DISSERTATION

SHARING WATER ACROSS BOUNDARIES IN THE COLORADO RIVER BASIN:

MAPPING AGRICULTURAL POLICIES, DATA, AND PERSPECTIVES

Submitted by

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ABSTRACT

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Emerging institutional arrangements that incorporate water sharing indicate changes in both the political and environmental climate in the Colorado River Basin (CRB). These arrangements are geographically taking shape at the intersections of hydrologic, political, and sectoral boundaries. Water sharing arrangements (WSAs) foster an array of relationships between institutions and between actors and organizations responsible for designing and administering rules and policies, where the agricultural (Ag) sector is at the center of these arrangements. Water sharing provides a means to better understand different types of overlapping boundaries, contributing to new theories and methodologies about changes in governance. Therefore, the culmination of this research seeks to answer the question: w*hat is the role of boundaries in water sharing arrangements and their potential contribution to agricultural water governance in the Colorado River Basin?*

This dissertation presents three boundary studies of WSAs in the CRB, illuminating changes in governance related to increasing the legal and political capacity to share water under stressed conditions. A political boundary analysis shows emergent patterns in Ag water governance, patterns which resulted from a boundary typology incorporating physical, political, and sectoral boundaries. The boundary typology was applied to the other two studies: a geospatial analysis of water sharing arrangements and a case study in the CRB through interviews with farmers and Ag water managers of Bureau of Reclamation (USBR) projects. A geospatial analysis provides the necessary arena to geovisualize Ag water governance through

the introduction of governance layers. Governance layers are defined by two key components: (a) mandated or naturally occurring geographic boundaries and (b) decisions made based on those boundaries. The third study tests the application of the boundary typology and its innate connection to scale to better understand the geographic perspectives of farmers regarding changes in Ag water governance, especially as they relate to WSAs in the Basin. The focus of the interviews is on the USBR, specifically to better understand whether the USBR inhibits or encourages water sharing across hydrologic, political, and sectoral boundaries. Together these three studies demonstrate the importance of hydrologic, political, sectoral, and other boundaries in collective and individual decision-making by agricultural water users, irrigation districts, the state, and the federal government about water management for agriculture across the basin. In addition, boundaries, whether *bonafied* or *fiat,* can be spatialized, or localized in space. Finally, just as space is integral in understanding agricultural water governance, so is place, such as the places that support agriculture. Places throughout the CRB are changing. The boundaries that define place are shifting, making way for new opportunities like the water sharing arrangements that have revolutionized an aging system.

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IT IS TRULY UPON GIANTS I STAND!

DEDICATION

To Bryan

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CHAPTER 1 INTRODUCTION

This dissertation is an interdisciplinary study that demonstrates the relationship between geography, hydrology, and governance; especially as it pertain to rules and policies about agriculture in the Colorado River Basin (CRB). This relationship is shown in three ways: through (a) an analysis of water sharing arrangements (WSAs) which resulted in a boundary typology; (b) the application of the boundary typology in a geospatial environment exemplified by WSAs; and (c) an analysis of social perceptions through interviews with farmers, agricultural producers, and agricultural water managers in the Basin applying the boundary typology. The culmination of these analyses includes: a review of boundaries in political geography; a historical account of the shifting boundaries and policies in the CRB; the spatialization of agricultural (Ag) water governance that highlights the Colorado River Basin Water Governance Geodatabase; and farmers' perspectives on *fiat* and *bonafied* boundaries established by the Bureau of Reclamation, which may divide or unite farmers who have advocated for, challenged, shaped, and enforced the institutional system that governs agriculture in the CRB. The boundary typology seeks to explain discrepancies between the physical, political, and social (special interest) landscape that shape decisions surrounding Colorado River water. Because boundaries are the link between the hydrologic, political, social, and geographic disciplines, it is essential to situate the study of boundaries, borders, and the differences and similarities between the two in the literature. First, I will present the roadmap.

Roadmap

The dissertation is organized as a multipart thesis that consists of five chapters where each chapter is a separate unit with its own sections, tables and figures (which are listed consecutively before the references), references, and appendices. Although each chapter may be considered its own separate unit, each chapter builds upon the previous one and references are made between chapters throughout. The boundary typology as considered in the context of Ag water governance in the CRB region is the thread that joins all chapters together. The first chapter is an introduction to the dissertation, the second, third, and fourth chapters are written as individual articles to be submitted to the Journal of Social and Legal Studies, The Professional Geographer, and the Journal of the American Water Resources Association, respectively. The fifth chapter concludes the dissertation with personal reflections and contributions to the field of geography. The goal in maintaining consistency is to test the boundary typology triangulating upon three different perspectives and methodologies (political, geospatial, and social analyses) and units of analysis (policies, geospatial data, and interviews) to better understand the implications of boundaries on Ag water governance.

Boundaries in the Colorado River Basin

Expansion of agriculture in the U.S. West necessitated the movement of water across the landscape, transcending physical and political boundaries. One instructive way to analyze this complex governance system is by analyzing the intersection of federal and state jurisdictions with hydrologic boundaries through a transboundary analysis or across boundaries. The CRB provides an example of the evolution of boundaries and their impact on the landscape. To answer the question how have shifting political and hydrologic boundaries in the CRB impacted agricultural water governance, the second chapter: (a) proposes a typology of boundaries based on agricultural water governance in the CRB, (b) operationalizes the typology using water sharing arrangements within the CRB, (c) analyzes the changing nature and intersection between political and hydrologic boundaries, and (d) geospatially demonstrates emerging governance patterns and processes, which facilitate or inhibit water sharing across the basin. This research reveals that hydro-geopolitical boundaries at the state and federal level have become fuzzy, enabling water sharing arrangements. Second, the boundary typology coupled with geospatial representation reveals both political patterns and processes, especially as they pertain to Ag water governance. Third, the application of the boundary typology leads to a clearer understanding of water sharing, its challenges and benefits, patterns and processes, and decisions at multiple scales. Such an understanding informs the mechanics of governance in the agricultural sector, compounded by the governance complexities of other sectors, opening opportunities for continued scholarship on transboundary water sharing.

Chapter three responds to the need to better understand water governance as a geospatial phenomenon by describing the development of the Colorado River Basin Water Governance Relational Geodatabase for this dissertation, which (a) applies a boundary typology through a geographic information system and (b) proposes governance layers as a method to integrate governance data in a geospatial relational database. Results define geospatial governance characteristics and address challenges to mapping governance data including standardization, data availability, and geovisualization.

Chapter four focuses on the postulation that Bureau of Reclamation projects facilitate water sharing within and outside of the irrigation districts that manage them. As part of a research team, we conducted interviews with farmers to ask them what they think about the changes that are occurring around Ag water in the Basin. A subset of interviews was extracted to specifically examine the boundaries that exist across multiple scales of Ag water governance, from the federal government to the irrigation district, specifically as they relate to Bureau of Reclamation projects. Boundaries are defined as the social, political, and physical similarities or differences between two or more groups that can be geospatially represented. This study answers the questions: (a) what are the boundaries based on farmers' perspectives, (b) can those boundaries be geospatially represented, and (c) do they indicate the presence of water sharing. Results show that farmers talk about geographic boundaries (place) and as political or sectoral boundaries (space). After analyzing boundaries through a boundary typology, different types of boundaries emerge that are not inherently geospatial. However, by scaling farmers' boundary perspectives, it is possible to understand their geographic frame of reference, providing a glimpse of the opportunities for water sharing in Reclamation projects.

Boundary Studies: Traditions and Frontiers

A boundary, according to the Dictionary of Human Geography, is "a geographical *marker* and a geographical *maker* of regulative authority in social relations" (Gregory, Johnston, Pratt, Watts, & Whatmore, 2009, p. 55). Along similar lines, a border, referring back to the Dictionary is "a *form* of a boundary associated with the rise of the modern nation-state and the establishment of an inter-state geopolitical order, founded on the political norms of national states claiming and using terror to control territory . . ." (Gregory et al., 2009, p. 52). Although many geographers use these terms interchangeably, it is important to differentiate between them because boundary and border inquiries converge and diverge depending on context and transdiciplinarity. Hirsch Hadorn et al. (2008) describe four goals of transdisciplinary research that can easily be applied to the geographical discourse: (a) a way to grasp the complexity of problems, (b) an interest in taking into account the diversity of views of a problem, (c) implementation of methods to link abstract and case specific knowledge, and (d) special attention to problem solving for the public good. Geography has lent itself well to transdisciplinary research due to the nature (practical and theoretical) of the field, which is steeped in inquiry about humans (humanities) and time (history), space (spatial sciences), place (social, cultural, linguistic, and environmental sciences), and power (economics and political sciences). Boundary and borderland studies are at the core of geographic inquiry.

Contemporary boundary studies encompass discourse about territories and deterritorialization as well as other types of boundaries both conceptual (psychological, emotional) and physical. Cross-fertilization with geography has led to many inter- and trans-disciplinary studies and has contributed to the growing body of literature on borders and boundaries including sociology and anthropology (Pellow, 1996); feminism (Staeheli et al, 2004; Nelson and Seager 2005), institutions and common pool resources (Heikkila, 2004); law (De Souza Santos, 1987; Valverde, 2009; Blandy and Sibley, 2010); linguistics (Lundén and Zalamans 2001); economic and information sciences which focus on globalization or *glocalization* (the idea that global actions have local implications and vice versa) and the notion of a border-less world (Swyngedouw, 1997, 2009); and bioregional planning (Brunckhorst & Reeve, 2006; Brunckhorst, 2000; Eden, Donaldson, & Walker, 2006; Reeve & Brunckhorst, 2007). Theses on environmental governance in border regions such as environmental justice is the outcome of cross-disciplinary endeavors resulting in the identification of a niche in academia gaining attention in cultural, sociological, economic, geographic, and institutional studies (Blomquist, Schlager, & Heikkila, 2004; Fernandez & Carson, 2002; Laituri, 2002; Mumme, 2008; Swyngedouw, 1997; Whiteley, Ingram, & Perry, 2008)

An extension of boundary studies can be traced to transdisciplinary themes that include socio-ecological processes and systems (Berkes, Folke, & Colding, 1998; Cumming, Cumming, & Redman, 2006; Kemp-Benedict, Bharwani, & Fischer, 2010), socio-spatial scales (Collinge, 2005; Pellow, 1996), production of space (Helmig & Kessler, 2007), power relations (Allen, 2003), the geopolitics of exclusion (Herbert, 2009), and the hybrid production of environmental knowledge (Eden et al., 2006; Lejano & Ingram, 2009; Pahl-Wostl, 2002). All of these themes are instrumental to understanding the relationship between physical and anthropogenic boundaries (Collinge, 2005; Kemp-Benedict et al., 2010; Pellow, 1996) common both in the environment and in the conceptual landscape or space within which humans create, exist, and behave. Outside of the political and social realms of scholarship, the organization and management sciences have long indicated the importance of geographic boundaries (Ashkenas, Ulrich, Jick, & Kerr, 2002). Since the electronic age and the expansion of relationships across time and space via technology and the internet through information sciences or cyber scholars, geographical boundaries or lack thereof have become one of the foremost tenets of understanding social organization (Sternlieb, Bixler, Huber-Stearns, & Huasca, 2013).

Boundary/border studies can also be evaluated geographically through regions. Some of the most renown studies are situated in and around the U.S. Mexico border (Mumme, 2008), Eastern Europe (Lundén & Zalamans, 2001), Russia and the historic Soviet Union Bloc, East and West Germany, Israel and Palestine (Feitelson & Fischhendler, 2009; Fischhendler, 2008) as well as thematic issues surrounding public health, environmental governance/justice, immigration (Herbert, 2009), ethnicity, peace, and conflict (Dinar, Dinar, McCaffrey, & McKinney, 2007; Wolf, 1998) and rural and urban settings (Petts, Owens, & Bulkeley, 2008). Studies on boundaries that are focused on geographic regions are indications that *geography* is at the core of border and boundary studies, just as the reverse is true, and is inherently linked to political and social processes.

The differences between boundary and border studies manifest in the historical and contemporary literature. Traditionally, the study of borders describes the historical, conceptual, descriptive, and analytical accounts regarding the role of boundaries in both geography and political science (Newman, 2006). Borderland studies capture the differences and interactions of people normally along an international boundary, from regions divided by political administration and delineated by jurisdiction at any scale across a spatial plain (Boggs, 1966; Guston, Jones, & Branscomb, 1997; Guston, 2001; Morehouse, 1996; Newman, 2006; Pavlakovich-Kochi, Morehouse, & Wastl-Walter, 2004). Border and borderland studies often focus on territoriality and deterritorialization, "a growing tendency for states to encounter and often encourage an uprooting of people and thinking with massive social, psychological, and political consequences" (Gregory et al., 2009, p. 745). Questions about sovereignty and power manifestations often result in the analyses of processes and patterns in territorial and deterritorialization cases (Alam, Dione, & Jeffrey, 2009).

Boundaries, on the other hand, are traditionally defined as "highly visible lines that constitute the physical separation between political, social, and economic spaces" (Newman, 2006, p. 144). Such boundaries define a person's understanding of space and decisions about how to use that space until its characteristics change (Morehouse, 1996) causing a spiral effect in change of resources, actors, and rules. Multiple people may use any one space for different purposes over a temporal and spatial extent causing the need for new rules by various actors. *Fiat* or human-demarcation-induced boundaries (e.g. cultural and social practices and organization; places and languages) and *bona fide* or physical boundaries (e.g. geologic formations, ecosystems, and climatic regions) define the relationships that exist between actors in a particular place, at a particular time (Sternlieb et al., 2013). Boundaries, whether actual or conceptual, often manifest themselves over the landscape in geographical (Sheppard & McMaster, 2004) and political patterns through social, political, cultural, and/or economic processes (Ingram, 1990).

Scholars debate whether the field is lacking a theoretical framework to understand changing boundaries in the political and social landscape over hundreds of years. Maps and narratives account for these changes (Newman, 2003). One obstacle in developing such a framework is that boundaries are considered social and political constructs (Newman, 2003; Pavlakovich-Kochi et al., 2004) and are dependent on the social and political milieu of the times. Conceptual terminology that describe boundaries and their social constructs include scale (Cash et al., 2006; Howitt, 2003; Kok & Veldkamp, 2011; Lebel, Garden, & Imamura, 2005; Wallis, Mac Nally, & Langford, 2011), power (Allen, 2003; Spalding, 2002) and place (Morehouse, 1996; Sauer, 1963 [1925]; Staeheli, 2003). These three tenets of geography provide an entryway to understand the "space of flows" (Agnew, Mitchell, & Toal, 2003; Pavlakovich-Kochi et al., 2004) not just movements, forces, and circulation of things, people, and ideas (Taylor 2008, Saunier 2004).

Institutions that govern the environment across a multitude of boundaries (such as WSAs) define how people behave, respond, interpret, communicate, and share natural resources. People who occupy the space within these boundaries may draw upon different knowledge systems or epistemologies including but not limited to science, law, bureaucracy, economy, culture, and religion (Morehouse, 1996) as well as different languages or terms that could strengthen or weaken relationships. These studies show that WSAs are dependent on shifting boundaries. Power transfers from one group to another with the movement of boundaries as can be seen in the CRB. The growing body of literature on boundaries has illuminated the critical interplay between ecosystem function, in this case hydrologic capacity, and institutional forms and functions (Brunckhorst & Coop, 2001; Folke, Pritchard, Berkes, Colding, & Svedin, 2007; Huitema et al., 2009; Spalding, 2002), providing a better understanding of changes in water governance. It is in this context that water sharing arrangements are an exemplary governance mechanism through which to analyze boundaries. In the CRB, WSAs have a long history and may very well dictate the future of agricultural water governance.

REFERENCES

Agnew, J., Mitchell, K., & Toal, G. (Eds.). (2003). *A companion to political geography*. Malden: Blackwell Publishing.

Alam, U., Dione, O., & Jeffrey, P. (2009). The benefit-sharing principle: Implementing sovereignty bargains on water. *Political Geography, 28*, 90-100.

Allen, J. (2003). Power. In J. Agnew, K. Mitchell & G. Toal (Eds.), *A companion to political geography* (pp. 95-108). Malden: Blackwell Publishing.

Ashkenas, R., Ulrich, D., Jick, T., & Kerr, S. (2002). *The boundaryless organization: Breaking the chains of organizational structure*. San Francisco, CA: John Wiley & Sons, Inc.

Berkes, F., Folke, C., & Colding, J. (1998). *Linking social and ecological systems: management practices and social mechanisms for building resilience*. Cambridge, U.K.; New York, NY, USA: Cambridge University Press.

Blandy, S., & Sibley, D. (2010). Law, Boundaries and the Production of Space. *Social & Legal Studies, 19*(3), 275-284.

Blomquist, W., Schlager, E., & Heikkila, T. (2004). *Common waters, diverging streams: Linking institutions to water management in Arizona, California and Colorado*. Washington, D.C.: Resources for the Future.

Boggs, S. W. (1966). *International boundaries: A study of boundary functions and problems*. New York: AMS Press.

Brunckhorst, D., & Reeve, I. (2006). A geography of place: Principles and application for defining 'eco-civic' resource governance regions. *Australian Geographer, 37*(2), 147-166.

Brunckhorst, D. J. (2000). *Bioregional planning: Resource managament beyond the new mllennium*. Amsterdam: Harwood Academic.

Brunckhorst, D. J., & Coop, P. (2001). The Influence of social eco-logics in shaping novel resource governance frameworks. In G. Lawrence, V. Higgins & S. Lockie (Eds.), *Environment, Society and Natural Resource Management: Theoretical Persepctives from Australasia and the Americas*. Cheltenham: Edward Elgar.

Cash, D. W., Adger, W. N., Berkes, F., Garden, P., Lebel, L., Olsson, P., . . . Young, O. (2006). Scale and cross-scale dynamics: Governance and information in a multilevel world. *Ecology and Society, 11*(2), 8.

Collinge, C. (2005). The difference between society and space: Nested scales and the retums of spatial fetishism. [Article]. *Environment and Planning D-Society & Space, 23*(2), 189-206.

Cumming, G. S., Cumming, D. H. M., & Redman, C. L. (2006). Scale mismatches in social-ecological systems: Causes, consequences, and solutions. *Ecology and Society, 11*(1).

De Souza Santos, B. (1987). Law: A map of misreading. Towards a postmodern conception of law. *Journal of Law and Society, 14*, 297-302.

Dinar, A., Dinar, S., McCaffrey, S. C., & McKinney, D. (2007). *Bridges Over Water: Understanding Transboundary Water Conflict, Negotiation and Cooperation* (Vol. 3). Singapore: World Scientific Publishing.

Eden, S., Donaldson, A., & Walker, G. (2006). Green groups and grey areas: Scientific boundary-work, nongovernmental organisations, and environmental knowledge. *Environment and Planning A, 38*(6), 1061-1076.

Feitelson, E., & Fischhendler, I. (2009). Spaces of Water Governance: The Case of Israel and Its Neighbors. *Annals of the Association of American Geographers, 99*(4), 728-745.
Fernandez, L., & Carson, R. T. (Eds.). (2002). *Both sides of the border: Transboundary environmental management, issues facing Mexico and the United States*. Dordrecht: Kluwer Academic Publishers.
Fischhendler, I. (2008). Ambiguity in transboundary environmental dispute resolution: The Israeli Jordanian water agreement. *Journal of Peace Research, 45*(1), 91-109.
Folke, C., Pritchard, J., L., Berkes, F., Colding, J., & Svedin, U. (2007). The problem of fit between ecosystems and institutions: Ten years later. *Ecology and Society, 12*, 1-30.
Gregory, D., Johnston, R., Pratt, G., Watts, M. J., & Whatmore, S. (Eds.). (2009). *The dictionary of human geography* (5th ed.). Malden, MA: Wiley-Blackwell.
Guston, D., Jones, M., & Branscomb, L. (1997). Universities and legislatures: Toward a better relationship. *Ieee Technology and Society Magazine, 16*(3), 5-6.
Guston, D. H. (2001). Boundary organizations in environmental policy and science: An introduction. *Science Technology & Human Values, 26*(4), 399-408.
Heikkila, T. (2004). Institutional boundaries and common-pool resource management: A comparative analysis of water management programs in California. *Journal of Policy Analysis and Management, 23*(1), 97-117.
Helmig, J., & Kessler, O. (2007). Space, Boundaries, and the Problem of Order: A View from Systems Theory. *International Political Sociology, 1*(3), 240-256.
Herbert, S. (2009). Contemporary geographies of exclusion II: Lessons from Iowa. *Progress in Human Geography, 33*(6), 825-832.
Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., . . . Zemp, E. (Eds.). (2008). *Handbook of transdisciplinary research*. Online: Springer Netherlands.
Howitt, R. (2003). Scale. In J. Agnew, K. Mitchell & G. Toal (Eds.), *A Companion to Political Geography* (pp. 138-157). Malden: Blackwell Publishing.
Huitema, D., Mostert, E., Egas, W., Moellenkamp, S., Pahl-Wostl, C., & Yalcin, R. (2009). Adaptive water governance: Assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. *Ecology and Society, 14*(1), 26.
Ingram, H. (1990). *Water Politics: Continuity and Change*. Albuquerque: University of New Mexico Press.
Kemp-Benedict, E. J., Bharwani, S., & Fischer, M. D. (2010). Using matching methods to link social and physical analyses for sustainabiltity planning. *Ecology and Society, 15*(3), 14.
Kok, K., & Veldkamp, T. A. (2011). Scale and governance: Conceptual considerations and practical implications. *Ecology and Society, 16*(2), 23.
Laituri, M. (2002). Equity and access to GIS for marginal communities. In W. Craig, T. Howard & D. Weiner (Eds.), *Community empowerment, public participation and Geographic nformation Science* (pp. 270-282). London: Taylor and Francis.
Lebel, L., Garden, P., & Imamura, M. (2005). The politics of scale, position, and place in the governance of water resources in the Mekong region. *Ecology and Society, 10*(2), -.
Lejano, R. P., & Ingram, H. (2009). Collaborative networks and new ways of knowing. *Environmental Science & Policy, 12*(6), 653-662.

