil degradation and land changes in desert regions generate intense wind-blown dust events that deposit heavy particulate layers on mountain snow, dropping albedo reflectivity and scrambling runoff simulations.
    - *Informed by:* **2016 Rapid Needs Assessment Report** (Section 4.1.1), which outlines how growing population centers and shifting vegetation can cause early peak snowmelt cycles that override standard reservoir operating guidelines.