Lundén, T., & Zalamans, D. (2001). Local co-operation, ethnic diversity and state territoriality – The case of Haparanda and Tornio on the Sweden – Finland border. *GeoJournal, 54*(1), 33-42.
Morehouse, B. J. (1996). *A place called Grand Canyon: Contested geographies*. Tuscon: University of Arizona Press.
Mumme, S. P. (2008). From equitable utilization to sustainable development: Advancing equity in water management on the U.S.-Mexico border. In H. Ingram, R. Perry & J. Whitely (Eds.), *Water, Place and Equity: Fair Practice in Apportioning Water among Places and Values* (pp. 117-146). Cambridge: MIT University Press.
Nelson, L., & Seager, J. (2005). A companion to feminist geography. Malden, MA: Blackwell Pub.
Newman, D. (2003). Boundaries. In J. Agnew, K. Mitchell & G. Toal (Eds.), *A Companion to Political Geography* (pp. 123-137). Malden: Blackwell Publishing.
Newman, D. (2006). The lines that continue to separate us: Borders in our 'borderless' world. *Progress in Human Geography, 30*(2), 143-161.
Pahl-Wostl, C. (2002). Towards sustainability in the water sector - The importance of human actors and processes of social learning. *Aquatic Sciences, 64*(4), 394-411. doi: 10.1007/pl00012594
Pavlakovich-Kochi, V., Morehouse, B. J., & Wastl-Walter, D. (Eds.). (2004). *Challenged borderlands: Transcending political and cultural boundaries*. Aldershot: Ashgate Publishing.
Pellow, D. (1996). *Setting boundaries the anthropology of spatial and social organization*. Westport, Conn.: Bergin & Garvey.
Petts, J., Owens, S., & Bulkeley, H. (2008). Crossing boundaries: Interdisciplinarity in the context of urban environments. *Geoforum, 39*(2), 593-601.
Reeve, I., & Brunckhorst, D. (2007). Spatially bounded regions for resource governance *Australian Journal of Environmental Management, 14*, 39-51.
Sauer, C. O. (1963 [1925]). Land and life: A selection from the writings of Carl Ortwin Sauer. In J. B. Leighly (Ed.). Berkeley, CA: University of California Press.
Sheppard, E. S., & McMaster, R. B. (2004). *Scale and geographic inquiry: Nature, society, and method*. Malden, MA: Blackwell Pub.
Spalding, M. J. (2002). Improving insitutional response to environmental problems. In L. Fernandez & R. T. Carson (Eds.), *Both Sides of the Border: Transboundary Environmental Management, Issues Facing Mexico and the United States* (pp. 15-28). Dordrecht: Kluwer Academic Publishers.
Staeheli, L. A. (2003). Place. In J. Agnew, K. Mitchell & G. Toal (Eds.), *A Companion to Political Geography* (pp. 158-170). Malden: Blackwell Publishing.
Saunier, P.-Y. (2006). Going transnational? News from down under: Transnational History Symposium, Canberra, Australia National University, September 2004. *Historical Social Research, 31*(2), 118-131.
Sternlieb, F., Bixler, R. P., Huber-Stearns, H., & Huasca, C. a. (2013). A question of fit: Reflections on boundaries, organizations and social-ecological systems. *Journal of Environmental Management, 130*, 117-125.
Swyngedouw, E. (1997). Neither global nor local: 'Glocalization' and the politics of scale. In K. Cox (Ed.), *Spaces of Globalization: Reasserting the Power of the Local* (pp. 137-166). New York/London: Guilford/Longman.

Swyngedouw, E. (2009). The political economy and political ecology of the hydro-social cycle. *Journal of Contemporary Water Research and Education*(142), 56-60.
Taylor, J. E. (2008). Boundary terminology. *Environmental History, 13*(3), 454-481.
Wallis, P. J., Mac Nally, R., & Langford, J. (2011). Mapping local-scale ecological research to aid management at landscape scales. *Geographical Research, 49*(2), 203-216. Whiteley, J. M., Ingram, H. M., & Perry, R. W. (2008). Water, place, and equity *American and comparative environmental policy* Retrieved from http://www.netlibrary.com/urlapi.asp?action=summary&v=1&bookid=237778
Valverde, M. (2009). Jurisdiction and scale: Legal 'technicalities' as resources for theory. *Social & Legal Studies, 18*(2), 139-157.
Whiteley, J. M., Ingram, H. M., & Perry, R. W. (Eds.). (2008). *Water, place, and equity*. Cambridge, MA: MIT Press.
Wolf, A. (1998). Conflict cooperation along international waterways. *Water Policy, 1*(2), 251-265.

CHAPTER 2 SHIFTING BOUNDARIES AND POLICIES: A TRANSBOUNDARY ANALYSIS OF WATER SHARING IN THE COLORADO RIVER BASIN

Introduction: Water Sharing in the Colorado River Basin

The Colorado River Basin (CRB) represents an area that exhibits characteristics where physical, political, and social boundaries define the movement or transfer of water. There is variability in the types of boundaries within these different contexts. As the types of boundaries change, so does the complexity of arrangements that encourage (or force) water users in the agricultural (Ag) sector to share water through the apportionment and reallocation mechanisms such as compacts, appropriation systems, water markets and water banks, transfers, exchanges, sales, and other types of interactions (Brewer, Glennon, Ker, & Libecap, 2007; Grafton, Landry, Libecap, & O'Brien, 2009; Howe, 1985; Libecap, 2010; MacDonnell, Howe, Miller, Rice, & Bates, 1994; Saliba & Bush, 1987; Schuster, Colby, Jones, & O'Donnell, 2012; Squillace, 2013; Wahl, 1989). There are many forms of water sharing transactions that involve allocation and reallocation of water. In the modern age, most new water sharing arrangements involve reallocation of water from Ag to other sectors that also involve many overlapping jurisdictions across multiple geographic scales (e.g. international, interstate, and intrastate transactions) (Cash et al., 2006; Feitelson & Fischhendler, 2009). The term water sharing is also used to describe multiple facets of water quantity (e.g. shortages and surpluses), as well as benefits and costs (Draper, 2007; Jones & Colby, 2012). The key to water sharing in the CRB is that the majority of transactions occur through the agricultural sector because 75% of water is used by and for Ag (USBR, 2012). Therefore, to understand water sharing, which is used in this paper very broadly to mean the initial apportionment and the later reallocation of water across the landscape, a transboundary perspective of agricultural water governance is of essence.

Historically, water in the CRB has been a source of rich scholarship (Fiege, 1999; Hundley, 1966, 2009; Limerick, 2012; Stegner, 1954; Worster, 2001). Of particular importance to understanding water sharing in the CRB is the history of the U.S. Bureau of Reclamation (USBR) (deBuys, 2001; Hundley, 2009; Rowley, 2006; Storey, 2002; Worster, 1985). This history includes water transfers as they pertain to the USBR (MacDonnell, Wahl, & Driver, 1991a, 1991b) as well as the water policy and institutional change that has resulted from water transactions across the U.S. West (Blomquist, Schlager, & Heikkila, 2004; Frederick, 1986; Getches, 1997, 2001; Hobbs, 1997, 1999; Ingram, 1990; Kenney, 1995; Mann, 1964; Schlager & Blomquist, 2008; Wilkinson, 1992). Much of the institutional and governance literature on water in the CRB is focused on irrigation and the role of irrigation districts (Bretsen & Hill, 2006; Burt & Styles, 2000; Griffin, 2012; Griffin & Kelly, 2012; Leshy, 1982; Mead, 1903; Moore, 1991) due to the first uses of water and rules which formalized norms in agriculture. However, research on water sharing from a geographic perspective (Feitelson & Fischhendler, 2009; Fischhendler & Feitelson, 2003), especially regarding its impact on agriculture, remains in its nascent form.

This paper addresses this discrepancy by drawing from the theoretical underpinnings of federalism situated within a spectrum of governance patterns and processes, revealed through water sharing (Gerlak, 2005). Within the governance spectrum, geo-political patterns convey the nature of the jurisdiction and how it manifests itself geographically on the landscape. "Patterns are defining characteristics of a system and often, therefore, are indicators of essential underlying processes and structures" (Grimm et al., 2005, p. 987). One end of the governance spectrum is territorial sovereignty while the other is polycentrism (multiple and overlapping centers of power) and shades of federalism are situated in between (including cooperative and new federalism). According to some scholars, territorial sovereignty inhibits and polycentrism facilitates water sharing (Andersson & Ostrom, 2008; Derthick, 1974; Gerken, 2010; Ostrom, 2005). By identifying the prevalent geopolitical patterns (federalist, territorial sovereignty, hierarchical, and polycentric patterns) and the boundaries that distinguish them, governance structures and processes become evident. However, even the boundaries between patterns can be fuzzy where federalist and sovereign systems can be hierarchical.

To answer the question *how have political and hydrologic boundaries in the CRB changed over time and how do those changes relate to water sharing in the Ag sector*, this paper addresses the discrepancy between the theory and geography of water sharing by: (a) developing and applying a conceptual typology of boundaries based on CRB policies and agricultural literature using examples of water sharing arrangements that include Ag; and (b) conducting a geographical analysis of the changing nature and intersection between political and hydrologic boundaries. Results will demonstrate the types of boundaries that represent emerging governance patterns and processes.

The first section presents the origination of historical boundaries that evolved from the development of the West through agriculture and the observations on physical, political, and social (those distinguished by sector) boundaries by John Wesley Powell. The second section reviews the literature to help better understand the evolution of shifting boundaries due to governance regimes that favored political ideology rather than a hydro-geologic one. The third section will show the value of the typology in delineating boundaries between the agencies, organizations, and other types of overlapping jurisdictions prevalent and their authority in the CRB. The fourth section is the transboundary analysis, focusing on six water sharing arrangements from the *Law of the River,* a set of treaties, compacts, federal laws, court decisions and decrees, contracts and regulatory guidelines that govern water in the seven Colorado River

Basin states (Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming) and Mexico. The final two sections reveal results and conclusions from the transboundary analysis and the implications that water sharing and agriculture in the CRB have on governance patterns in the West, the U.S. and globally.

Historical Agricultural Boundaries

The CRB (Figure 2.a) is a highly complex and diverse ecoregion where water from the River crosses many political, cultural, ecological, economic, and social boundaries. Competition for Colorado River water has driven demand among multiple sectors and industries and has been the center of both collaboration and conflict between environmentalists, municipalities, and farmers. The headwaters of the Green River in Wyoming converge in Canyonlands National Park, Utah with the Colorado River headwaters located in Rocky Mountain National Park, Colorado. The Colorado River supplies water from the Rocky Mountains to the desert and farmlands of the Colorado Plateau, and has historically drained into the Sea of Cortez. The length of the Colorado when measured from the Green River headwaters is 2,736 km (1,700 miles) long, draining an area of 63.7 million hectares (246,000 miles^2) and spanning between 43°09′13″N 109°40′18″W at the headwaters in Rocky Mountain National Park and 31°39′N 114°38′W at the Gulf of California (Sea of Cortez).

The natural climate of the region has been a prominent factor dictating natural and political boundary configurations. The Arid Region, demarcated by John Wesley Powell in the Eleventh Annual Report of the United States Geological Survey of 1889-1890, is one of the most important naturally occurring boundaries, delineated by the precipitation resulting from the unique combination of latitude, altitude, and topography (Powell, 1891). Aridity is due to the difference of precipitation and evapotranspiration, which was estimated to be on average 50.8

cm/year (20in) with great variability in time and space. Powell estimated that “the amount of rainfall required for the production of crops, for an ordinary production, would be from [50.8 - 63.5cm] 20-25 inches” (p. 214). Arid conditions were prominent in the West. Powell recognized this and conveyed his concern through reports, articles, speeches, and congressional hearings (deBuys, 2001; Stegner, 1954; Worster, 1985). Prolonged drought during the mid to late nineteenth century, particularly the Civil War Drought (1856-1865), the drought of the locusts (1870-1877) and the drought beginning in the late 1880’s lasting through 1896 (Cook, Seager, Cane, & Stahle, 2007), in addition to the land give-away through the General Land Office, catalyzed the institutionalization of federal irrigated agriculture through the Reclamation Service (now known as USBR). Based on Powell’s statement to the Committee on Irrigation of the House of Representatives on February 27, 1880, the CRB falls wholly within the Arid Region.

To address the question of water for agriculture in the Arid Region, Powell suggested managing water in districts. Hydrographic basins were first suggested by Powell in an Address to the Montana Constitutional Convention in the summer of 1889 (deBuys, 2001; Stegner, 1954; Worster, 1985) and written in his 1889-1890 report on Arid Lands (Powell, 1891). Powell delineated 150 hydrographic basins, otherwise known as drainage basins or natural districts based on natural features. He suggested that irrigation be managed as independent units where “each one of which has its problems so interwoven that the entire district must be considered in planning its system for irrigation works, but which is practically independent of all other districts” (p. 215). Powell identified three classes of districts in the Arid Region: first class districts were headwater districts; second class districts were river-trunk districts; and third class districts were lost stream districts (ephemeral streams where water disappears in sand reservoirs or sinks and are known as closed basins). Powell predicted that the act of watering agriculture in the Arid Region would require hydrologic manipulation, namely through infrastructure. He also anticipated that the geography and climate of the Arid Region would create challenges for the development of irrigated agriculture. He saw that state and territory boundaries intersected natural boundaries in ways that were not congruent with the limited valuable resources dispersed throughout the region. It is within this context that the definition of boundaries is paramount to understanding water for agriculture in the context of water sharing in the CRB.

Framework for Shifting Boundaries

In contrast to Powell's insight, current configurations of politically constructed boundaries in the CRB can be traced to political and legal decisions that follow lines of latitude and longitude (Jefferson Public Land Survey System), rather than to naturally occurring hydro-geologic features. These boundaries have been established over decades of agreements, litigation, and negotiation between the federal government, the seven basin states of the CRB and the Native American tribes. There are over 40 tribes in the Colorado River Basin region. In addition, some of the starkest contrasts can be seen in differences between the upper and lower basins, where the dividing line is based on the hydrologic division at Lee Ferry. The upper basin water is governed by the Upper Colorado River Basin Compact. In the lower basin, the federal government has a stronghold on the water through the USBR, instituted through the U.S. Supreme Court Case *Arizona v. California* (1963). The Upper Basin contributes an estimated 90% of the flows and the Lower Basin only 10%. The Lower Basin has the most and oldest water rights in the Basin and has allocated all of their water. The Upper Basin has water rights yet to adjudicate but reportedly insufficient quantities of water to allocate, a narrow distinction between political boundaries, some of which are defined by water rights, and physical boundaries, defined by the natural flow of water. As a general rule, the Lower Basin is more dependent on groundwater resources than the Upper Basin, except for those areas in the Lower Basin that receive mainstream Colorado River water through elaborate delivery systems and large infrastructure projects such as Las Vegas, Nevada, Yuma, Arizona, Southern California, and the tri-county Central Arizona area. The Upper Basin is largely dependent on surface water flow due to numerous tributaries flowing from the snow pack of the Rocky Mountains. These physical boundaries mark the natural state of the basin and its impact on watershed politics.

Embedded within U.S. watershed politics, water resources development and conservation in the western U.S. is federalism, the interplay between federal, state, and local power, revealing the evolution of boundaries and their manifestation on the landscape (Anderson & Hill, 1997; Fischman, 2005; Gerken, 2010; Gerlak, 2005; Hall, 2006; Robison et al., 2012; Schlager & Blomquist, 2008). Gerken (2010) describes federalism as "a system that permits minorities to rule . . .with its benefits: federalism promotes choice, competition, participation, experimentation, and the diffusion of power" (p.6).

Geo-political boundaries lie at the heart of federalism: the "nation state" or the federal government on one side and the state, a territory in which nation and state coincide, on the other side (Corker, 1957; Hooghe & Marks, 2012). The important role of local authority, whether general or special purpose governments, whether instigated by the federal government or not, cannot be forgotten in a federalist system (Gerlak, 2005). Due to the complexity of local Ag water governance in the Basin, the focus of the interplay between the state and federal units are further considered here. More often than not, the state and federal government have engaged in a tug-of-war for power since the signing of the U.S. Constitution (Thomas, 2008). A characterization of the relationship between water resources policy and Ag water governance in the CRB can be made through a historical transboundary analysis of water sharing of compacts, policies, laws, and other forms of arrangements. In the CRB, water politics follow the physical hydrologic boundaries but manipulate political boundaries to compensate for the differences in water availability (e.g. transbasin diversions). Water governance patterns, therefore, are made up of multiple layers of overlapping policies and jurisdictions which include parts of two countries, nine states (two in Mexico and seven in the U.S.), and over 40 tribal governments among thousands of local agricultural water supply organizations.

In the U.S., the relationship between the states and the federal government ranges from cooperative federalism, where the federal government and subordinate jurisdictions such as states and tribes share authority (Fischman, 2005) to new federalism or a devolution of authority (Hall, 2006). Cooperative federalism impacts the boundaries that have thus far been unchanged in the political and environmental spheres of government. Interest groups inflate the federal-state relationship by incorporating stakeholders that represent different forms of decision-making into the water policy arena expanding the governance spectrum to what has been referred to as the 'Iron Triangle,' a mutually beneficial arrangement between legislators, interest groups and federal agencies (McCool, 1987). Such interest groups are instrumental in changing Ag water governance in the CRB and include quasi-governmental Ag water supply organizations (e.g. irrigation districts) and non-profit (e.g. environmental organizations) as well as for-profit businesses. With the growing presence of such interest groups, the institutional picture consists of overlapping, complex political subsystems, across levels of government and sectors. Because federalism dominates structural governance in the U.S., layers of jurisdictional complexity create an arena for changes to take place over time that have led to water sharing. Understanding those changes requires an understanding of jurisdictional boundaries and the linkages between boundaries (Heikkila, 2004).

Geo-political patterns convey the nature of the jurisdiction and how it manifests itself geographically on the landscape. Based on Grimm et al.'s (2005) definition of patterns aforementioned, the prevalent geopolitical patterns and governance structures and processes become evident through a governance spectrum (Figure 2.b). Although it is true that each system functions within a federalist system in the U.S., the same is not true for all countries. For this reason, territorial sovereignty is at one end of the spectrum, federalism is situated in the middle and polycentricity is at the other end. Federalist patterns are revealed at federal and state/tribal intersections, where the U.S. Constitution vests certain powers on the federal government and on the States (Thomas, 2008). Territorial sovereignty is an inherent attribute of the state's power (Thomas, 2008), positioning the state at the center of authority, above federal and local entities. Territorial sovereignty may function as an independent system or within other systems. Nested hierarchy is a system of hierarchical patterns of concentric polygons that nest within each other in any one location or region, from a global to local scale, ranging in both geographic and temporal extents (Sheppard & McMaster, 2004), meaning that the local rests within the state and that the state rests within the federal. Another way governance boundaries can be structured is through polycentricity, which is a pattern of governance made up of institutions consisting of governmental and nongovernmental actors within a system of overlapping jurisdictions at multiple scales. These systems are regarded as mechanisms that increase institutional capacity where decisions are made by diverse sets of actors linked across different organizational units (McGinnis, 1999; Ostrom, 1993). Organizational units within Ag water governance in the CRB are defined by statutory law of each state and are generally situated across the local scale in both hierarchical and polycentric patterns.

The governance spectrum is a simplistic representation of how authority is divided and the boundaries that ensue based on that division in order to better understand governance patterns. Even within polycentric systems, both the devolution (new federalism) and sharing (cooperative federalism) of authority may be present. Likewise, federalism accounts for the individuality within a group and the collective good of a group (Schlager & Blomquist, 2008). As with polycentricity, federalism lends itself to fragmented, redundant, and overly complex arrangements. Governance trends have shifted in this direction within an open state-centered system that is increasingly looking to engage the public, especially with watershed management initiatives (Mumme, 1985; Sabatier et al., 2005; Schlager & Blomquist, 2008). Key criteria that define polycentric systems include: dispersal of political authority, separately constituted bodies, overlapping jurisdictions, increased self-governing capacity of local communities, and increased cross-scale linkages between horizontal and vertical levels of organizations (Berkes, 2002; Huitema et al., 2009; Ostrom, 2005). The literature on geopolitical patterns above informs inquiries on the different types of boundaries and how those boundaries shift over time in relation to agricultural water governance processes.

Methods

The cynical definition of a boundary according to the Devil's Dictionary is "an imaginary line between two nations, separating the imaginary rights of one from the imaginary rights of the other" (Bierce, 2008). A more deferential definition of a boundary from the Dictionary of Human Geography is "a geographical marker and a geographical maker of regulative authority in social relations" (Gregory, Johnston, Pratt, Watts, & Whatmore, 2009, p. 55, emphasis added). Or as Newman and Paasi (1998) note, many geographers consider boundaries as "expressions or manifestations of the territoriality of states" (p. 187). To clarify the subtle difference between a boundary and border, a border is “a form of a boundary associated with the rise of the modern nation-state and the establishment of an inter-state geopolitical order, founded on the political norms of national states claiming and using terror to control territory . . .” (Gregory et al., 2009, p. 52, emphasis added), where state in this definition implies nation-state. For the purposes of this research, though territoriality is a question specifically as it relates to sovereignty at a nation-state (international) scale, the focus is on boundaries at an intranational level.

Qualitative methods were used to conduct a geographic boundary analysis unlike the quantitative methods applied in Jacquez, Maruca, and Fortin (2000) where statistical analyses were implemented to demonstrate object (boundary) representations and then weighted to test their significance within a geospatial environment. Qualitative methods, including the process of identifying geopolitical and hydrologic boundaries in policies, were required to match those boundaries within policies to their geographic counterparts that were later mapped in a geospatial environment. This study focuses attention on the boundaries that have been laid out by rules, laws, and norms that exist within the *Law of the River*, namely compacts, treaties, case law, and operational guidelines that have governed the Colorado River from 1922 to the present day. Each of the seven Basin states within the U.S. and two states within the Basin in Mexico, as well as the federal agencies within each government adheres to the *Law of the River*, which resides with any one of the partner agencies. In addition, each tribe, state, and country has their own rules that govern the water resources within their boundaries. The *Law of the River* therefore is a set of shared rules to share water. Herein lies the key to sharing water across boundaries in the CRB.

Inherent within each rule, whether formal or informal, is a specific geographic boundary within which the policy applies. In addition to the boundaries indicated in a rule, actors in the forms of agencies, organizations, and jurisdictional entities are often named. Each of these units comes with an assigned geographic boundary or jurisdiction. The focus of this analysis is on six key water sharing arrangements (WSAs), which were identified as a part of the *Law of the River*. Criteria for choosing each WSA were based on representation of diverse configurations of boundary types and geopolitical patterns. For each of the six WSAs, the methodology consisted of a systematic analysis and identification of hydrologic, political, and sectoral boundaries according to the boundary typology.

Three types of boundaries, physical, political, and sectoral, have become apparent from an historical and geospatial analysis of WSAs and were incorporated in a typology for transboundary analysis (Table 2.a). The physical boundaries formed naturally through time and hydro-geologic processes. There are two types of naturally occurring physical boundaries: hydrologic, those based on natural drainage systems defined by the National Hydrography Dataset of the U.S. Geologic Survey (USGS) (Seaber, Kapinos, & Knapp, 1987), and hydrographic boundaries delineated by a state or tribe. In some cases, these two types of boundaries coincide. New physical boundaries are those created by physical infrastructure. Any inference to infrastructure would be classified as a political boundary as water infrastructure is often mandated and managed by federal, state, local, and/or private entities. Political boundaries, sometimes referred to as organizational or institutional boundaries (Heikkila, 2004), are politically constructed and are formed by a combination of political, social, and cultural forces. Political boundaries are based on four sub-types: statutory, judicial, administrative, and time. Sectoral boundaries are socially constructed and formed by social and cultural processes that delineate different types of water users as well as economic interests at local and regional scales (Fischhendler & Heikkila, 2010). Agricultural water policy has both formed and evolved from physical, political, and sectoral boundaries which have spatially manifested across the landscape.

More importantly, these boundaries have either evolved from or initiated rules and norms on sharing water in the CRB (Sternlieb, Bixler, Huber-Stearns, & Huasca, 2013). The transboundary analysis operationalizes this boundary typology.

Geospatial data were collected from the organizations, agencies, and jurisdictions represented in each of the water sharing arrangements. A geographic information system (GIS) database was created and organized by state and by water sharing arrangement. By mapping the jurisdictions at multiple scales, international, intranational, interstate, and intrastate patterns emerged coinciding with the four geopolitical governance patterns that appeared in both the transboundary analysis and the literature review on boundaries as they relate to governance processes.

Transboundary Analysis

This section launches the transboundary analysis conducted based on the above methodology of the six chosen WSAs within the *Law of the River* (Table 2.b), beginning with historical-political background of water sharing in CRB. Three sections follow: (a) the Colorado River Compact of 1922 which also includes analyses of the 1944 Water Treaty and the Upper Colorado River Basin Compact of 1948, (b) *Arizona v. California* (1963) which includes an analysis of the 2007 Interim Guidelines and (c) Minute 319.

An historical overview warrants an entry point to provide context to the Colorado River Compact of 1922. The first international agreement impacting the waters of the Colorado River took place between the U.S. and Mexico with the Treaty of Guadalupe Hidalgo of Peace, Friendship, Limits and Settlement between the United States and Mexico (1848). The Treaty of Guadalupe was a water sharing agreement, not to share use of the waters, but to share the right to navigate: “the navigation [of the waters considered in the treaty] . . .shall be free and common to the vessels and citizens of both countries; and neither shall, without the consent of the other, construct any work that may impede or interrupt, in whole or in part, the exercise of this right; not even for the purpose of favoring new methods of navigation" (Treaty of Guadalupe (1848)). In addition, it marked the official end of the Mexican-American War, established the Rio Grande as the international boundary while the U.S. acquired present-day Arizona, New Mexico, Texas, and parts of Utah, Nevada, and Colorado. Interstate water sharing in the western U.S. was initiated by two important events: (a) the Convention of March 1, 1906, which allocated 60,000 acre feet of Rio Grande water to Mexico in exchange for a new water storage and delivery facility funded by and constructed in the U.S., and (b) the *Kansas v. Colorado* (1907) Supreme Court decision, a landmark case that set the precedence for interstate water sharing in the legal and administrative realms. As described by Sherow (1990), *Kansas v. Colorado* was not just about sharing interstate waters; it was about the powers of the prior appropriation versus riparian doctrines and about Colorado's state sovereignty.

Kansas v. Colorado not only determined the level of states' power over the waters within their boundaries, but it determined the survival of the newly formed Reclamation Service (1902) and federal control over non-navigable interstate streams (Sherow, 1990, p. 55). Justice Brewer's decision "rested upon an equitable distribution of the economic benefits derived from the river and sidestepped deciding which doctrine, prior appropriation or riparian governed the interstate flow of the river" (Sherow, 1990, p. 57). In addition, the case rested partially upon the question of the Harmon Doctrine (Sherow, 1990), a legal principle that states "a nation is absolutely sovereign over the portion of an international watercourse within its borders" (McCaffrey, 1996). The Harmon Doctrine was asserted by U.S. Attorney General, Judson Harmon in 1895 in the U.S.-Mexico Rio Grande River dispute but was later abandoned in the 1906 and 1944 water treaties with Mexico (McCaffrey, 1996; Umoff, 2008; Utton, 1967). Sherow (1990) also suggests that Brewer did not only grant Colorado sovereignty over its waters, but "denied Congress the right to control non-navigable interstate rivers in the arid west, [supporting the states' rights] to devise their own regulatory institutions" (p. 57). Although economics determined the *Kansas v. Colorado* decision, its significance for boundaries and water sharing is revealed in two ways: (a) this case established the boundary between states' and federal rights to control and manage water resources, independent of a navigable classification, reinforcing the federalist system and (b) this case would set a precedent of interstate disagreement on water sharing. Both concerns are still debated today.

Colorado River Compact (1922)

The Colorado River has received much attention by scholars and practitioners alike for one main reason: the Colorado River Compact of 1922 (1922 Compact). The 1922 Compact is internationally renowned because it was the first interstate agreement ever made for the purpose of facilitating multi-purpose water sharing (Hundley, 2009). Although the Colorado River extended beyond the U.S. and flowed along tribal lands, the negotiation for the Compact (presided over by Herbert Hoover, Secretary of Commerce and Chairman of the Colorado River Commission), only included the seven tributary state governments. Many attribute the conception of the Compact to Delph Carpenter, the father of Interstate Water Treaties (Grigg, 1991; Hundley, 2009; Tyler, 2003; Worster, 1985).

A transboundary analysis of the 1922 Compact and succeeding WSAs form the foundation of the *Law of the River* that include an array of policies, laws, and operational guidelines. The physical, political, and sectoral boundaries that can be derived from the *Law of the River* and the associated agreements and arrangements, laws, and policies following the ratification of the 1922 Compact have created an intricate, interdependent system dependent on water sharing (Table 2.c).

According to the 1922 Compact, the CRB's geographic boundaries are defined as "all of the drainage area of the Colorado River System and all other territory within the United States of America to which the waters of the Colorado River System shall be beneficially applied" (Colorado River Compact of 1922, 1928, Article II(a)). The CRB is divided into an Upper and Lower Division as well as an Upper and Lower Basin. This terminology is important as it distinguishes between political and physical boundaries and supports the application of the boundary typology. Upper Division means parts of the States of Colorado, New Mexico, Utah, and Wyoming (Article II (c)). Lower Division means those parts of States of Arizona, California and Nevada (Article II (d)). Upper Basin means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming above Lee Ferry within which water drains and outside of which Colorado River water is beneficially used (Article II (e)). And Lower Basin means those areas encompassed within the states of Arizona, California, Nevada, New Mexico, and Utah below Lee Ferry within which water drains where Colorado River water is beneficially used (Article II (f)).

Although the distinction between Upper and Lower Basins versus Divisions is not necessarily significant to agricultural water, these boundaries establish the right to divert water outside of the physical boundaries that form the CRB through social and physical engineering and they distinguish the difference between political and hydrologic boundaries. Such transboundary diversions allow for both Ag and municipal water use outside of the hydrologic Basin (see Pritchett (2011) and Cohen, Christian-Smith, and Berggren (2013) for quantification of Ag water use for the Colorado River System), extending localized boundaries, addressing impacts on water quality, benefits from increased water supply, and threats due to water scarcity throughout the U.S. West. The boundary that marks the Upper and Lower Basin (Lee Ferry) which is a political line based on a physical boundary, is particularly important for Ag water governance. Because the Upper Basin was much slower in developing and allocating water rights compared with the Lower Basin, the 1922 Compact was a vehicle to establish their dominion on water resources for the Upper Division states (Hundley, 2009). It was also the first time that the Upper Division states recognized shared interests, which later led to the unification and a formal agreement on equitable water allocation (Upper Colorado River Basin Compact, 1949).

In the case of the 1944 Water Treaty, there are no geographic boundaries specified, however the title of the arrangement implies that Ag water governance is under the mandate of two international jurisdictions with two very different government systems: a decentralized system in the U.S. and a centralized government in Mexico. The difference in government systems is reflected in the water governance of both countries. In terms of water sharing and Ag water, the 1944 Water Treaty was critical. It was only the second international water distribution treaty in the border region for the utilization of waters from three rivers along the U.S.-Mexico border for purposes other than navigation, including agriculture (IBWC, 2013).

Within the context of the 1922 Compact, the Upper CRB Compact follows the boundary for the Upper Division States: Colorado, New Mexico, Utah, and Wyoming (Article VIII (a)). Ag water is governed by four distinct political boundaries each defined by the political characteristics and mandated by statutory, judicial, and administrative law; two temporal boundaries: the one established by the 1922 Compact and the doctrine of prior appropriation; and hydrological boundaries that define percentage of Colorado River flow for each of the Upper Division states (Upper Colorado River Basin Compact of 1948, 1949).

Arizona v. California (1963)

The state boundaries of the Lower Basin were much more problematic and provoked the beginning of a long judicial battle, particularly between California and Arizona, initiating the longest U.S. Supreme Court case ever tried, *Arizona v. California* (1963) since that time. (August, 2007). The division not only accentuated differences between state boundaries, but between sectoral boundaries such as differences between agricultural and municipal interest groups and physical boundaries in terms of Colorado River flows and native tributaries. *Arizona v. California* (1963) is a landmark case upholding the Boulder Canyon Project Act of 1928, which apportioned the Colorado River Lower Basin's mainstream waters with California receiving 4.4 million acre feet (MAF), Arizona receiving 2.8 MAF, and Nevada receiving 0.3 MAF. In addition, each state (Arizona in particular which fought for their rights to the Gila River) has entitlement to their own tributaries. USBR, under the Department of the Interior (DOI), is responsible for Lower Basin water administration for federal lands including tribal reservations, National Recreation Areas, and National Forests, which hold federally reserved water rights. In addition, the USBR administers water through contracts to any entity that uses Colorado River water, in the case of agriculture, this means irrigation districts, companies and enterprises.

Governance of agricultural water is mandated by political boundaries based on hydrology. In *Arizona v. California* (1963) some of the political boundaries follow watersheds, however the majority are more complicated due to the number of overlapping jurisdictions at the federal, state, and tribal levels as well as organizations driven by interest groups included in the case are multi-scalar (federal to local including states and tribes) and multi-political (Seven Party Agreement of California, an intrastate WSA that includes both municipal and agricultural sectors). Hydrologically, language in *Arizona v. California* refers to the Colorado River as the Mainstream. Translated, this means that the Colorado River waters downstream from Lee Ferry within the U.S. (Section B), which forms the boundary between Arizona and California and continues as the international border between the U.S. and Mexico for 25 miles. Though it is difficult to classify legal cases due to their temporal nature, the *Arizona v. California* (1963) case exemplifies a polycentric agreement due to the multiplicity of physical, administrative, and sectoral boundaries as well as their geographic arrangement.

Political boundaries of the *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (2007) include federal jurisdictions or departments under the DOI encompassing multiple sectors, including especially the energy sector (USBR, 2007). Within the Interim Guidelines, three main administrative units under which Ag water is governed are the USBR, Bureau of Indian Affairs (BIA), and Western Area Power Administration (Western). USBR acts on behalf of the DOI to manage the Lower Colorado River System (*Arizona v. California* (1963)) and operates Ag water projects throughout the Upper and Lower Basins; BIA administers and manages Ag water programs and lands on Indian reservations; Western markets and transmits hydropower to irrigation districts. Political and hydrologic boundaries also include all of those boundaries established by the 1922 Compact, Upper CRB Compact, and the 1944 Water Treaty as well as those boundaries specified by Acts of Congress in the Colorado River Storage Project Act, the Boulder Canyon Project Act, and the Boulder Canyon Project Adjustment Act.

<u>Minute 319 (2012)</u>

International Boundary and Water Commission's (IBWC) Minute 319 is the most recent international WSA of the CRB. The IBWC was established in 1889 resulting from temporary joint commissions responsible for negotiating the international boundary between the U.S. and Mexico. The Treaty of Guadalupe-Hidalgo (1848) and the Gadsden Treaty of 1853 were the first agreements between U.S. and Mexico delineating the boundary from the towns of El Paso Texas and Ciudad Juarez, Chihuahua terminating in San Diego, California and Tijuana, Baja California. Three transboundary rivers were addressed in these agreements: the Tijuana, the Colorado, and the Rio Grande, two of which formed the actual border (IBWC, 2013). The IBWC is divided into two national sections: the USIBWC and the *Comisión Internacional de Límites y Aguas entre México y Los Estados Unidos*, or CILA. Both are dependencies of their respective foreign ministries.

Established as the International Boundary Commission (IBC) in 1889, the IBC was renamed in 1944 and established as the administrative unit responsible implementing and interpreting all bilateral water and boundary agreements in force between the two governments. Its formal decisions, or Minutes, have the status of treaty law, superseding domestic law in both countries. The Minutes portray patterns that are temporally hierarchical, one embedded within the other through time. Minutes related to the Colorado River can be traced to the 1944 Water Treaty. However, the geographic extent of each Minute can be considered within its own context, exhibiting polycentric governance patterns depending on the number and level of jurisdictions involved. Physical boundaries listed in Minute 319 include: the Colorado River System (defined by the 1922 Compact), the limitrophe section and delta of the Colorado River in the Mexicali Valley, Baja California, as well as the boundaries for the Environmental Restoration Project at the Miguel Aleman Site, "located in Mexico near the Colorado River limitrophe reach across from the Hunter's Hole restoration site in the U.S." (p.15). The stated political boundaries include: the IBWC (the border region between Mexico and the U.S. in the

Colorado River Basin) and those boundaries situated within other relevant IBWC agreements including Minutes 317, 306, 318, 242, and 314.

Although the only signatories to Minute 319 were the Commissioners and Section Secretaries for both countries, many more were party to the agreement through three related domestic (U.S. parties) agreements, encompassed within the Memorandum of Agreement (MOA) on the Implementation of Minute 319 “in the absence of which Minute 319 cannot be implemented” including: the Interim Operating Agreement for Implementing Minute No. 319, the 2012 Lower Colorado River Basin Forbearance Agreement for Binational Intentionally Created Surplus and the 2012 Contributed Funds Agreement. One agreement not listed in the 319 MOA is the Memorandum of Agreement between the Arizona Department of Water Resources and the Central Arizona Water Conservation District Regarding the Forbearance by the State of Arizona of Binational Intentionally Created Surplus. This agreement diverges from the water sharing trend in that Arizona ensures sovereignty over the waters that flow within the state per the 1944 Water Treaty and *Arizona v. California* (1963) (for detailed historical account of Arizona’s sovereign claim over her waters, see Hundley and Worster).

Signatories to the MOA include those representing the federal government and the State Department (U.S. IBWC), local irrigation and municipal districts, state agencies and Compact organizations (Upper Colorado River Commission). These entities represent a broad range of sectors (e.g. agricultural, municipal, industrial, environmental, inter-state, intra-state, federal, and international) in the basin across vertical and horizontal scales, where there are exchanges of currency and water for the benefit of all signatory parties. Water governance in the context of tribes may offer exception(s) to the trends in patterns and are important themes for future research. On the governance spectrum where territorial sovereignty is at one end and polycentricity is at the other end, Minute 319 is situated at the far end as a polycentric regime. This analysis demonstrates that since the time of the *Arizona v. California* (1963), the governance paradigm in the CRB has indeed gradually shifted from that of competition to a new regime of cooperation, situating water sharing as a key strategy within the agricultural sector. This transboundary analysis can be considered in two steps. The first was to categorize each WSA according to the types of boundaries they emphasize. The second was to map the WSA's boundaries to identify the representative geopolitical patterns. The results show the degree to which boundaries relate to the governance spectrum.

Results

The management regimes based on physical boundaries were found to represent a pattern indicative of nested hierarchy (Figure 2.c). Hydrologic domains (otherwise referred to as river basins or watersheds) are operationalized by the USGS as Hydrologic Units, "levels of divisions and subdivsions, used for the collection and organization of hydrologic data . . ." identified by hydrologic unit codes (HUCS) and assigned names "that correspond to the principal hydrologic feature" and an associated numerical classification (Seaber et al., 1987, p. 1). According to Seaber et al. (1987), the Hydrologic Map Series was officially initiated by the Office of Water Coordination of the USGS in coordination with the U.S. Water Resources Council in 1972. The Series depicts drainage, hydrography, and hydrologic unit boundaries and codes "providing a standard geographic and hydrologic framework for detailed water resource and related land-resource planning" (Seaber et al., 1987, p. 1), a practice whose origins date as far back as 1878 and Powell's Report on the Lands of the Arid Region (Powell, 1891).

From the federalist inter-state agreement of 1922 (Figure 2.c) to the present day, all other arrangements were based on political interests, creating boundaries that did indeed shift. The

1922 Compact as it is depicted in Figure 2.c only shows the hydrologic boundaries and does not include the transbasin diversions. Today, the 1922 Compact may be interpreted to include all of regions that receive Colorado River water, including those that did not exist at the time of the Compact, such as the Big Thompson Project (Colorado), the Central Arizona Project, the Central Utah Project, the San Juan Chama project (New Mexico and Colorado), among others, all constructed with the financial support by the USBR and subsidies from the U.S. Government to provide water for the growing metropolises of Albuquerque, Denver, Cheyenne, Salt Lake City, and Los Angeles, which are connected to the basin through infrastructure (Article IIa). Boundaries shifted during the middle of the 19th Century when Territories slowly evolved into states. At first, territory boundaries followed physical boundaries, mountain ranges, rivers, and other topographic features. With rejection of Powell's special districts, state lines in the West were delineated based on the Jeffersonian Public Land Systems, which largely followed lines of longitude and latitude, a land system that worked better in the mid-west where precipitation and water sources were more abundant.

The question of territorial or state sovereignty lies at the heart of boundary questions as they pertain to water sharing between two nations (e.g. Mexico and the U.S.) and between states within one nation (e.g. Arizona and Colorado). In addition, water sharing between up and downstream interests cross invisible social or economic boundaries. McCaffrey (1996) hints to the sovereignty spectrum, at which one end is 'absolute territorial sovereignty' and the other 'absolute territorial integrity.' There has since been significant movement away from these principles in water governance at an international scale (Dinar, Dinar, McCaffrey, & McKinney, 2007), but the absolute territorial sovereignty principle remains very much alive within the U.S., at an intranational scale as is evident in tribal governance.

Even within sovereignty, political boundaries shifted with the administration of the Colorado River: first with the U.S. government (the Constitution of the United States), the CRB states (the 1922 Compact) and the tribes (the Winter Doctrine of 1907; Figure 2.c). Beginning in the middle of the 19th Century, water use in the western U.S was established by early miners who set up the first 'white' settlements and for whom the Mining Act was approved by Congress in 1866 to allow territories and states to adopt their own water laws (Hobbs, 1999; Schorr, 2012; Wilkinson, 1992). The federal opportunities for land that "opened" the West (such as the Pre-emption Act (1830) and the Homestead Law (1863)) enabled farmers to follow suit and later adopted the common law "first in time, first in right" or the doctrine of prior appropriation (Wilkinson, 1992; Worster, 1985), giving rise to a political boundary based on time, where one's junior water rights only make sense in reference to another's senior water rights. Sovereignty therefore is supported by the boundary typology as it pertains to the types of political boundaries: statutory (Boulder Canyon Project Canyon Act), judicial (*Arizona v. California* (1963)), administrative (the institution of states), and temporal (the doctrine of prior appropriation, see Appendix 1-I for a transboundary analysis of political boundaries).

Sectoral boundaries are important to consider in the transboundary analysis for a number of reasons. First, they are not just boundaries but they represent special interests. Secondly, boundaries cannot be isolated. Boundaries reinforce one another and coexist. A political line distinguishes between water use, conservation, and development on both sides of any one line, creating differences or commonalities, depending in part on the natural variability of the water resource within and outside of those boundaries. Interests, however may pertain to a particular place, a region, or may occur in patchwork patterns, cutting across political (invisible) and physical boundaries (visible). Sectoral boundaries coupled with the political and physical, form polycentric systems (Figure 2.d). These systems are fragmented and made up of multiple overlapping boundaries with coinciding centers of power. They create new spaces, drawing from and facilitating water sharing arrangements such as the most recent example, Minute 319.

In addition to actors, rules, and norms, boundaries are as much an aspect of governance, as is the case of boundaries that have evolved from special interests, such as those that represent the agricultural sector. Special interests however, are not new; they are a historic component of the system, even as new boundaries evolve. As the variety, extent, and multiplicity of boundaries increase on the landscape, governance also increases in complexity. But where those merging and deviating boundaries can be assimilated to patterns, new processes will eventually emerge.

Conclusion

This transboundary analysis in conjunction with the boundary typology and a geospatial demonstration of the resulting patterns has illuminated answers to the question: how have shifting political and hydrologic boundaries in the CRB impacted agricultural water governance? Understanding and mapping the coincidence of physical, political, and sectoral boundaries can identify geopolitical patterns and processes in locations, in this case, where there is a confluence with agriculture. Identifying governance patterns and processes will help in answering new questions about environmental governance regarding access and allocation of water resources and systems adaptiveness such as: what factors and characteristics of governance systems facilitate water sharing? Which inhibit water sharing? Who are the winners and losers? Transboundary analysis facilitates the study of WSAs by illuminating the role of key interest groups that are integral to decisions about Ag water governance such as those embodied by sectoral boundaries. Fuzzy and shifting boundaries enable us to consider questions about interest groups and their role in shaping new patterns of governance, so when we consider a phenomenon like water sharing we see boundaries in a new way. And describing the boundaries helps us understand the challenges of governance, including the need to consider overlapping boundaries and the patterns and processes they represent.

This study points to a number of conclusions. First, boundaries at the state and federal level that were once well defined are more complex. New institutional arrangements in the CRB are forming at multiple levels including rules that have changed where, when, and how water is used across multiple scales, crossing political and hydrologic boundaries such has been accomplished with the Intentionally Created Surplus (USBR, 2007). Such changes are indicators that despite rigid policies and laws (e.g. prior appropriation), changes in sectoral boundaries have forced multi-level, cooperation and collaborative decision-making such as Minute 319 (Dinar, 2004, 2010; Fish, Ioris, & Watson, 2010; Schlager & Heikkila, 2009; Yoffe et al., 2004; Yoffe, Wolf, & Giordano, 2003).

From an analysis of WSAs in the CRB, key findings point to a spectrum of governance patterns that can be geospatially demonstrated: territorial sovereignty on one end and polycentricity on the other end, with federalism and nested hierarchy somewhere in between (Figure 2.d). Although polycentric types of patterns can be found within federalism in the U.S., both are considered independently in order to allow more flexibility if the spectrum were to be considered in the context of other governments. The trend has shown that governance patterns have shifted over time from that of territorial sovereignty to polycentricity (there are a few exceptions to this rule as noted above). There is a notion that polycentric governance systems are more resilient and adaptable to change for two reasons: (a) issues from a range of geographic scopes can be managed at different levels and (b) due to a high degree of overlap and redundancy, they are less vulnerable (Huitema et al., 2009; McGinnis, 1999; Ostrom, 1993, 2005). However, challenges to polycentric systems make collaborative governance difficult to attain “because of the need to accommodate the complexity of spatial patterning, multiple function overlays, partial polity formation, and variable systems coupling” (Huitema et al., 2009, p. 3). Despite benefits and challenges, the emphasis of polycentricity in the Colorado River System is on the role of water sharing arrangements, perhaps for the purpose of maximizing water use efficiency, in river basin governance regimes (Megdal, Varady, & Eden, 2012; Whiteley, Ingram, & Perry, 2008).

In order to better understand governance over the U.S.-Mexico border, Mumme and Ibanez (2011) suggest that multi-level governance features on the border resemble a polycentric system, where independent centers of decision-making at multiple scales, which include features such as independent geographical scales that horizontally overlap, vary in size and have specialized function (Hooghe & Marks, 2003, 2010; Schlager & Blomquist, 2008). These same patterns prevail in the CRB, especially as demands for agricultural water increase and supplies decrease as they are projected to do in the Rocky Mountains (Pederson, Betancourt, & McCabe, 2013). Although these processes tend to be more fragmented in nature, they can facilitate water sharing and support both vertical (local to global and vice versa) and horizontal (across the landscape) integration (Berkes, 2002).

The evolution of shifting boundaries tells more than a story about a geographic region; it tells of a story and political transition from government to governance, where decisions were once made by a single actor (the government) and are now made through pluralistic channels (Keating, 2001; Sternlieb et al., 2013). They tell a story of patterns and trends in which the changing nature of individual roles of the state and federal government and their relationship with each other as they pertain to a particular sub-region within the Basin. These patterns can be seen on the landscape as water sharing arrangements, where multiple parties (actors) formulate agreements, whether officially or informally, to divide the available water in a particular time period within a specific location that suits the parties in question.

These findings point to new governance patterns and processes that will continue to unfold as more extensive transboundary analyses are conducted that will address questions about boundaries including tribal arrangements and groundwater resources. They also illuminate new questions such as: how will further analyses increase our understanding of the impact that diverse boundaries have on decision-making and governance? And, which boundaries facilitate or inhibit cooperation? In addition, how can we spatially portray the other sectoral boundaries that contribute to governance processes? A larger set of questions pertains to the sustainability, adaptiveness and persistence of polycentric systems in environmental governance, not only in the CRB but in transboundary river basins around the world.

Tables and Figures

Figure 2.a: Colorado River Basin (USBR, 2012)

Table 2.a: Boundary Typology, Description and Matching Geo-political Patterns.

Boundary Type	Governance Layer	Description	Geo-political Pattern
Physical	Hydrologic	Based on natural drainage systems defined by the National Hydrology Dataset (USGS)	Nested hierarchy
	Hydrographic	Based on drainage basin delineated by each state and tribe	Territorial Sovereignty
Political	Statutory	Based on federal, state and tribal laws and policies	Federalist
	Judicial	Based on US Federal/State, District and Appellate Court system	Federalist, nested hierarchical
	Administrative	Rules and regulations based on governmental jurisdictions (federal, state, tribe, county, municipality, city)	Nested hierarchy
	Temporal	Based on time/history largely due to sequential legal and political decisions	Nested hierarchy
Sectoral	Agricultural	Based on social and political interests and supported by organizations' bylaws and occasionally reinforced by state statute	Polycentric
	Environmental		
	Municipal		
	Industrial		
	Recreational		

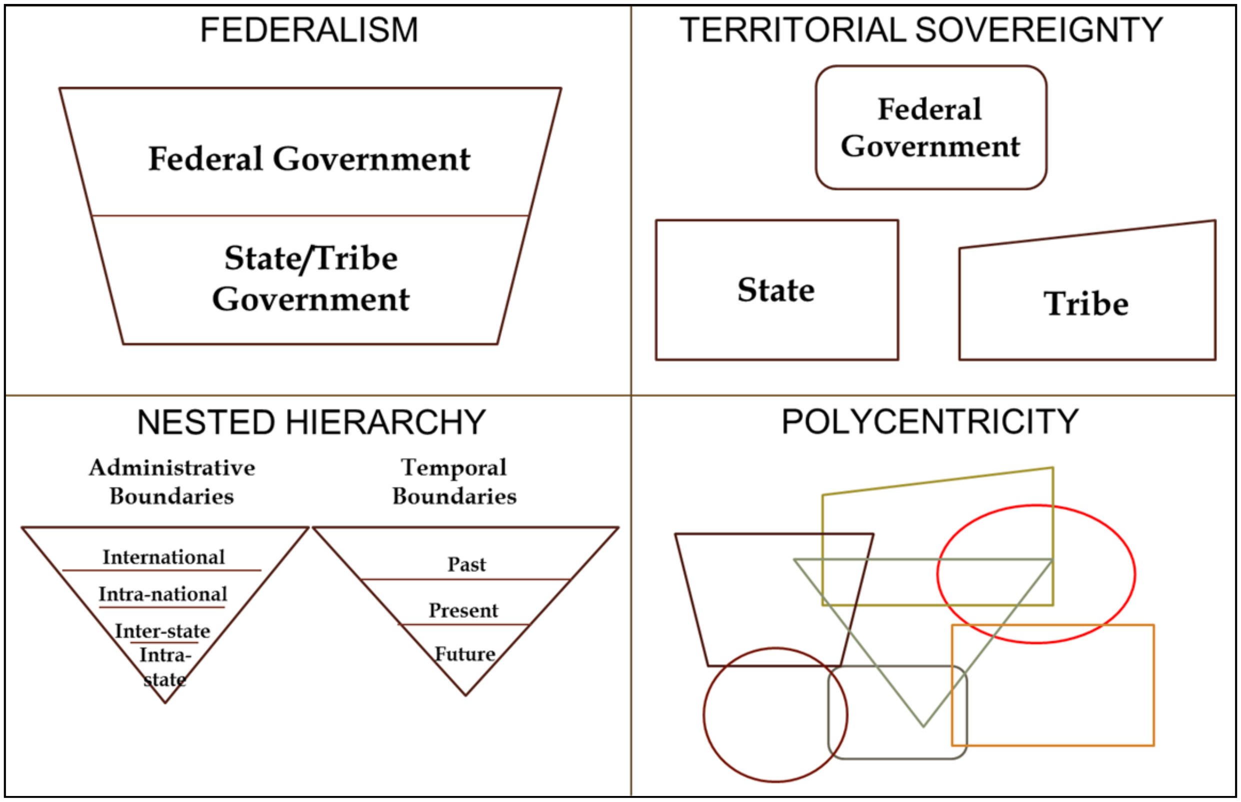


Figure 2.b: Geo-political Patterns of Agricultural Water Governance.

Table 2.b: Selected Water Sharing Arrangements in the Colorado River Basin within the U.S. and the U.S. and Mexico.

Water Sharing Arrangement[a]	Jurisdiction	Boundary Type	Year	Description
CRB Compact	6 basin states	Hydrologic, political	1922	Divides basin in to upper and lower sub-basins; defines scope of resources and basin; does not affect federal obligations to Indian Tribes
Mexico Water Treaty	U.S. and Mexico State Departments	Hydrologic, political	1944	Distributed the waters of the Colorado, Rio Grande and Tijuana Rivers between U.S. and Mexico based on the U.S. Mexico international boundary
Upper CRB Compact	Upper Colorado River Commission	Hydrologic, political	1948	Incorporates provisions defining geographic (jurisdictional) scope of CRB Compact's apportionment schedule based on hydrologic boundaries and established the Upper Colorado River Basin Commission
Arizona v. California (373 U.S. 546)	U.S. Supreme Court	Physical, administrative, sectoral	1963	Upholds the Boulder Canyon Project Act of 1928; DOI is responsible for Lower Basin water administration; federal lands have federally reserved rights.
Interim Guidelines	Bureau of Reclamation	Physical, political, sectoral	2007	Includes shared shortages to conserve reservoir storage and a coordinated operation of Lake Powell and Lake Mead determined by specified reservoir conditions that would minimize shortages in the Lower Basin and avoid risk of curtailments of use in the Upper Basin; and also adopts the Intentionally Created Surplus mechanism for promoting water conservation in the Lower Basin.

Minute 319	U.S. and Mexico sections of the basin, within the boundary designated by IBWC (U.S.) and CILA (Mexico)	Physical, political, sectoral	2012	Binational agreement that allows Mexico to store water in Lake Mead during a temporary period; provides provisional environmental flows to enhance the Colorado River delta; enables an exchange of water and financial resources between Mexico and the U.S. to help Mexico continue rehabilitating the delivery system destroyed in the 2010 earthquake.

[a] The full titles of the water sharing arrangements are: the Rio Grande, Colorado and Tijuana Treaty of 1944 (1944 Water Treaty), The Upper Colorado River Basin Compact of 1948 (Upper CRB Compact), Arizona v. California (1963), the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (Interim Guidelines) and the Interim International Cooperative Measures in the Colorado River Basin through 2017 and Extension of Minute 318 Cooperative Measures to Address the Continued Effects of the April 2010 Earthquake in the Mexicali Valley, Baja California (Minute 319)

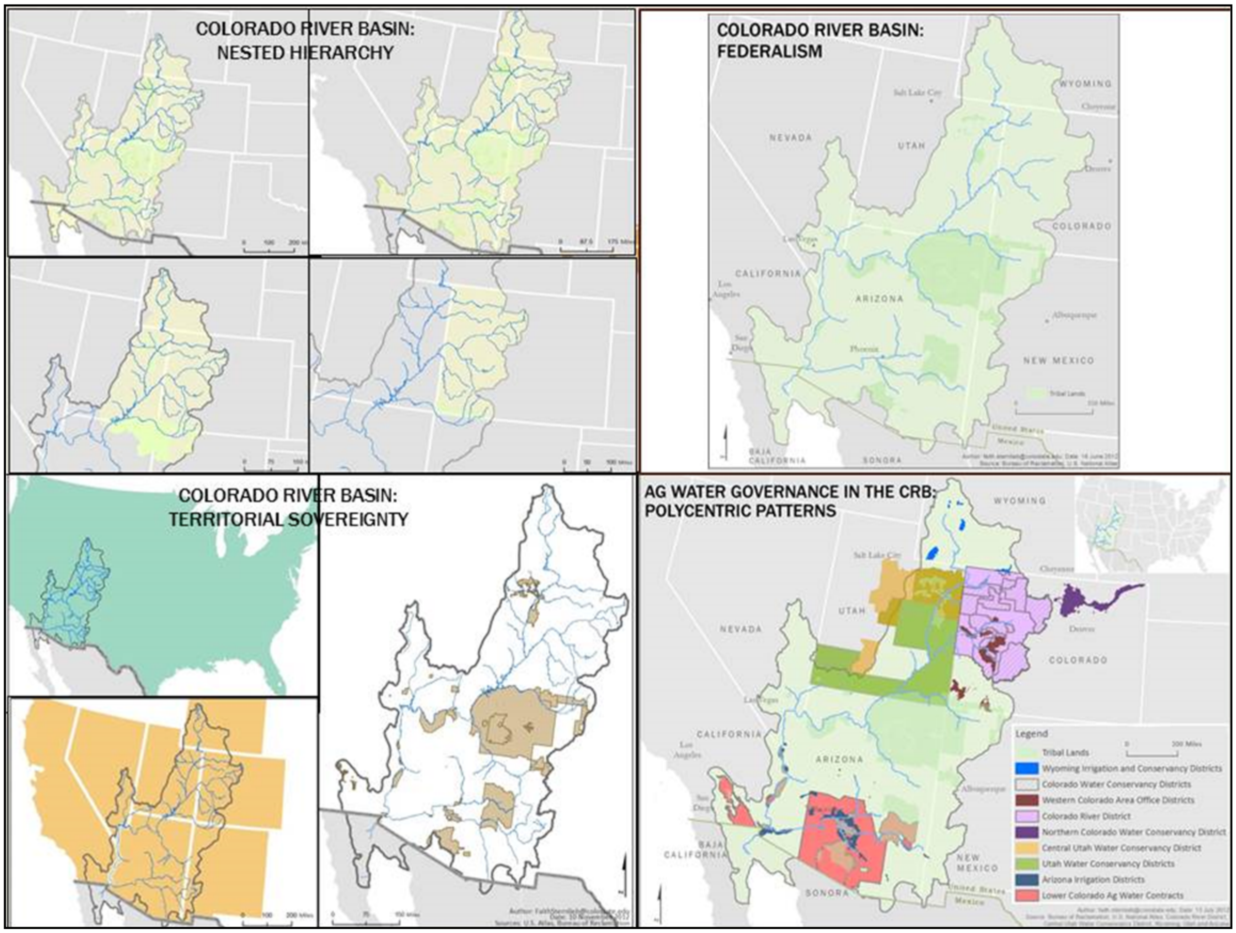


Figure 2.c: Maps of the Colorado River Basin Depicting Geo-political Governance Patterns. Four patterns include (a) nested hierarchy, (b) federalism, (c) territorial sovereignty, and (d) polycentrism.

Table 2.c: Water Sharing Arrangements in the Colorado River Basin and its Institutional Model and Function.

Water-sharing Agreement	Institutional Model	Boundary	Pattern
Colorado River Compact 1922)	Interstate Compact (Draper, 2007)	Hydrologic, political	Federalist
Mexico Water Treaty (1944)	International Treaty	Political	Territorial Sovereignty (at a binational level)
Upper Colorado River Basin Compact (1948)	Federal-Interstate Compact (Draper, 2007)	Hydrologic, political	Nested hierarchy, Sovereignty
Arizona v. California (1963)	Legal Decree	Political, sectoral	Polycentric
Interim Guidelines (2007)	Operational	Hydrologic, political, sectoral	Polycentric
Minute 319 (2012)	International Agreement	Hydrologic, political, sectoral	Polycentric

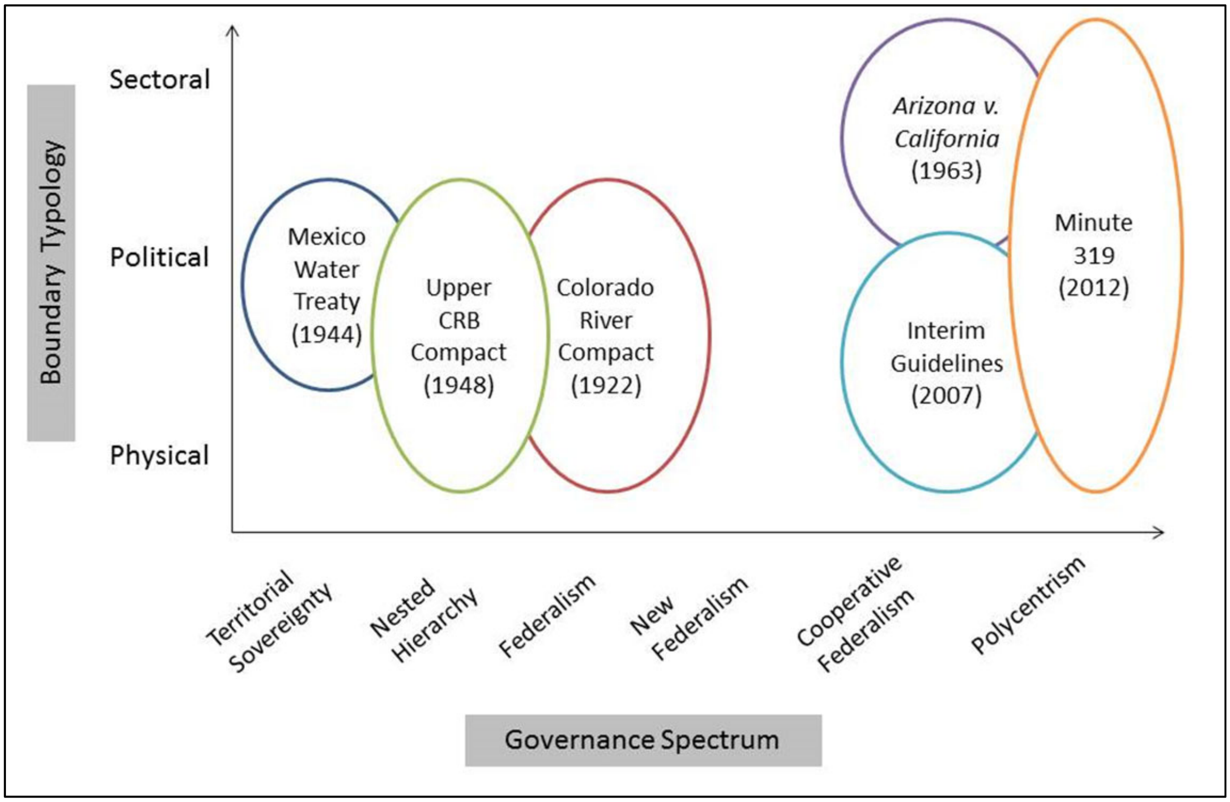


Figure 2.d: Governance Spectrum of Water Sharing Arrangements (WSAs) in the Colorado River Basin.

REFERENCES

Treaty of Guadalupe Hidalgo of Peace, Friendship, Limits and Settlement Between the United States and Mexico, TS 207, 9 Stat. 922-43 (1848).

Kansas v. Colorado, 206 U.S. 46 (1907).

Boulder Canyon Project Act of 1928, 45 Stat. 1057 (1928).

Colorado River Compact of 1922, 70 Cong. Rec. 324 (1928).

Rio Grande, Colorado and Tijuana Treaty of 1944, TS 994, 59 Stat. 1219 (1944).

Upper Colorado River Basin Compact of 1948, 63, Stat. 31 (1949).

Arizona v. California, et al., 373 U.S. 546 (1963).

Interim International Cooperative Measures in the Colorado River Basin through 2017 and Extension of Minute 318 Cooperative Measures to Address the Continued Effects of the April 2010 Earthquake in the Mexicali Valley, Baja California, Minute 319 (2012).

Anderson, T. L., & Hill, P. J. (Eds.). (1997). Water Marketing: The Next Generation. Lanham, MD: Rowman & Littlefield Publishers, Inc.

Andersson, K. P., & Ostrom, E. (2008). Analyzing decentralized resource regimes from a polycentric perspective. *Policy Sciences*, 41(1): 71-93.

August, J. L. J. (2007). Dividing Western Waters: Mark Wilmer and Arizona v. California. Fort Worth, TX: TCU Press.

Berkes, F. (2002). Cross-Scale Institutional Linkages: Perspectives from the Bottom Up. In E. Ostrum (Ed.), The Drama of the Commons (pp. 293-321). Washington, D.C.: National Academy Press.

Bierce, A. (2008). The Devil's Dictionary. Retrieved from http://www.gutenberg.org/files/972/972-h/972-h.htm

Blomquist, W., Schlager, E., & Heikkila, T. (2004). Common Waters, Diverging Streams: Linking Institutions to Water Management in Arizona, California and Colorado. Washington, D.C.: Resources for the Future.

Bretsen, S. N., & Hill, P. J. (2006). Irrigation institutions in the American West. *UCLA Journal of Environmental Law and Policy*, 25.

Brewer, J., Glennon, R., Ker, A., & Libecap, G. (2007). Transferring Water in the American West: 1987-2005. *University of Michigan Journal of Law Reform*, 40: 30.

Burt, C. M., & Styles, S. W. (2000). Irrigation district service in the Western United States. Journal of Irrigation and Drainage Engineering (September/October), 279-282.

Cash, D. W., Adger, W. N., Berkes, F., Garden, P., Lebel, L., Olsson, P., . . . Young, O. (2006). Scale and cross-scale dynamics: Governance and information in a multilevel world. *Ecology and Society*, 11(2): 8.

Cohen, M., Christian-Smith, J., & Berggren, J. (2013). Water To Supply the Land: Irrigated Agriculture in the Colorado River Basin (pp. 110). Oakland, CA: Pacific Institute.

Cook, E. R., Seager, R., Cane, M. A., & Stahle, D. W. (2007). North American drought: Reconstructions, causes, and consequences. *Earth-Science Reviews*, 81: 93-134.

Corker, C. E. (1957). Water rights and federalism: The Western Water Rights Settlement Bill of 1957. *California Law Review*, 45(5): 604-637.

deBuys, W. (2001). Seeing Things Whole: The Essential John Wesley Powell: Island Press.

Derthick, M. (1974). Between State and Nation: Regional Organizations of the United States. Washington, D.C.: The Brookings Institution.

Dinar, A. (2004). Exploring transboundary water conflict and cooperation. *Water Resources Research*, 40(5).
Dinar, A. (2010). Conflict, Cooperation, and Institutions in International Water Management: An Economic Analysis. *Land Economics*, 86(4): 843-845.
Dinar, A., Dinar, S., McCaffrey, S. C., & McKinney, D. (2007). Bridges Over Water: Understanding Transboundary Water Conflict, Negotiation and Cooperation (Vol. 3). Singapore: World Scientific Publishing.
Draper, S. E. (2007). Administration and institutional provisions of water sharing agreements. *Journal of Water Resources and Planning*, 133(5): 446-455.
Feitelson, E., & Fischhendler, I. (2009). Spaces of Water Governance: The Case of Israel and Its Neighbors. *Annals of the Association of American Geographers*, 99(4): 728-745.
Fiege, M. (1999). Irrigated Eden: The Making of an Agricultural Landscape in the American West. Seattle, WA: University of Washington Press.
Fischhendler, I., & Feitelson, E. (2003). Spatial adjustment as a mechanism for resolving river basin conflicts: the US–Mexico case. *Political Geography*, 22(5): 557-583.
Fischhendler, I., & Heikkila, T. (2010). Does integrated water resources management support institutional change? The case of water policy reform in Israel. *Ecology and Society*, 15(1): 16.
Fischman, R. (2005). Cooperative federalism and natural resources law. *NYU Environmental Law Journal*, 14: 179-231.
Fish, R. D., Ioris, A. A. R., & Watson, N. M. (2010). Integrating water and agricultural management: Collaborative governance for a complex policy problem. *Science of the Total Environment*, 408(23): 5623-5630.
Frederick, K. D. (Ed.). (1986). Scarce Water and Institutional Change. Washington, D.C.: Resources for the Future.
Gerken, H. K. (2010). Foreword: Federalism all the way down Faculty Scholarship Series (pp. 72), New Haven, CT: Yale Law School.
Gerlak, A. K. (2005). Federalism and U.S. Water Policy: Lessons for the Twenty-First Century. *Publius: The Journal of Federalism*, 36(2): 231-257.
Getches, D. H. (1997). Colorado River governance: Sharing federal authority as an incentive to create a new institution. *University of Colorado Law Review*, 68(573), 57.
Getches, D. H. (2001). The metamorphosis of western water policy: Have federal laws and local decisions eclipsed the state's role. *Stanford Environmental Law Journal*, 20(3): 70.
Grafton, R. Q., Landry, C., Libecap, G. D., & O'Brien, R. J. (2009). Water Markets: Australia's Murray-Darling and the US Southwest. Crawford School of Economics and Government. The Australian National University. Acton, Australia.
Gregory, D., Johnston, R., Pratt, G., Watts, M. J., & Whatmore, S. (Eds.). (2009). The Dictionary of Human Geography (5th ed.). Malden, MA: Wiley-Blackwell.
Griffin, R. (2012). Engaging irrigation organizations in water allocation. *Natural Resources Journal*, 52: 277-313.
Griffin, R., & Kelly, M. (2012). The future of irrigation organizations in the Colorado River Basin. *The Water Report*, 95: 18-22.
Grigg, N. (1991). Delph Carpenter, Father of Colorado River Treaties: Text of Governor Ralph L. Carr's 1943 Salute to Delph Carpenter (pp. 20). Fort Collins, CO: Colorado State University.

Grimm, V., Revilla, E., Berger, U., Jeltsch, F., Mooij, W. M., Railsback, S. F., . . . DeAngelis, D. L. (2005). Pattern-oriented modeling of agent-based complex systems: Lessons from ecology. *Science*, 310: 987-991.

Hall, N. D. (2006). Toward a new horizontal federalism: Interstate water management in the Great Lakes region. *University of Colorado Law Review*, 77: 405-456.

Heikkila, T. (2004). Institutional boundaries and common-pool resource management: A comparative analysis of water management programs in California. *Journal of Policy Analysis and Management*, 23(1): 97-117.

Hobbs, J. G. J. (1997). Colorado water law: An historical overview. *University of Denver Water Law Review*, 1(1): 74.

Hobbs, J. G. J. (1999). Colorado's 1969 Adjudication and Administration Act: Settling in *University of Denver Water Law Review*, 3(1): 18.

Hooghe, L., & Marks, G. (2003). Unraveling the central state, but how? Types of multi-level governance. *American Political Science Review*, 97(2): 233-243.

Hooghe, L., & Marks, G. (2010). Types of Multilevel Governance. In H. Enderlein, S. Walti & M. Zurn (Eds.), Handbook on Multilevel Governance (pp. 17-31). Cheltenham, UK: Edward Elgar.

Hooghe, L., & Marks, G. (2012). Beyond federalism: Estimating and explaining the territorial structure of government. *Publius: The Journal of Federalism*, 1-26.

Howe, C. E. (1985). Economic, legal, and hydrologic dimensions of potential interstate water markets. *American Journal of Agricultural Economics*, 67(5), 1226-1230.

Huitema, D., Mostert, E., Egas, W., Moellenkamp, S., Pahl-Wostl, C., & Yalcin, R. (2009). Adaptive water governance: Assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. *Ecology and Society*, 14(1): 26.

Hundley, N. (1966). Dividing the waters: a century of controversy between the United States and Mexico. Norris Hundley, Jr. Berkeley: Los Angeles, CA: University of California Press.

Hundley, N. (2009). Water and the West: the Colorado River Compact and the politics of water in the American West (2nd. ed.). Berkeley, CA: University of California Press.

Ingram, H. (1990). Water Politics: Continuity and Change. Albuquerque, NM: University of New Mexico Press.

Jacquez, G. M., Maruca, S., & Fortin, M. J. (2000). From fields to objects: A review of geographic boundary analysis. *Journal of Geographical Systems Analysis*, 2: 221-241.

Jones, L., & Colby, B. G. (2012). Measuring, monitoring, and enforcing temporary water transfers: Considerations, case examples, innovations and costs.

IBWC. (2013). Synopsis of the International Agreements Establishing and Institutionalizing the International Boundary and Water Commission (IBWC) Retrieved September 13, 2013, from http://www.ibwc.state.gov/About_Us/synopsis.html

Keating, T. J. (2001). Lessons from the Recent History of the Health Effects Institute. *Science, Technology & Human Values*, 26(4): 409.

Kenney, D. S. (1995). Institutional options for the Colorado River. *Water Resources Bulletin*, 31(5), 837-850.

Leshy, J. D. (1982). Irrigation districts in a changing west: An overview. *Arizona State Law Journal*, 345: 345-376.

Libecap, G. D. (2010). Water rights and markets in the U.S. semi-arid west: Efficiency and equity issues. Working Paper Series. International Centre for Economic Research.

Limerick, P. N. (2012). A Ditch in Time: The City, the West and Water. Golden, CO: Fulcrum Publishing.

MacDonnell, L. J., Howe, C. W., Miller, K. A., Rice, T. A., & Bates, S. F. (1994). Water Banks in the West (pp. 271). Boulder, CO: Natural Resources Law Center, University of Colorado.

MacDonnell, L. J., Wahl, R. W., & Driver, B. C. (1991a). Facilitating Voluntary Transfers of Bureau of Reclamation: Supplied Water (Vol. II, pp. 346). Boulder, CO: University of Colorado.

MacDonnell, L. J., Wahl, R. W., & Driver, B. C. (1991b). Facilitating Voluntary Transfers of Bureau of Reclamation: Supplied Water (Vol. I, pp. 72). Boulder, CO: University of Colorado.

Mann, D. E. (1964). The Politics of Water in Arizona. Tucson, AZ: University of Arizona Press.

McCaffrey, S. C. (1996). The Harmon Doctrine one hundred years later: Buried, not praised. *Natural Resources Journal*. (36): 549-590.

McCool, D. (1987). Command of the Waters: Iron Triangles, Federal Water Development and Indian Water. Berkeley: University of California Press.

McGinnis, M. D. (Ed.). (1999). Polycentric Governance and Development. Ann Arbor: University of Michigan Press.

Mead, E. (1903). Irrigation institutions: A discussion of the economic and legal questions created by growth of irrigated agriculture in the West. New York: The Macmillan Company.

Megdal, S. B., Varady, R. G., & Eden, S. (Eds.). (2012). Shared Borders, Shared Waters: Israeli-Palestinian and Colorado River Basin Water Challenges. Boca Raton, FL: CRC Press.

Moore, M. R. (1991). The Bureau of Reclamation's new mandate for irrigation water conservation: purpose and policy alternatives. *Water Resources Research*, 27(2): 145-155.

Mumme, S. P. (1985). State influence in foreign policymaking: water related environmental disputes along the United States-Mexico border. *The Western Political Quarterly*, 38(4).

Mumme, S. P., & Ibanez, O. (2011). Multilevel governance of water on the U.S.-Mexico border. Paper presented at the Earth Systems Governance, Fort Collins, CO.

Newman, D., & Paasi, A. (1998). Fences and neighbours in the postmodern world: boundary narratives in political geography. *Progress in Human Geography*, 22(2), 186-207.

Ostrom, E. (1993). Design Principles in Long-Enduring Irrigation Institutions. *Water Resources Research*, 29(7), 1907-1912.

Ostrom, E. (2005). Understanding Institutional Diversity. Princeton: Princeton University Press.

Pederson, G. T., Betancourt, J. L., & McCabe, J. (2013). Regional patterns and proximal causes of the recent snowpack decline in the Rocky Mountains, *U.S. Geophysical Research Letters,* 40, 1811-1816.

Powell, J. W. (1891). Eleventh Annual Report of the U. S. Geological Survey, 1889-1890: Part II-Irrigation Annual Reports to the Secretary of the Interior (pp. 395). Washington, D.C.: U.S. Geological Survey.

Pritchett, J. (2011). Quantification Task: A Description of Agriculture Production and Water Transfers in the Colorado River Basin (pp. 28). Fort Collins, CO: Colorado State University.

Robison, J., Bratrschovsky, K., Latchan, J., Morris, E., Palmer, V., & Villanueva, A. (2012). Forging ahead in the era of limits: The evolution of interstate water policy in the Colorado River Basin. Water Federalism Project. Harvard University.

Rowley, W. D. (2006). The Bureau of Reclamation: Origins and Growth to 1945 (Vol. 1). Denver, CO: U.S. Department of the Interior, Bureau of Reclamation.
Sabatier, P. A., Focht, W., Lubell, M., Trachtenberg, Z., Vedlitz, A., & Matlock, M. (Eds.). (2005). Swimming upstream: collaborative approaches to watershed management. Cambridge, MA: MIT Press.
Saliba, B. C., & Bush, D. B. (1987). Water Markets in Theory and Practice: Market Transfers, Water Values and Public Policy (Vol. 12). Boulder, CO: Westview Press.
Schlager, E., & Blomquist, W. A. (2008). Embracing watershed politics. Boulder, CO: University Press of Colorado.
Schlager, E., & Heikkila, T. (2009). Resolving Water Conflicts: A Comparative Analysis of Interstate River Compacts. *Policy Studies Journal*, 37(3): 367-392.
Schorr, D. (2012). The Colorado Doctrine: Water Rights, Corporations, and Distributive Justice on the American Frontier. New Haven, CT: Yale University Press.
Schuster, E., Colby, B., Jones, L., & O'Donnell, M. (2012). Understanding the Value of Water in Agriculture: Tools for Negotiating Water Transfers. In B. G. Colby (Ed.), Water Transaction Guidebooks for Water Professionals (pp. 67). Tucson, AZ: University of Arizona.
Seaber, P. R., Kapinos, F. P., & Knapp, G. L. (1987). Hydrologic Unit Maps U.S. Geologic Survey Water Supply Paper (pp. 63): U.S. Department of the Interior, U.S. Geological Survey.
Sheppard, E. S., & McMaster, R. B. (2004). Scale and geographic inquiry: nature, society, and method. Malden, MA: Blackwell Pub.
Sherow, J. E. (1990). The contest for the "Nile of America": Kansas V. Colorado (1907). *Great Plains Quarterly*, 10: 48-61.
Squillace, M. (2013). Water transfers for a changing climate. *Natural Resources Journal*, 53: 55-116.
Stegner, W. (1954). Beyond the Hundredth Meridian: John Wesley Powell and the Second Opening of the West. New York, NY: Penguin Books.
Sternlieb, F., Bixler, R. P., Huber-Stearns, H., & Huasca, C. (2013). A question of fit: Reflections on boundaries, organizations and social-ecological systems. *Journal of Environmental Management*, 130: 117-125.
Storey, B. A. (2002). Evolution of the Bureau of Reclamation: An insider historian's perspective on the legacy and the challenge. Paper presented at the Colorado Water Workshop, Gunnison, CO.
Thomas, K. R. (2008). Federalism, State Sovereignty, and the Constitution: Basis and Limits of Congressional Power CRS Report for Congress (pp. 29). Washington, D.C.: Congressional Research Service.
Tyler, D. (2003) Silver Fox of the Rockies: Delphus E. Carpenter and western water compacts. Norman, OK: University of Oklahoma Press.
Umoff, A. A. (2008). An analysis of the 1944 U.S.-Mexico Water Treaty. *Environs* 32(1): 69-98.
USBR. (2007). Record of Decision: Colorado River Interim Guidelines for Lower Shortages and the Coordinated Operations for Lake Powell and Lake Mead. Washington, D.C.: Department of the Interior.
USBR. (2012). Colorado River Basin Water Supply and Demand Study: Study Report *Reclamation: Managing Water in the West*. Boulder City, NV: Bureau of Reclamation, Department of the Interior.

Utton, A. E. (1967). International Streams and Lakes. In R. E. Clark (Ed.), Waters and Water Rights (pp. 401-495). Indianapolis, Indiana: The Allen Smith Company.
Wahl, R. W. (1989). Markets for Federal Water: Subsidies, Property Rights, and the Bureau of Reclamation. Washington, D.C.: Resources for the Future.
Whiteley, J. M., Ingram, H. M., & Perry, R. W. (Eds.). (2008). Water, place, and equity. Cambridge, MA: MIT Press.
Wilkinson, C. F. (1992). Crossing the Next Meridian: Land, Water and the Future of the West. Washington, D.C.: Island Press.
Worster, D. (1985). Rivers of empire: water, aridity, and the growth of the American West (1st ed.). New York, NY: Pantheon Books.
Worster, D. (2001). A River Running West: The Life of John Wesley Powell. New York, NY: Oxford University Press.
Yoffe, S., Wolf, A. T., & Giordano, M. (2003). Conflict and cooperation over international freshwater resources: indicators of basins as risk. *Journal of American Water Resources Association*, 1109-1126.
Yoffe, S., Fiske, G., Giordano, M., Larson, K., Stahl, K., & Wolf, A. T. (2004). Geography of international water conflict and cooperation: Data sets and applications. *Water Resources Research*, 40: 12.

APPENDIX 1-I: BOUNDARY ANALYSIS

Physical Boundaries

Hydrologic Units (otherwise referred to as river basins or watersheds) are "levels of divisions and subdivisions, used for the collection and organization of hydrologic data . . ." whereas hydrologic unit codes (HUCS) are "the numeric codes associate with hydrologic units" and are expressed by names "that correspond to the principal hydrologic feature" and an associated numerical classification (Seaber, Kapinos, & Knapp, 1987, p. 1). According to Seaber et al. (1987), the Hydrologic Map series was officially initiated by the Office of Water Coordination of the United States Geologic Survey (USGS) in coordination with the U.S. Water Resources Council in 1972. The Series depicts drainage, hydrography and hydrologic unit boundaries and codes "providing a standard geographic and hydrologic framework for detailed water resource and related land-resource planning" (Seaber et al., 1987, p. 1). Although the official, standardized Map Series dates back to 1972, watershed boundaries were delineated as far back as 1878 at the time of Powell's Report on the Lands of the Arid Region (Powell, 1891). In fact, the disputes in Congress during the last two decades of Powell's control over the USGS and the Bureau of Ethnographic Studies were not about the watershed boundaries he mapped (as they are remarkably close to those of the modern watershed boundaries (Isham and Simley, 2011)) but about how to organize and administer jurisdictions during the development of the west (deBuys, 2001; Worster, 2001).

In 1910, the USGS, USBR and the Weather Bureau (which has since been dismantled) agreed that a general plan for the hydrologic division of the U.S. was necessary for the purpose of hydrologic analysis and water planning, resulting in a 12-part hydrologic subdivision (Seaber et al. 1987). Long after 1910, institutional efforts spanning from 1959 – 1991 paved the way for the 1972 Map Series, which is the foundation for the HUC system being used today.

Political Boundaries: Federal Legislation

In the United States' federalist system, both federal and state governments have authority to manage water resources, sometimes in contradiction with each other (Table 2). Under the Commerce (U.S. Const. art. I, §8, cl. 3.) and Property Clauses (U.S. Const. art. IV, §3, cl. 2.) of the U.S. Constitution, federal regulation may affect interstate commerce including the navigability of waterways and for the beneficial use of federal property, respectively (GAO, 2003). In addition, "the Compact Clause of the Constitution, states cannot enter into any Agreements or Compacts with another State, or with a foreign Power – including those for the management of interstate waters – without the consent of Congress" (U.S. Const. art. I, §10, cl. 3). Despite the weight of these three federal clauses, states maintain direct authority over intrastate water management.

Federal legislation including the Reclamation/Newlands Act (1902) attests to states power in requiring adherence to states' laws governing "control, appropriation, use or distribution of water used in irrigation unless applying the state's law would be consistent with explicit congressional directive regarding the project" (GAO, 2003, p. 20). In addition, the Water Supply Act of 1958 culminating with the 1972 amendments to the Federal Water Pollution Control Act known as the Clean Water Act and the Endangered Species Act (1973) not only recognize state interests in water supply development but confirms that federal agencies should recognize, participate and cooperate in conjunction with state and local interests in developing multiple use projects (GAO, 2003). The National Environmental Policy Act (NEPA) of 1970 changed the course of water sharing by requiring environmental impact statements for big water project proposals, such as dams and reservoirs which constitute much of the multi-purpose water usage in the basin (USBR, 2007). With the passing of NEPA, the federal role in water development changed. While it once was the funder, after NEPA, the federal government became the regulator. More importantly, NEPA indirectly supported and enforced water for the environment as a beneficial use, adding to the number of water users and uses in the basin.

Political Boundaries: State Water Codes & Statutory Law

The question of territorial or state sovereignty lies at the heart of boundary questions as they pertain to water sharing between two nations (e.g. Mexico and the U.S.) and between states within one nation (e.g. Arizona and Colorado). In addition, water sharing between up and downstream interests cross invisible social or economic boundaries. McCaffrey (1996) hints to the sovereignty spectrum, at which one end is 'absolute territorial sovereignty' and the other 'absolute territorial integrity.' There has since been some movement away from these principles in governance at an international scale, depending on the country's area (Hooghe & Marks, 2012), but a principle that remains very much alive within the U.S., at an intranational scale (Elazar, 1990; Kincaid, 2008).

When it comes to power and control of water resources, the CRB states take absolute sovereignty very seriously. Beginning in the middle of the 19th Century, water use in the western U.S was established by early miners who set up the first 'white' settlements and for whom the Mining Act was approved by Congress in 1866 to allow territories and states to adopt their own water laws (Hobbs, 1999; Schorr, 2012; Wilkinson, 1992). The federal opportunities for land that "opened" the West (such as the Pre-emption Act (1830) and the Homestead Law (1863)) enabled farmers to follow suit and later adopted the common law "first in time, first in right" or the doctrine of prior appropriation (Wilkinson, 1992; Worster, 1985). Due to the arid climate, the unforgiving geology and topography of much of the basin, and the juxtaposition between the geography of water sources and land, farmers quickly realized the Riparian Doctrine, the rule that governed water use in the eastern U.S. which entitled water to users who owned land immediately adjacent to the stream, was not socially feasible or physically efficient (Schorr, 2012; Wilkinson, 1992; Worster, 1985).

Due to minimal rainfall in the Arid Region, farmers were dependent on the rivers that brought water from the snowpack in the mountains to water crops in the high plains but as more settlements spread across the landscape, farmers were located great distances from water sources. Ditches and canals became necessary, as settlements were located far from surface water sources. As more people migrated to the new frontier, water for agriculture became a political and social endeavor (Schorr, 2012; Wilkinson,1992; Worster, 1985). In addition to the temporal boundaries established by prior appropriation, the doctrines of beneficial use, "whose principles spurned waste and speculation" (Hobbs, 1997, p. 5) and for which uses were merely implied in the Colorado Constitution as domestic, agricultural, manufacturing, and mining (Corbridge & Rice, 2007) as well as the "use it or lose it" rule were a few of the very first legal decisions that determined sectoral boundaries, boundaries based upon the specific use of water.

Water codes, adopted in most western states at the time territories transitioned into statehood "set the pattern for western state administrative statutes" (Hutchins, 1962, p. 421). Water codes established some of the first formal boundaries and determined territorial rules regarding water resources such as the Howell Code, which instituted prior appropriation by the Arizona Territorial Legislature in 1864 (Goff, 1967). State statutes (or statutory law) define and describe the political rules associated with appropriation and adjudication of surface and groundwater based on state boundaries (specifically Arizona and Colorado). State water codes determine administration of watershed boundaries, whether or not they follow naturally occurring hydrologic regimes, in that they institute how water (ground or surface water) is managed within each state.

"The dominant factor of development in the West was [and still is] the limited availability of water" and the irregularity of river flows due to precipitation variability of the region initiated by the physical movement of water from source to field (Corbridge & Rice, 2007, p. 3). The Doctrine of Prior Appropriation was the first rule reinforcing the physical challenge of moving water from its source to where it was most needed. The earliest recorded adoption of this rule was in 1855 when the California Supreme Court legally institutionalized the prior appropriation based on diversion of a stream for mining (Corbridge & Rice, 2007; Wilkinson, 1992). Decades later, the Colorado Laws of 1879 and 1881 initiated "general procedures applicable to contests over title to real property," in this case water rights were considered real property (Hutchins, 1962, p. 424). Under the guidance of Elwood Mead, Wyoming set precedence for the appropriation, determination, and distribution of water rights in 1890 by instituting the first "administrative system for the initiation and determination of water rights in accordance with state administered hydrographic planning" (Corbridge & Rice, 2007, p. 3), centralizing water rights administration and thereby propagating the states' power over public resources in the West.

Exemplifying an Upper and Lower Basin state, state statutes in Arizona (Lower Basin) and Colorado (Upper Basin) are enacted by the state legislature and implemented by either the Office of the State Engineer (Colorado) or the state's department of water resources (Arizona). In the case of Colorado, the Water Right Determination and Administration Act (1969) established a new administration system for water allocation in line with Powell's original proposal, the first of all U.S. states that initiated the development "of specialized court procedures for the adjudication of water rights" (Corbridge & Rice, 2007, p. 3; Hobbs, 1997). Under the revised statutes, each state also established the ability to form local jurisdictions. This was especially important for the management of agricultural and municipal water early on in statehood and became important as water development expanded in scope for other interests. In Arizona, water codification falls under the Arizona Revised Statues (A.R.S.) Title §45 entitled Waters, adopted in 1919. At the local level, Arizona legislates water for agriculture specifically under Water Districts, A.R.S. §45-109 and Groundwater Code, A.R.S. §45, Chapter 2. In Colorado, the water code falls under Colorado Revised Statutes (C.R.S) §37 entitled Water and Irrigation, established with the adoption of the State Constitution in 1876. At the local level, Colorado legislates water specific to agriculture under Water Divisions C.R.S. §37-92-201, which falls under the Water Right Determination and Administration Act (1969) and pertains to hydrologic divisions administered by the Colorado water court, and as part of the Water Conservation and Irrigation Districts of Title 37 (Articles 41-47 are those that pertain directly to the CRB).

The shift from administering political boundaries to hydrologic boundaries has had a profound impact on agricultural water governance in the Basin. In Arizona, due to limited surface water resources, rules were established based on groundwater basins, which were delineated for administrative purposes. Article 1 of Chapter 2, of A.R.S. §45 declares the designation of groundwater basins and sub-basins. Articles 2 and 3 further define groundwater use administration for Active Management Areas and Irrigation Non-Expansion Areas (respectively) based on water development accounting for economic interests (sectors). In Colorado, C.R.S. §37 Part 2 of Article 92 legislates water divisions, division engineers, water judges and their jurisdiction and water clerks and their duties all established by the 1969 Water Right Determination and Administration Act. These divisions of ground and surface water resources are directly in line with Powell's original proposal of basing administrative units on natural districts (although the implication of districts on groundwater management and administration was unforeseen at that time), fitting within the proposed boundary typology (physical and political boundary types).

In Arizona, groundwater administration can be traced back to 1904 (*Howard v. Perrin*, (1904, 1906)), not long after Powell's proposition (Staudenmaier, 2006), whereas Colorado only mandated ground (and surface) water administration in 1957. Despite the time it took to create legislation for management of groundwater, Colorado set a precedent on surface water administration and appropriation, beginning in 1872 with the *Yunker v. Nichols* decision, prior to reaching statehood.

Differences between water sources in Arizona and Colorado explain why Colorado was a leader in the West of surface water appropriations and Arizona in groundwater policy. Despite this clear distinction, groundwater boundaries are still not as clear. Where surface water flows over the landscape and can be traced from source to mouth, diverted from one basin to another, conserved or used to extinction, groundwater is much more complicated as the evidence shows in over fifty years of litigation and statutory legislation in Colorado alone (Corbridge & Rice, 2007). Much of the current groundwater policy was debated in both legal and scientific terms and is still in debate to this day (e.g. CO HB 1278, South Platte Groundwater Study). The resulting boundaries from groundwater delineation, administration and appropriation are just as complicated as the legal and political frameworks that drive decision-making and thus remain a topic for further research. However, because many of the key legal cases in Arizona treat groundwater, the cases that are represented here are disproportionally from Colorado.

Political Boundaries: Judicial Law

In considering boundaries in the Colorado River Basin, it is impossible to ignore the role of the judicial system, particularly as decisions pertain to physical (hydrologic), temporal (historical), administrative (political and judicial), and sectoral (social and cultural) boundaries. Trends in western history show that state and federal laws as well as a court decisions determined the flow of limited water resources in an expansive arid and semi-arid landscape (Sherow, 1990). These selected judicial cases demonstrate the historical evolution of boundaries derived from case law and the impact it has had and continues to have on water resources in the Basin, particularly in the states of Arizona and Colorado.

There are eight selected legal cases (Table 4) that are critical in understanding the formulation of boundaries that drive governance decisions about agricultural water. In addition, each case represents a particular governance pattern. Federal and statutory policies tell only part of the water-sharing history in the basin. Case law tells another side. Although many of these cases do not strictly treat the use of water for agriculture, there are strong implications for agricultural water governance, particularly as it pertains to water sharing. These cases have paved the way for creating new boundaries or diminishing those that once existed, opening arenas for water sharing arrangements. This is not an exhaustive review of case law geographically bounded within the CRB; however, key cases have been chosen based on Hobbs (1997). There are many subsequent decisions that have followed these milestone cases impacting water for agriculture, which are not included here.

The establishment of polycentric governance can be traced back to *Yunker v. Nichols*, (1872). Tried by the Territorial Supreme Court before Colorado was declared a state, *Yunker v. Nichols* (1872) determined water could be diverted and have a right of way passage from an irrigation ditch through private and public lands to the place of use based on multiple factors, one of them on climatic conditions, but grounded upon economic necessity (Hess, 1916). This ruling is one of the first that allows dismissal of terrestrial boundaries, particularly land under private ownership (Hess, 1916) such as that of agriculture, which led to the acceptance of rulings based on sectoral boundaries.

In 1882, Colorado followed California by officially adopting the appropriation doctrine and the principle of beneficial use (*Coffin v. Left Hand Ditch Co.* (1882)). Arizona followed soon thereafter with *Clough v. Wing* (1888). In the context of boundaries, *Clough v. Wing* (1888) is the most restrictive in that it suggests permanence of water rights through time, independent of the ecological, social, political, and economic changes that might occur from increases in population and development. Like the prior appropriation rule, the *Clough v. Wing* (1888) decision is demonstrative of hierarchical governance patterns, as temporal boundaries are largely based on sequential legal and political decisions. Water users benefited from the permission to sell or transfer water rights (*Strickler v. City of Colorado Springs* (1891)), which expands the temporal and geographic bounds of *Clough v Wing* (1988). Transfers also incorporate administrative and geographic flexibility within the rigidity of prior appropriation rules.

Water sales (or transfers) and the separation of water from land were permitted as long as no injury to other water rights holders were incurred. Two important boundary concepts were established in this rule: water transfer and no injury. The ability to transfer water from one place to another undermines physical boundaries for personal property rights and ownership. That water inherently has no boundaries and, at the same time, is individually bounded is one of the first major contradictions in the hydro-political system (refer again to Table 2). Water management centered on watershed drainages trends towards a complimentary governance pattern (nested hierarchy) when political boundaries follow naturally occurring physical boundaries. Under the prior appropriation, no-injury and water transfer rules, water rights have control over water flows, inducing competition between political and physical boundaries, fragmenting both and complicating administrative systems, such as those we are familiar with today.

Water sharing has emerged in many different forms, at multiple levels and between different groups of people. *Kansas v. Colorado*, (1907) was the first case with language about water sharing between states (Sherow, 1990) specifically regarding equitable apportionment: “two or more states sharing water from one system are entitled to a water allocation.” One year later and by broad definition, *Winters v. United States*, (1908), otherwise known as the federal reserved water rights doctrine, determined that water rights for tribal reservations apply to the time the reservations were established (in this case the hierarchical pattern typified for temporal boundaries does not apply; the timing of this case supersedes older water rights established by prior appropriation). Not only does this case override the prior appropriation doctrine, but it also implies that entities such as states must share their water with tribes and other federal reservations where water for the environment could lawfully be considered beneficial use. Although the implications for water sharing in this case are strong, the typology for boundaries and governance patterns do not fully explain this paradox. Underlying the *Winter v. United States* (1908) decision are political boundaries tied to territorial sovereignty governance patterns, still within a federalist framework. Due to rules under the federal legal system, tribes were suddenly able to exercise their right to administer their own water within their political boundaries just as western states had been doing since the inception of the State of California in 1850. In addition, their rights in some cases were older than private rights established by the prior appropriation. In these two ways, boundaries diverged from patterns of governance with the decision of this case, and very possibly, for all tribal cases going forward.

Taking the transfer and no-injury rules one step further, the decision in the *City and County of Denver v. Fulton Irrigating Ditch Co.* (1972) case determined that a user of imported water has rights of re-use (use for the same purposes as original use), successive use (use water for different purpose), and disposition (right to sell, lease, exchange) of foreign water to extinction in order to maximize amount of water removed from western Colorado. There are three types of boundaries implied in this case: physical (diversion of the natural flow of the river), administrative (statutory, administrative, and judiciary) and sectoral (multi-interest). In Colorado, *City and County of Denver v. Fulton Irrigating Ditch Co.* (1972) was further established in statutory law by the Water and Irrigation statute. Multiple boundaries that cause overlapping jurisdictions such as those demonstrated in this case, are indicative of polycentric governance patterns.

Arizona v. California (1963) is a landmark case upholding the Boulder Canyon Project Act of 1928, which apportioned the Colorado River Lower Basin’s mainstream waters with California receiving 4.4 MAF, Arizona receiving 2.8 MAF and Nevada receiving 0.3 MAF. In addition, each state (Arizona in particular which fought for their rights to the Gila River) has entitlement to their own tributaries. USBR under the Department of the Interior (DOI) is responsible for Lower Basin water administration, and tribal reservations, National Recreation

Areas, and National Forests adjacent to the river in the Lower Basin have federally reserved rights.

Governance of agricultural water is mandated by political boundaries based on hydrology. In *Arizona v. California* (1963) some of the political boundaries follow hydrology, however the majority are more complicated due to the number of overlapping jurisdictions at the federal, state and tribal levels included in the case: the states of Arizona, California and Arizona (II6D), Chemehuevi Indian Reservation (1), Cocopah Indian Reservation (2), Yuma Indian Reservation (3), Colorado River Indian Reservation (4), Fort Mohave Indian Reservation (5), Lake Mead National Recreation Area (6), The Havasu Lake National Wildlife Refuge (7), Imperial National Wildlife Refuge (8), the Seven-Party CA Agreement (PVID, IID, CVCWD, MWD, Los Angeles, San Diego, County of San Diego) (III), and the state of New Mexico (IV). Jurisdictions for Ag water governance encompass both political and sectoral boundaries as is indicated by both agricultural (e.g. Imperial Irrigation District) and municipal (e.g. Los Angeles) representation of the Seven-Party Agreement. Hydrologically, language in the case refers to the Colorado River as the Mainstream, which means the Colorado River downstream from Lee Ferry within the U.S. (Section B), which is the boundary between Arizona and California and continues as the international boundary between the U.S. and Mexico for 25 miles. Though it is difficult to classify legal cases due to their temporal nature, the *Arizona v. California* (1963) case exemplifies a polycentric agreement in the multiplicity of physical, administrative and sectoral boundaries as well as their geographic arrangement.

REFERENCES

Irwin v. Phillips, et al., 5 Cal. 140 (1855).
Yunker v. Nichols, 1 Colo. 552 (1872).
Coffin v. Left Hand Ditch Co., 6 Colo. 443 (1882).
Clough v. Wing, 2 Ariz. 371 (1888).
Strickler v. City of Colorado Springs, 16 Colo. 61 (1891).
Howard v. Perrin, 76 P. 460 (1904).
Howard v. Perrin, aff'd 200 U.S. 71 (1906).
Kansas v. Colorado, 206 U.S. 46 (1907).
Winters v. United States, 207 U.S. 564 (1908).
Water Supply Act, 43, U.S.C. § 390b (1958).
Arizona v. California, et al., 373 U.S. 546 (1963).
Water Right Determination and Administration Act, C.R.S § 37-92-101 et seq. (1969).
Water Right Determination and Administration Act, C.R.S. § 37-2-92 (1969).
National Environmental Policy Act of 1969, 83 Stat. 852 (1970).
City and County of Denver v. Fulton Irrigating Ditch Co., 179 Colo. 47, 506 P.502d 144 (1972).
Federal Water Pollution Control Act Amendments of 1972, 33, U.S.C. § 1251 et seq. (1972).
Endangered Species Act of 1973, 87 Stat. 884 (1973).
Corbridge, J. N. J., & Rice, T. A. (2007). *Vranesh's Colorado Water Law* (Updated ed.). Niwot, Colorado: University Press of Colorado
deBuys, W. (2001). *Seeing Things Whole: The Essential John Wesley Powell*: Island Press.
Elazar, D. J. (1990). Opening the third century of American federalism: Issues and prospects. *Annals of the American Academy of Political and Social Science, 509*, 11-21.
GAO. (2003). Freshwater Supply: States' View of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages *Report to Congressional Requesters* (pp. 118). Washington, D.C.: U.S. General Accounting Office (GAO).
Goff, J. S. (1967). William T. Howell and the Howell Code of Arizona. *The American Journal of Legal History, 11*(3), 221-233.
Hess, R. H. (1916). The Colorado water right. *Columbia Law Review, 16*(8), 649-664.
Hobbs, J. G. J. (1997). Colorado water law: An historical overview. *University of Denver Water Law Review, 1*(1), 74.
Hobbs, J. G. J. (1999). Colorado's 1969 Adjudication and Adminstration Act: Settling in *University of Denver Water Law Review, 3*(1), 18.
Hooghe, L., & Marks, G. (2012). Beyond federalism: Estimating and explaining the territorial structure of government. *Publius: The Journal of Federalism*, 1-26.
Hutchins, W. A. (1962). Background and modern developments in the water law in the United States. *Natural Resources Journal, 2*, 416-444.
Irwin v. Phillips, et al., 5 Cal. 140 (1855).
Isham, K., & Simley, J. (2011). *Watershed boundary dataset: Past and present: John Wesley Powell's vision for the west*. U.S. Geologic Survey. Denver, CO.
Kincaid, J. (2008). Contemporary U.S. federalism: Coercive change with cooperative continuity. *Revista d'Estudis Autonomics I Federals, 6*, 10-36.
McCaffrey, S. C. (1996). The Harmon Doctrine one hundred years later: Buried, not praised. *Natural Resources Journal*(36), 549-590.

Powell, J. W. (1891). Eleventh Annual Report of the U. S. Geological Survey, 1889-1890: PartII-Irrigation *Annual Reports to the Secretary of the Interios* (pp. 395). Washington, D.C.: U.S. Geological Survey.
Schorr, D. (2012). *The Colorado Doctrine: Water Rights, Corporations, and Distributive Justice on the American Frontier*. New Haven, CT: Yale University Press.
Seaber, P. R., Kapinos, F. P., & Knapp, G. L. (1987). Hydrologic Unit Maps *U.S. Geologic Survey Water Supply Paper* (pp. 63): U.S. Department of the Interior, U.S. Geological Survey.
Sherow, J. E. (1990). The contest for the "Nile of America": Kansas V. Colorado (1907). *Great Plains Quarterly, 10*, 48-61.
Staudenmaier, L. W. (2006). Arizona Groundwater Law. *The Water Report*(33), 1-10.
USBR. (2007). *Record of Decision: Colorado River Interim Guidelines for Lower Shortages and the Coordinated Operations for Lake Powell and Lake Mead*. Washington, D.C.: Department of the Interior.
Wilkinson, C. F. (1992). *Crossing the Next Meridian: Land, Water and the Future of the West*. Washington, D.C.: Island Press.
Worster, D. (1985). *Rivers of empire: water, aridity, and the growth of the American West* (1st ed.). New York: Pantheon Books.
Worster, D. (2001). *A River Running West: The Life of John Wesley Powell*. New York, NY: Oxford University Press.

CHAPTER 3 SPATIALIZING WATER GOVERNANCE IN THE COLORADO RIVER BASIN

Introduction

Because water availability and quality studies dominate geospatial research in the Colorado River Basin (CRB), the majority of geospatial data documents water supply and quality metrics for decision-makers, not about decision-making (USBR, 2012). However, a geospatial perspective on governance allows us to spatially analyze policy outcomes (Feitelson & Levy, 2006; Feitelson & Fischhendler, 2009; Fischhendler & Feitelson, 2003; Starr, 2002; Wolf, 1999). There is also a need to better understand the geospatial aspects (or spatialization) of water governance, especially at regional and local scales (Fabrikant, 2000; Kraak, 2004) and between boundaries. Boundaries are important in questions about water governance, especially as they relate to scale because they can determine political, economic, and social decisions, as is the case in the production of agriculture and where agricultural endeavors originate and endure. Through a better understanding of geospatial data and a boundary analysis, agriculture (sector) emerges as a local phenomenon and defines governance at a local level (scale).

This chapter is a demonstration of how water governance can be spatialized in the CRB and how policy can be identified on the landscape. In addition, this chapter addresses a gap in the geospatial data that is instrumental for a better understanding of Ag water governance in the CRB. The CRB is an international transboundary river basin estimated at 242,000 square miles that covers the greater Southwestern U.S. and borders the U.S. and Mexico for 22 miles (Figure 3.a). In this study, water sharing arrangements in the CRB (as established by the *Law of the River*) are the unit of analysis, where agriculture is the central focus. Geospatial data collections in the CRB include online interactive maps (Web maps) that demonstrate and visualize physical water data including supply and quality from multiple sources at different scales (Kraak, 2004, 2003; MacEachren & Kraak, 2013). However, the CRB Water Governance Relational Geodatabase (WGRG) responds to the need to better understand water governance as a geospatial manifestation by (a) applying the boundary typology established in Chapter 2 (hydrologic, political and sectoral boundaries) in a geographic information system, (b) identifying geospatial governance characteristics, and (c) proposing governance layers as a method to integrate governance data in a relational geodatabase, with an emphasis on special interests, in this case, agriculture (Ag). The Environmental Defense Fund contracted Dr. Melinda Laituri and a student (the author of this dissertation) to initiate the development of the WGRG in 2010, which was further developed in conjunction with the USDA project, *Addressing Water for Agriculture in the Colorado River Basin* where it is housed (http://www.crbagwater.colostate.edu/gismapping.shtml) in 2011. In addition to the application of the boundary typology, the WGRG is an application for the Ag water governance dataset.

To examine the spatialization of water governance, the first section focuses on geospatial governance characteristics that are key to translating boundaries from the boundary typology to spatially explicit boundaries. The second and third sections are a review of geospatial representations of water governance through boundaries regarding two aspects: (a) the geovisualization of governance, where maps are used to “stimulate visual thinking about geospatial patterns” (Kraak, 2003, p. 391; 2004, p. 85; Tufte, 2006) and (b) the use of the digital environment through the Internet, software, and digital globes. Specific examples of efforts to map governance globally and in the CRB are provided as well as different types of datasets and databases developed to date. The fourth section describes a systematic methodology and utility of the CRB WGRG. This database applies the boundary typology through governance layers by identifying the governance characteristics of water sharing arrangements (WSAs). WSAs demonstrate governance characteristics that describe transactions between water users for agriculture (and other sectors), making the link between governance and geography explicit through geovisualization. Governance layers are defined by two key components: (a) mandated or naturally occurring geographic boundaries and (b) political decisions made based on those boundaries. Governance layers describe physical and political boundaries that are (a) organized politically, hydrologically, and/or by sector (boundary type in Table 3.a) and (b) described by types of political, hydrologic, and sector boundaries (governance layers in Table 3.a).

The utility of the geodatabase is to analyze subsets of data regarding water and data sharing. Water sharing is one medium to analyze the role of boundaries in governance patterns and processes in a geospatial environment and is key to understanding Ag water governance in the CRB, as shown in Chapter 2. For the purposes of this article and based on definitions of environmental governance, Ag water governance is the rules, policies, organizational structures, and tools that structure how people produce agriculture including how they access and use water for Ag. The fifth section evaluates results from data analysis that address issues of scale, the role of standardization in data sources, data availability, and establishing geospatial linkages to governance. This chapter concludes with implications for future research regarding the spatialization of water governance and the boundaries that enable the geovisualization of governance data.

Geospatial Governance Characteristics

According to Fabrikant (2000), “spatialization is based on envisioning and comprehending spatial properties . . . rooted in physical and cultural experiences” (p. 68). Therefore, to spatialize governance means to create a metaphor that represents “abstractions and selections of reality,” (Kraak, 2004, p. 83). In this study, spatialize means to localize characteristics such as geographic boundaries that represent governance patterns and processes and link them to geospatial data.

Water governance is inherently geospatial. It is important to distinguish between spatializing government and spatializing governance, just as differentiating between government and governance is important to consider in understanding the inter-relationship between policies, decision-makers, and stakeholders (Krahmann, 2003). Historically, governments have been mapping their territories using cartographic lines to depict boundaries. Governance however, entails more than just lines that represent territoriality; it is the formal and informal rules, policies, and regulations and the boundaries defined by decision-making at multiple levels (Krahmann, 2003; Biermann et al., 2010). The analytical problems of Biermann et al. (2010) and governance dimensions of Krahmann (2003) situate the conceptual application of governance to geographic information science (GIScience), where scale is the most salient for identifying governance characteristics. Sternlieb, Bixler, Huber-Stearns, & Huasca (2013) describe scale as a transboundary concept which is useful for linking governance characteristics and geospatial data.

Water scarcity is the cause of many boundary debates within both theoretical and applied discourses, giving rise to questions about shared water resources and governance. Water resources in particular, have driven scholarship on many international, transboundary river basin and water mapping efforts (De Stefano, Duncan, Dinar, Stahl, Stzepek, & Wolf, 2010; Stimie et al., 2001; Sullivan et al., 2006; Thompson et al. 2001; Wolf, 1999). As a governance characteristic and a geospatial attribute, boundaries are key to governance studies. One governance boundary is the normative or *bonafide* boundary (Sternlieb et al. 2013), which can also be described as the agreement (cooperation) or disagreement (conflict) between two water users in shared river basins (Feitelson & Fischhendler, 2009; Feitelson & Levy, 2006;

Fischhendler & Feitelson, 2003; Starr, 2002; Wolf, 1999). Boundaries also have an important role in providing the link between qualitative GIScience data analysis and textual materials (e.g. policy documents) that are otherwise absent in GIS software (Kwan & Ding, 2008). More specifically, they are an essential underlying component that can be used to link governance characteristics to geospatial data.

Boundaries can be represented geospatially in many ways: (a) through administrative boundaries (GADM 2012; SALB, 2013), (b) naturally occurring boundaries marking lines of territoriality (Furlong, Hegre, & Gleditsch, 2006; Gleditsch et al., 2006; Toset, Gleiditsch, & Hegre 2000), (c) institutional capacity (Yoffee et al., 2003; Yoffe et al. 2004), and (d) mapping indicators that assess risk and vulnerability in water resources systems (Vörösmarty et al. 2010) (Table 3.b). An implicit goal of many governance maps is the aim to make the data dynamic for analysis and accessible to different audiences. Geospatial science and datasets in transboundary studies make an important contribution to governance by exposing bonafide boundaries (e.g. Global Administrative Areas), differentiating between *bonafide* (socially constructed) and *fiat* (naturally occurring) boundaries (e.g. Second Administrative Level Boundaries and International River Boundaries Database, respectively), and revealing spatial patterns in water sharing, demonstrating governance processes (e.g. Transboundary Dispute Freshwater Database, Aqueduct) that might not otherwise be seen.

Geospatial governance characteristics represent governance priorities, activities, and actors and locate and connect them to physical, political, and sectoral boundaries. Like physical characteristics, points (e.g. cities), lines (e.g. rivers and canals), and polygons (e.g. jurisdictions) represent governance characteristics. Points, lines, and polygons represent governance characteristics for analysis at different scales. Points mark specific locations, while a polygon can provide information about the extent, size, and the number of locations. Governance characteristics situated within an area can be identified by attributes in tabular information linked to the X, Y coordinates that define the different shapes (points, line, polygons). Despite differences in analysis due to factors of scale, the zoom tool enables GIS users to transcend scale where points become polygons and neither is dependent on scale, unless the original source of the data is considered. This is true in dynamic online applications in such virtual application as Google Earth, ArcGIS OnLine, and OpenStreetMap.

Maps & Geospatial Data of the Colorado River Basin

The urgency of water scarcity in the CRB characterized by an increase in water demand, a decrease in supply, and increasingly variable precipitation patterns (USBR, 2012), has culminated in an increase of online activity by private and public entities attempting to provide water data and information to the public. Water scarcity in the CRB has captured the attention of the media venues evidenced by radio, newspapers, and blogs, investment of federal and state dollars in the two year Bureau of Reclamation CRB Supply and Demand Study (2012), and in privately funded initiatives like Save The Colorado (Wockner, 2010), *Nuestro Rio* (Kane, 2011), and Change the Course (National Geographic, 2013) among others. With the prevalence of Colorado River initiatives and research, maps are widely available for the Colorado River stakeholder Internet community including expeditions, conservation areas, management challenges, as well as water supply and development issues (Table 3.c). An analysis of the boundaries from the review of interactive maps of the CRB boundary typology reveal new boundaries such as anecdotal (stories and narratives found in PBS' Powell's First Voyage) and graphical (pictures and drawings demonstrated in National Geographic's Change The Course) boundaries. In addition to the non-profit and quasi-governmental organizations that collect, aggregate, and demonstrate geospatial data demonstrated in Table 3.c pertaining to particular governance themes such as water quality, water rights, and water supply systems, each state provides online water data related to Colorado River use, development, and conservation (Table 3.d). All boundary types are represented in state geospatial datasets, especially that of the sectoral boundaries where agriculture, municipal, environmental, and industrial water is characterized. However, much of the geospatial data from the state applies only to the political and hydrologic boundaries relevant to that state rather than the larger CRB that crosses many of these boundaries.

Federal agencies responsible for managing resources in the basin overlap jurisdictions with other managing entities, resulting in complex boundary intersections. The Bureau of Reclamation Supply and Demand Study (2012) is the most extensive federal-state data collection effort in the CRB to date. The Study was a result of a partnership between the Upper and Lower Basin states. The partnership exists and is based upon an historical set of policies, court cases, laws, and operational guidelines that set the political course for governing water in the CRB called the *Law of the River*. The aim of the study was to characterize current and future water supply and demand imbalances in the Basin and assess the risks to Basin resources that impact special interests, natural and human systems, and operations (USBR, 2013). The geospatial data collected were largely based on physical boundaries related to water measurements to test quantity and quality scenarios (USBR, 2012). Although implicit, the data collected in the Supply and Demand Study is important in understanding governance. However, explicit geospatial governance data are needed due to complex governance arrangements, overlapping jurisdictions, the quantity and variety of actors involved in decision-making, and the types of decision being made about water use, conservation, and development. The USBR and other federal and state agencies, as well as local irrigation districts typify the information necessary to build governance layers.

Methods

The CRB WGRG responds to the need to collect and examine geospatial water governance data. Using ESRI ArcGIS 10.1, a file geodatabase was constructed containing feature datasets and feature classes arranged by WSA and by state (see Appendix 3-I for the geodatabase architecture). Data were collected from different federal agencies, the seven Basin states, agricultural water organizations such as irrigation districts, non-profit organizations, federal and local public entities, as well as the National Atlas (2013), a collection of data provided by the U.S. government. All of the data collected were freely available on the Internet. Although the data came from different sources and have different geographic references, all of the data have been transformed to North America Albers Equal Area Conic projection and the GCS North American 1983 geographic coordinate system (see Appendix 3-II for metadata).

Boundary data were collected for organizations representing special interests within the basin, specifically agricultural interests. The utility of the CRB WGRG is to spatially represent Ag water governance in the CRB and apply the boundary typology. Special interests such as agriculture (organized in districts) are central to Ag water development and management in the CRB (Leshy, 1982) and exemplify sectoral boundaries (Table 3.e), such as those represented by Ag water governance layers. There is often a very fuzzy distinction between private and public districts because of how they are organized and authorized. Changes in management and project repayment can alter the public or private status of an irrigation district that has a contract with the federal government. Special districts such as service and supply organizations for Ag can be classified in two types: (a) private owned by shareholders, and (b) public, which are federal, state, or quasi-governmental (Getches, 2009). Private service and supply organizations are water utilities, mutual water companies, carrier ditch companies, and mutual ditch and irrigation companies. Public service and supply organizations are municipalities, irrigation districts, conservancy districts, conservation districts, USBR districts, water control districts, fresh water supply districts, and municipal water districts, providing a multitude of boundaries from which to create governance layers. The geospatial data available for Ag water governance collected from the USBR and Ag water projects link the federal government directly to these special interests creating governance layers. The data collected describing these entities attests to both the importance of the local scale in Ag water governance where sectoral boundaries define scale and the hundreds if not thousands of small irrigation companies that dot landscape (see Appendix 3-III for a list of Ag water supply organizations in the CRB).

Governance Layers

Governance layers are an integral component of the boundary typology in that they characterize the three types of boundaries: hydrologic, political, and sectoral. The goal of this geodatabase is to integrate two different types of data based on political and hydrologic boundaries, from which sectoral boundaries are derived. A subset of WSAs was selected to demonstrate governance that includes: the Colorado River Compact (1922), Mexico Water Treaty (1944), the Upper Colorado River Basin Compact (1948), *Arizona v. California* (1963), Interim Guidelines (2007), and Minute 319 (2012). Geospatial data includes: (a) hydrologic boundaries defined both by state and by hydrologic unit and (b) political boundaries that represent entities and their respective scale and jurisdiction (e.g. county, city, and district). Physical, political, and sectoral boundaries were linked by joining related tables in the relational database to governance layers (geospatial data) in the geodatabase (Figure 3.b; also see Appendix 3-IV for relational geospatial database procedure).

Each governance layer is represented in the geodatabase by a geospatial file and in the relational database through related tables. Each administrative area refers to a jurisdiction governed by distinct rules, actors, and cultural, social, and behavioral codes. Governance layers depict the complexity of water governance in the CRB because they demonstrate overlapping jurisdictions and arrangements driven by norms and behaviors of actors who have different and sometimes opposing claims in the use, conservation, and development of water resources. The process required to map physical boundaries is simple because geologic features such as mountain ranges and rivers can be geospatially located. However, sectoral boundaries (that are based on common cultural interests, norms, and values) are more difficult to locate because they are not necessarily tied to specific geographic coordinates and are often founded upon lifestyles and social and cultural norms. For example, temporal governance layers represent the political aspect of time (i.e. doctrine of prior appropriation). In the CRB, prior appropriation is the rule that established state's water rights. Although water rights data are not represented in the geodatabase, they can be represented as geospatial data as long as the water right is tied to a specific location (accomplished in the California New Water Atlas, refer to Table 3.d).

Because the boundaries in the *Law of the River* are configured in a temporally and spatially nested hierarchical pattern, it was necessary to identify all of the boundaries that applied to the agreements, policies, laws, and infrastructure upon which each WSA was founded. Although not explicit, Bureau of Reclamation projects are at the center of WSAs (Figure 3.c). Reclamation projects and their authorizing legislation exemplify local WSAs in the form of physical water storage, which maintain the viability of agriculture but sustain multiple sectors, water users and water uses. Initially built to support expansive agricultural development in the West, Reclamation projects support WSAs through dams and reservoirs as well as water delivery infrastructure. Reclamation projects demonstrate governance layers because they were authorized by federal acts of Congress, which funded storage and delivery systems that cross physical (watersheds), political (federal and state), and sectoral boundaries (agriculture among others).

The physical and political boundaries for each WSA are new feature datasets (governance layers) within the geodatabase (Figure 3.b, Step 1). The collected boundaries for each WSA were compiled in an excel spreadsheet and transferred to a relational database (Microsoft Access; see Appendix 3-V for the relationships and relational database). After objects (relationship tables) and relationships were established in the relational database (Figure 3.b, Step 2), database tables were imported into the geodatabase (Figure 3.b, Step 3). *Policy_Name* is an item that exists in both geodatabase attribute and relational tables and makes the join possible between the relational and geospatial attribute tables. With a complete dataset, the overlays of physical and political data reflect a governance system representing WSAs. With the complement of water rights data, representation of the temporal datasets will more accurately reflect water governance in the Basin. Based on the spatialization of Ag water governance, a number of results that can both inform academic research and help clarify challenges with developing such a database regarding scale, data collection, standardization, compilation, and geovisualization.

Results

Ag water governance is complex due to overlapping federal, state and local jurisdictions in the CRB as well as two different management systems in the Upper and Lower Basins. Data collection reflects this complexity posing multiple challenges for mapping scale, especially compilation from multiple sources, some of which are private and hold proprietary information such as data at the local scale regarding water rights. In addition, multiple scales of relevant data are collected for different purposes. Compounding scale challenges are the different types of data such as satellite imagery, paper maps, historical records, and field data collection as well as techniques used to collect data including global positioning systems, surveying instruments, and photogrammetry, among others. Finally, data collection at a coarse versus fine resolution as well as disparate standards for metadata and minimal coordination in data collection efforts makes it difficult to standardize datasets and to visualize governance through GIS.

Scale: Scale plays an important role in characterizing governance at the micro scale (local), relating to Ag water governance. For example, in Utah (a state located in both the Upper and Lower Basin of the CRB) Ag water governance generally falls under the jurisdiction of county 'districts', the only state in the basin where the county has a political presence in the agricultural sector. In the rest of the Basin, counties' responsibilities rest with municipal and industrial water management, not Ag water. An example of an intrastate WSA where counties have a role in Ag water is the California Seven Party Agreement, the intersection of water jurisdictions from the agricultural (irrigation districts) and municipal (counties and cities) sectors. Exceptions to the county rule for Ag in Utah and all over the basin are those districts that have contracts with the USBR, often referred to as Reclamation Projects. Ag water governance data related to Reclamation projects were collected from both districts in charge of projects and the USBR.

Wyoming Ag water organizations are largely governed through the state. Ag water in Colorado is managed by small private undertakings, which manage fewer than 1,000 acre feet of water, large USBR projects that manage thousands of acre feet (Lieberman, 2011), and state water projects, which can range anywhere in between private and federal projects. Intrastate districts such as the Colorado River District (CRD), responsible for managing water as well as advocating for special Ag interests on the West Slope, cover a large geographic extent in a region with multiple competing interests. These districts are able to manage, collect, and provide data and information for their stakeholders. In the Upper Basin, data for small, privately owned irrigation districts are difficult to obtain because they are responsible for paying the costs associated with collecting and maintaining geospatial information. However, the geospatial data CRD provided on boundaries for quasi-governmental conservancy districts within their jurisdiction is a starting point to mapping Ag water governance in Colorado and the CRB (Figure 3.d).

Data availability: Data collection for governance data was driven by the *governance of data*. In other words, the ability to collect data depended on the source and scale: federal, state, or local sources. The geospatial data from Ag water companies (administered by the state legislature but managed independently), whether surface or groundwater, were more difficult to access. The geospatial data on Ag water districts in the Lower Basin (governed by USBR) were available and provided by the Lower Colorado River Office (LCRO); however these data pertain only to the Lower Basin Division states. Data for Reclamation projects were easier to obtain from the Yuma Area, Western Colorado, and Provo regional offices. USBR offices in the CRB range in jurisdiction, a few of which cross state lines, resulting in data for one project in one state, which resided in a regional office located in another state. This was also true for USBR offices in Arizona and California. Geospatial data for Wyoming were provided by the state; however the state was not able to verify which districts still supplied water for agriculture (personal communication). Geospatial data for the individual irrigation companies were often not available online and because there are hundreds if not thousands of small irrigation companies and ditches, it was not feasible to contact each one individually. More importantly, when and if data regarding district and farm boundaries were available, that information was often considered private and confidential. In some cases, districts responded to my data requests with skepticism and suspicion about the data's use and its intended audience, raising questions about transparency and the proprietary nature of water rights data.

Standardization: Just as in many CRB states, water governance in California is situated within a complex arena and the geospatial data available on Ag water governance compounds the problem. The state of California differentiates between Private Water Districts and State Water Districts. "Private water district boundaries are areas where private contracts provide water to the district in California" (California Geoportal, 2013a) and "State water district boundaries are areas where state contracts provide water to the district in California" (California Geoportal, 2013b). Based on these definitions, the Imperial Irrigation District (IID) and the Coachella Valley County Water District (CVCWD) are Private Water Districts while the Coachella Valley Water District is listed as a State Water District.

Although the source of this information originated from metadata housed in the California Geoportal, a state driven geospatial data provider, a district's boundaries can be easily misconstrued, complicating the governance rules for a district within a sector. In the case of CVWD, the number of services it provides to different sectors confounds governance complexity. In the Geoportal, there are two distinct datasets: the Private Water District dataset and the State Water District dataset. In the Private Water District dataset, CVWD is listed, however the State Water District dataset lists the *Coachella Valley County Water District* (*CVCWD)*. In reality, these districts are one of the same, as the CVWD website state that it dropped the word "County" in 1979 (CVWD, 2013). In fact, CVWD is a "special district" established by state legislature in 1918, which provides a range of services including domestic water, groundwater replenishment and imported water, wastewater treatment, recycled water, storm water protection and flood control, agricultural irrigation and drainage, and water conservation (CVWD, 2013). Also confusing is that some irrigation districts are private while others are state and still others are simply considered Special Districts or quasi-public entities, which have taxing or financing authority like a public jurisdiction, but retain some authorities that are more "private" in nature.

The state of California has differing types of authorizing legislation for special districts for different purposes. Some districts are formed under "general authorization" (e.g. farmers who want to create a district have to petition to meet the requirements of the state that have been set under general legislation for districts) and others are formed under specific legislation (e.g. the legislature creates a number of specific, named districts via legislation). The Palo Verde Irrigation District is not listed in either dataset, however it is listed in the USBR Lower Colorado River Office (LCRO) dataset (dated 31 May 2011) as a district with a USBR contract. The Private Water District IID and State Water District CVWD also both have contracts with the USBR and are listed in the LCRO dataset. As these examples demonstrate, standardization is a challenge because geospatial data does not often reflect changes in policy and management, and are therefore frequently left as relics that make it difficult to conduct geospatial data analysis on governance.

Geospatial Link to Governance: The majority of Ag water in Arizona is divided into two geographic regions and three different governance regimes. The main regions include the southwestern corner of Arizona in Yuma County and central Arizona encompassed within a tri-county region: Maricopa, Pinal, and Pima counties. Ag water in other parts of the state is under tribal governance and interstate multi-party WSAs. The governance regimes include the governance of ground water (Central Arizona), surface water (Southwestern Arizona), and that of conjunctive use management, the management of ground and surface water together (Blomquist, Heikkila, & Schlager, 2001). Both regions are dependent on Colorado River water however, only the agriculture under surface water governance is dependent on the Colorado River and the USBR for delivery through Reclamation projects. Agriculture in Central Arizona is dependent in part on Central Arizona Project (CAP) water under the Ag Settlement Pool and in part groundwater administered by the State under the Groundwater Savings Facility program (CAP, 2010). The Ag Pool was established by the Arizona Water Settlement Act and "entitles a pool of first priority Excess Water to be allocated to the CAP agricultural water customers" (CAP 2010, 1). Ag Pool water is supplied by USBR but governed regionally by the Central Arizona Water Conservancy District (CAWCD), and locally by special irrigation districts under the states' statutes within the CAWCD jurisdiction. The CRB WGRG geospatially reinforces this tripartite relationship between the federal government, the state, and local district (McCool, 1987), linking sectors by identifying boundaries with local scale.

Conclusion

According to Butenuth, Gosseln, Tiedge, Heipke, Lipeck, & Sester (2007), practical integrated database applications include the verification, update, and enrichment of datasets, projections for future development based on past analyses that have been updated from cross referencing integrated datasets, as well as more detailed classifications of specific areas and regions. Based on this assessment, the purpose of this geodatabase is twofold. First, inclusion of the water sharing data based on the formal political and institutional boundaries enriches the geophysical dataset of the CRB. Secondly, governance layers from the boundary typology expand upon the description and classification of the political and institutional setting in the region, introducing socially constructed boundaries such as sectors. In this case, the agricultural sector in the CRB is viable precisely because of the infrastructure that is supported by water policy. The CRB WGRG geographically ties the *Law of the River* to the physical landscape through a transboundary analysis of water governance, which entailed the identification of geospatial governance characteristics and the application of the boundary typology to water sharing in the CRB. Specific places enhance our understanding of macro-governance systems (e.g. *Law of the River*) and the micro systems that depend upon them (e.g. Ag water governance). Through the geovisualization of water governance, adaptation strategies (e.g. WSAs) demonstrate that a highly regulated political system has been able to navigate in the face of climate uncertainty (Mulroy, 2008).

Historically, thematic spatial maps with a specific emphasis on boundaries reveal the power of water resources governance at the intersection of physical, political, and social realms (Alexander, 2005; Boggs, 1930, 1937a, 1937b, 1941, 1947, 1948, 1966). The CRB WGRG was created from select WSAs in the *Law of the River* by developing a systematic process to identify boundaries. The result is a boundary typology that provides a method to examine the agricultural sector, the main water user in the CRB. In summary, there are three types of boundaries within the boundary typology: physical, political, and sectoral. The physical boundaries formed naturally through time and hydro-geologic processes. There are two types of naturally occurring physical boundaries: hydrologic, those based on natural drainage systems defined by the National Hydrography Dataset of the U.S. Geologic Survey (USGS) (Seaber, Kapinos, & Knapp, 1987), and hydrographic boundaries delineated by a state or tribe. New physical boundaries are those created by physical infrastructure. Political boundaries, sometimes referred to as organizational or institutional boundaries (Heikkila, 2004), are politically constructed and are formed by a combination of political, social, and cultural forces. Political boundaries are based on four sub-types: statutory, judicial, administrative, and time. Sectoral boundaries are socially constructed and formed by social and cultural processes that delineate different types of water users as well as economic interests at local and regional scales (Fischhendler & Heikkila, 2010). Agricultural water policy has both formed and evolved from physical, political, and sectoral boundaries. Water for agriculture in the CRB has made its mark on the spatialization of governance, at the local, intrastate, interstate, intranational, and international scales. A close examination of WSAs, and the application of the boundary typology as well as collection of geospatial data pertaining to Ag water governance, has shown the diversity of agricultural jurisdictions across boundaries at multiple levels, and therefore across scale. Mapping governance can lead to a better understanding of the dynamics of water governance.

Future Research

Governance is geospatial on macro and micro-scales. In addition to the WSAs in the CRB analyzed here, geospatial analysis of micro-governance systems such as agriculture, the environment, recreation, and municipal and industrial sectors are important to better understand levels of actors' influence and participation in decision making. Each sector is also geographically tied to a place. Geovisualization can help identify those places where there is an abundance of competing interests and other places that are lacking. One way to show this is to conduct a transboundary analysis of the other sectors that have a stake in water resources, such as the municipal and industrial sectors. In the CRB WGRG, the agricultural sector was the only geospatial data collected. However, the transboundary analysis of WSAs identified other sectors with a stake in water resources in a specific location. By implementing the methodology outlined here, it is possible to overlay governance layers from each sector to locate places where high demand and competing management are challenges. Adding physical data including infrastructure and flow quantities pertaining to the Basin, salinity control areas, wild and scenic stretches of the Colorado River and tributaries, and areas where endangered species are of concern may espouse new explanations about governing competing demands and how they relate to specific policies on the landscape. Geospatial theory and science have contributed to applied geography through new technologies in geovisualization. Theories of environmental governance also have a role in understanding how to improve geovisualization, while governance layers have a role in helping to navigate the boundary between geospatial theory and sciences and environmental governance.

Additional inquires for future research include: (a) an empirical test of the boundary typology, using different units of analysis such as the ecoregions (Omernik 1987) or the boundaries established by the Bureau of Land Management Landscape Conservation Cooperatives, which like watersheds, are jointly managed by political and physical influences, (b) compile additional governance data, specifically on groundwater, water rights, and infrastructure to contribute to datasets from other sectors, (c) add small irrigation companies to the Ag water governance dataset, (d) create new datasets for other river basins, both national and international, and (e) conduct a deeper scale analysis for an investigation of boundaries at more localized or global levels. It is important to think about the future use of datasets and databases that extend beyond typical physical data collections and that come from a range of sources. In considering multiple sources, data availability, standardization, and scale must also be considered as questions of transparency. Results from this research demonstrate two governance questions: that of water sharing and data sharing. In order to discover a full range of innovative solutions to water scarce regions of the world, it is essential to consider governance questions about water and data sharing.

Tables & Figures

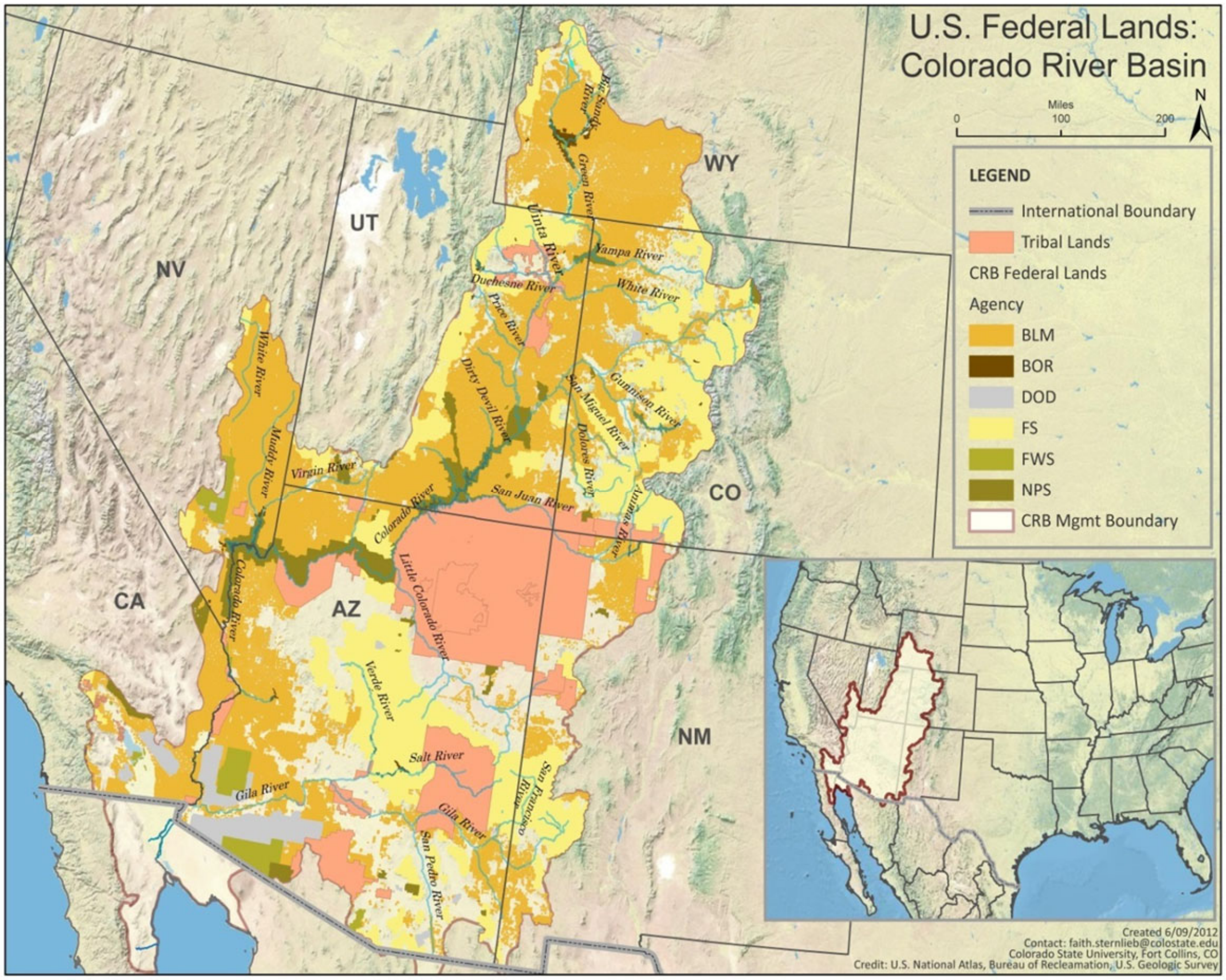


Figure 3.a: Federal Lands of the Colorado River Basin (National Atlas, 2012).

Table 3.a: Boundary Typology Specializes Water Governance through Governance Layers.

Boundary Type	Governance Layer	Boundary Description
Physical	Hydrologic	Based on natural drainage systems defined by the National Hydrology Dataset (USGS)
	Hydrographic	Based on drainage basin delineated by each state and tribe
Political	Statutory	Based on federal, state and tribal laws and policies
	Judicial	Based on US Federal/State, District and Appellate Court system
	Administrative	Rules and regulations based on governmental jurisdictions (federal, state, tribe, county, municipality, city)
	Temporal	Based on time/history largely due to sequential legal and political decisions
Sectoral	Agricultural	Based on social and political interests and supported by organizations' bylaws reinforced by state statute
	Environmental	
	Municipal	
	Industrial	
	Recreational	

Table 3.b: Global governance GIS Datasets and Databases.

Organization/ Source	Database	Theme	Boundary Type
Oregon State University	Transboundary Dispute Freshwater Database (OSU, 2013)	Global water conflict and cooperation	Physical Political Other*
Durham University	International River Boundaries Database (IRBD, 2013)	International river boundaries	Physical
United Nations Geographical Working Group	Second Administrative Level Boundaries (SALB, 2013)	Global country and sub-country governmental data	Political
Unknown	Global Administrative Areas (GADM, 2013)	Global country and sub-country governmental data	Administrative
World Resources Institute	Aqueduct (WRI, 2013)	Global water risk	Physical Sectoral

Table 3.c: Review of Interactive Maps of the Colorado River Basin on the Internet.

Organization	**Database**	**Theme/Purpose**	**Boundary Type**
Colorado River Water Conservation District	Interactive map of the Colorado River Basin Map (CRD, 2014)	Identify and locate the states and watersheds	Political, Physical
Colorado Water Institute	Agricultural Water Governance in the Colorado River Basin (CWI, 2014)	Develop a dataset specific to Ag water governance in the CRB	Political, Physical, Sectoral
National Geographic	Change the Course: Colorado River (National Geographic, 2013)	Promote advocacy campaign	Physical, Graphical, Anecdotal
Pacific Institute	Water to Supply the Land: Irrigated Agriculture in the Colorado River Basin (Pacific Institute, 2014)	Demonstrate locations in the basin where Ag water dominates water use	Physical, Sectoral
PBS	Powell's First Expedition Down the Colorado River (PBS, 2009)	Document history	Temporal, Anecdotal
The Nature Conservancy	Conservation and protection sites throughout the basin (TNC, 2014)	Locate and raise awareness about TNC work to protect natural resources of the Colorado River	Physical, Graphical
Western Resources Advocates	Power plants, dams, diversions and pipelines impact water resources in the CRB (WRA, 2014)	Demonstrate the complexity of the water management system	Sectoral
Western Resources Advocates	Points of Interest Map (WRA, 2014)	Identify and locate recreational opportunities	Sectoral

Table 3.d: Review of the Seven CRB State Agencies' Interactive Maps Demonstrating Water Data.

State	Agency	Themes (Purpose)	Boundary Type	Download-able Format Files
AZ	Department of Water Resources (ADWR, 2013)	Registry of Wells in AZ	Physical, Political	NA
		Assured and Adequate Water Supply Issued Determination	Political	NA
		Groundwater Levels and Elevation	Physical	NA
	Department of Water Resources, Geographic Information Systems	Groundwater Basins, Subbasins and Inventory	Physical	SHP
		Buckeye Water Logged Area	Physical, Sectoral	SHP
		Irrigation Districts and Irrigation Grandfathered Rights	Political, Sectoral	SHP
		Municipal Service Areas	Sectoral	SHP
		Recharge Underground Storage Facility	Political	SHP
		Surface Watersheds, Water Filings, Water Sampling Sites	Political, Physical, Sectoral	SHP
CA	New California Water Atlas (NCWA 2013)	Water Rights	Political, Sectoral	NA
	CA Department of Water Resources Integrated Water Resources Information System (IWRIS) (CDWR, 2014a)	Water Data Management Tool	Physical, Sectoral	NA
	CA Department of Water Resources Water Data	Monitoring stations for groundwater levels and water quality	Physical	NA

	Library (CDWR, 2013b)			
	California Department of Technology, Geoportal (California Geoportal, 2013)	Geospatial data regarding public safety, natural resources, education, health and government	Physical, Political, Sectoral	SHP
CO	Division of Water Resources (CDWR, 2014c)	AquaMap: Water Well Application, Structure, and Oil and Gas Commission Well Location	Physical, Political	NA
		Colorado Decision Support System	Physical Political,	SHP
	Colorado Water Conservation Board (CWCB, 2014)	Colorado River Water Availability Study	Physical, Political, Sectoral	KML
NM	Geospatial Advisory Committee (NMGAC, 2012)	Surface Water Quality Board Mapping Tool	Physical, Political	NA
		Ground Water quality Board Mapping Tool	Physical	NA
		Outstanding National Resource Waters	Physical	NA
		Source Water Protection Atlas	Physical, Political, Sectoral	NA
	Resource Geographic Information System Clearinghouse (EDAC, 2011)	New Mexico state geospatial database	Physical, Political, Sectoral	SHP (ZIP)
UT	Maps (UDWR, 2011)	Water rights (ESRI Map)	Political	NA
		Colorado River Basin	Physical	NA
		Green River Basin	Physical	NA
	Utah State Geographic	Utah state geospatial database	Physical, Political, Sectoral	GDB (ZIP), SHP (ZIP)

	Information Database (AGRC, 2013)			
WY	Wyoming Water and Climate Map Server (WWDO, 2014)	Compilation of all Wyoming water data	Physical	NA
	2010 Green River Basin Plan: GIS Products (WWDO, 2010)	Aquifers, aquifer recharge and sensitivity, annual precipitation, lakes, rivers, wells, HUCs, and springs	Physical	SHP, Metadata (XML)

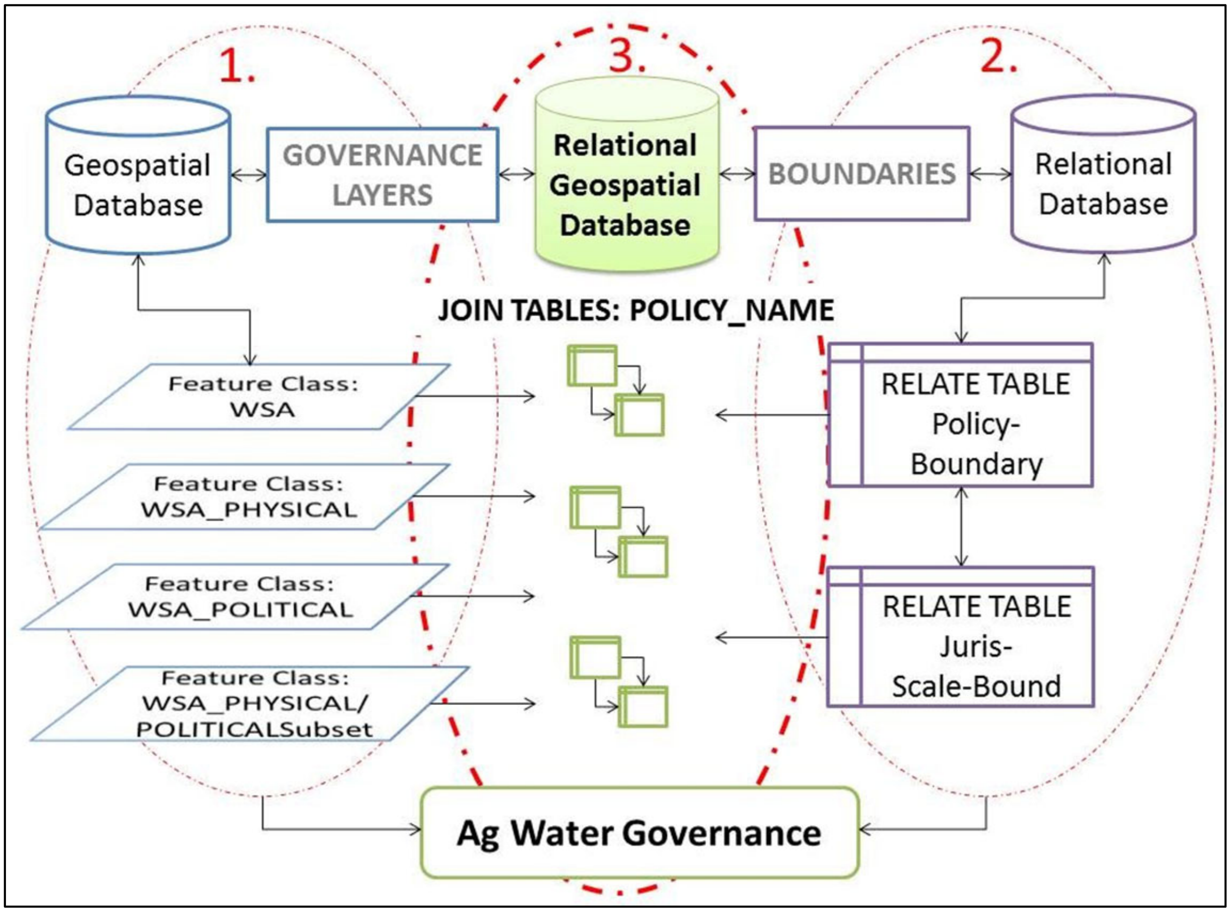


Figure 3.b: The Relational Geospatial Database Architecture and Process. 1.The structure and process for the development of the geospatial database, 2. The relational database, and 3. The relational geospatial database which is where the two databases are joined through a like item in their database tables (i.e., Policy_Name).

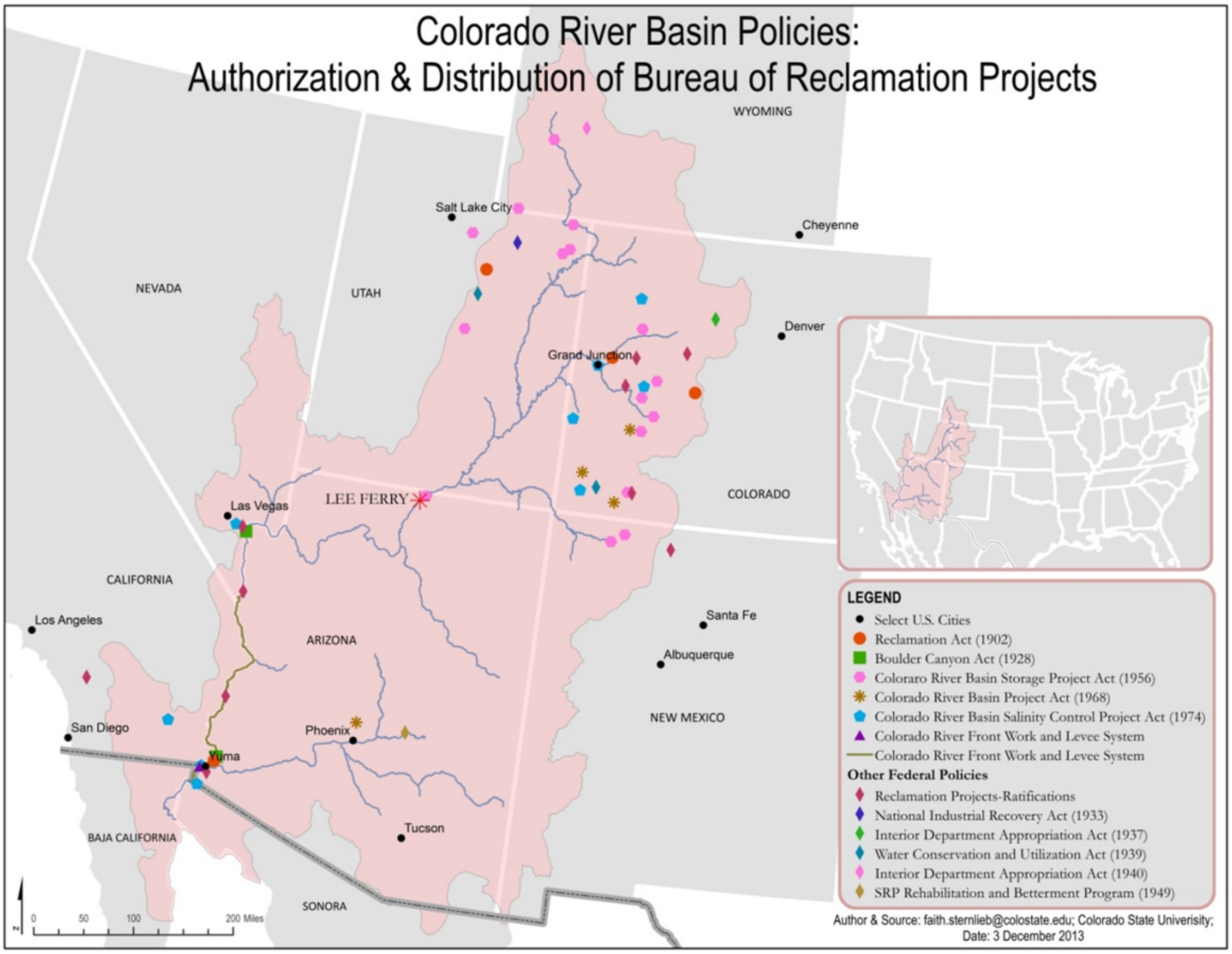


Figure 3.c: Colorado River Basin Policies and Projects. The policies that were created to authorize Bureau of Reclamation (USBR) projects support water sharing arrangements. Projects consist of dams and reservoirs as well as infrastructure for water delivery.

Table 3.e: Agricultural Water Governance Layers Derived from Sectoral Boundaries. The geographic extent, specific examples and data sources pertaining to the spatialization of agricultural water governance in the Colorado River Basin.

Governance Layer	**Geographic Extent**	**Example**	**Geospatial Data Source per Example**
Individual Contractee (farmer)	Farm Boundaries	West Divide Water Conservancy District	West Divide Water Conservancy District
Water Conservation Districts	Basin-wide	Colorado River Water Conservation District	Colorado River Water Conservation District
Water Conservancy Districts	Upper Basin	Central Utah Water Conservancy District	Central Utah Water Conservancy District
Water Users Associations	Basin-wide	Yuma County Water Users Association	LCRO Bureau Contract
Irrigation Districts	Basin-wide	Palo Verde Irrigation District	LCRO Bureau Contract
Irrigation and Drainage Districts	Arizona	Maricopa-Stanfield Irrigation and Drainage District	LCRO Bureau Contract
Irrigation Delivery Districts	Arizona	Ranchos Jardines Irrigation Delivery District	LCRO Bureau Contract
State Water District	California	Coachella Valley Water District	CA Geoportal
Private Water Districts	California	Imperial Irrigation District	CA Geoportal
Drainage Districts	Colorado	Grand Valley Drainage District	NA
Cooperatives	Arizona	Yuma Mesa Fruit Growers Association	LCRO Bureau Contract
Irrigation, Canal & Mutual Ditch Companies	Basin-wide	Montezuma Valley Irrigation Co.	NA
Ranches & Farms	Basin-wide	Ute Mountain Farm and Ranch Enterprise	National Atlas (tribal reservation boundary)

Private-Public Partnerships	Basin-wide	Colorado Corn Growers Association/ Ducks Unlimited/ City of Aurora	NA
Water Bank	Arizona	Arizona Water Banking Authority	NA
Water Market	Basin-wide	Examples do not have official names	NA
Ag Water Infrastructure	Basin-wide	Ditches, canals, etc.	Geographic Names Information System; Colorado Decision Support System; National Hydrologic Dataset

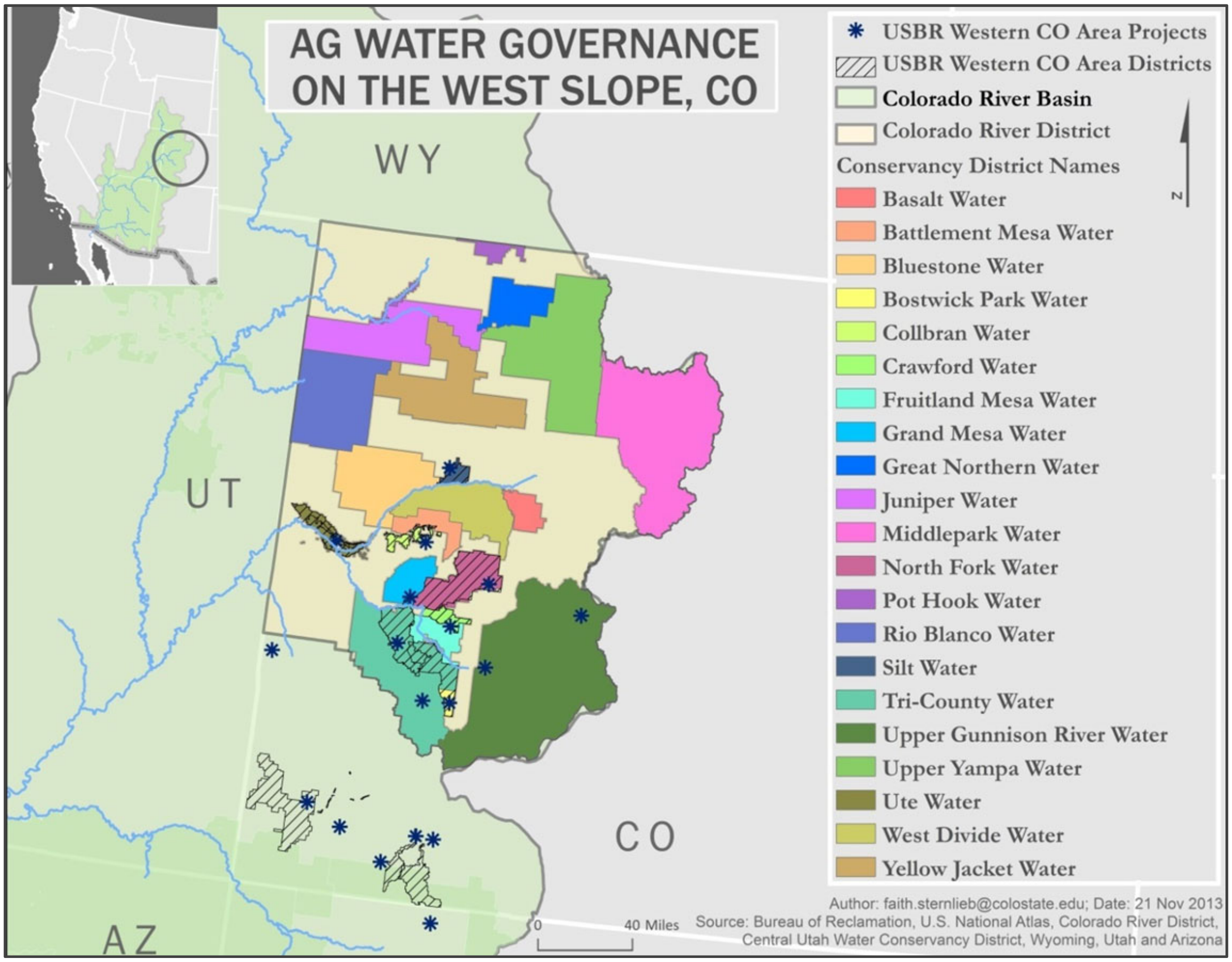


Figure 3.d: Agricultural Water Governance on the West Slope, CO of the Colorado River Basin. There are six levels of governance layers. Beginning with the most local level is the irrigation and water conservancy districts (represented by the State, the USBR and the local agricultural interests); the Colorado River District (represented by the State and two-thirds of the Western Slope constituency); the full extent of the West Slope defined by the Continental Divide, which includes the Colorado River District and southwestern Colorado; the State of Colorado; the Upper CRB; and full extent of the CRB, which includes the Upper and Lower Basins as well as Mexico.

REFERENCES

ADWR. (2013). Water Resources Data. Retrieved February 10, 2014, from https://gisweb.azwater.gov/waterresourcedata/Default.aspx

AGRC. (2013). Utah Automated Geographic Reference Center. Retrieved February 10, 2014, from http://gis.utah.gov/data/

Alexander, L. M. (1958). Boggs, Samuel Whittemore - An appreciation. *Annals of the Association of American Geographers*, 48, 237-243.

Biermann, F., Betsill, M. M., Vieira, S. C., Gupta, J., Kanie, N., Lebel, L., . . .& Zondervan, R. (2010). Navigating the anthropocene: the Earth System Governance Project strategy paper. Current Opinion in Environmental Sustainability, 2(3), 202-208.

Blomquist, W., Heikkila, T. & Schlager, E. (2001). Institutions and conjunctive water management among three western states. *Natural Resources Journal*, 41(3), 653-683.

Boggs, S. W. (1930). Delimitation of the territorial sea the method of delimitation proposed by the delegation of the United States at the Hague Conference for the codification of international law. *American Journal of International Law*, 24, 541-555.

Boggs, S. W. (1937a). Library classification and cataloging of geographic material. *Annals of the Association of American Geographers*, 27, 49-93.

Boggs, S.W. (1937b). Problems of water-boundary definition median lines and international boundaries through territorial waters. *Geographical Review*, 27, 445-456.

Boggs, S.W. (1941). Mapping the Changing World: Suggested Developments in Maps. *Annals of the Association of American Geographers*, 31, 119-128.

Boggs, S.W. (1947). North Atlantic Triangle: The interplay of Canada, the United States and Great Britain. *American Journal of International Law*, 41, 348-349.

Boggs, S.W. (1948). Geographic and Other Scientific Techniques for Political Science. *American Political Science Review*, 42, 223-238.

Boggs, S.W. (1966). International boundaries: A study of boundary functions and problems. New York, NY: AMS Press.

Butenuth, M., Gosslein v. G., Tiedge, M., Heipke, C., Lipeck, U., & Sester, M. (2007). Integration of heterogeneous geospatial data in a federated database. *Journal of Photogrammetry & Remote Sensing*, 62, 328-346.

California Geoportal. (2013a). Private water districts. California Department of Technology. Retrieved November 5, 2013 from http://portal.gis.ca.gov/geoportal/catalog/search/search.page.

California Geoportal. (2013b). State water districts. California Department of Technology. Retrieved November 5, 2013 from http://portal.gis.ca.gov/geoportal/catalog/search/search.page.

CAP. (2010). An alternative to the current Ag pool allocation procedure, impact on the blended cost of Ag water, and effect on continued Ag water use. In *Agenda Number 6*, edited by B. o. Directors. Pheonix, AZ: Central Arizona Project.

CDWR. (2014a). Integrated Water Resources information System. California Division of Water Resources. Retrieved February 10, 2014, from http://www.water.ca.gov/iwris/

CDWR. (2014b). Water Data Library. California Division of Water Resources. Retrieved February 10, 2014, from http://www.water.ca.gov/waterdatalibrary/index.cfm

CDWR. (2014c). AquaMap. Colorado Division of Water Resources. Retrieved February 10, 2014, from http://water.state.co.us/DATAMAPS/GISANDMAPS/AQUAMAP/Pages/default.aspx
CRD. (2014). Interactive Map of the entire Colorado River Basin. Colorado River District. Retrieved February 10, 2014, from http://www.crwcd.org/media/maps/map2.htm
CVWD. (2013). Groundwater replenishment and imported water. Coachella Valley Water District. Retrieved November, 5 2013 from http://www.cvwd.org/about/groundwater.php.
CWCB. (2014). Colorado River Water Availability Study Data Viewer. Colorado Water Conservation Board. Retrieved February 10, 2014, from http://www.dataviewer.info/CRWAS/info
CWI. (2014). Ag Water Governance Interactive Map. Colorado Water Institute. Retrieved February 10, 2014, from http://www.crbagwater.colostate.edu/gismapping.shtml
De Stefano, L., Duncan, J., Dinar, S., Stahl, K., Stzepek, K., & Wolf, A. (2010). Mapping the Resilience of International River Basins to Future Climate Change-Induced Water Variability. In Water Sector Board Discussion Paper Series, Paper No. 15. Washington, D.C.: World Bank.
EDAC. (2014). Earth Data Analysis Center. University of New Mexico. Retrieved February 10, 2014, from http://edac.unm.edu/
Fabrikant, S. I. (2000). Spatialized browsing in large data archives. *Transactions in GIS*, 4(1), 65-78.
Feitelson, E., and Fischhendler I. (2009). Spaces of Water Governance: The Case of Israel and Its Neighbors. *Annals of the Association of American Geographers*, 99(4), 728-745.
Feitelson, E., and Levy, N. (2006). The environmental aspects of reterritorialization: Environmental facets of Israeli–Arab agreements. *Political Geography*, 25(4), 459-477.
Fischhendler, I., and Feitelson, E. (2003). Spatial adjustment as a mechanism for resolving river basin conflicts: the US–Mexico case. *Political Geography*, 22(5), 557-583.
Fischhendler, I., & Heikkila, T. (2010). Does integrated water resources management support institutional change? The case of water policy reform in Israel. *Ecology and Society*, 15(1), 16.
Furlong, K., Hegre, H., & Gleditsch, N. P. (2006). Geographic opportunity and neomalthusian willingness: Boundaries, shared rivers, and conflict. *International Interactions*, 32(1), 79-108.
GADM. (2013). GADM database of Global Administrative Areas. Retrieved October 6, 2013 from http://www.gadm.org/.
Getches, D. H. (2009) Water in a nutshell, 4th Edition. St Paul, MN: Thomson Reuters.
Gleditsch, N. P., Furlong, K., Hegre, H. Lacina, B. & Owen, T. (2006). Conflicts over shared rivers: Resource scarcity or fuzzy boundaries? *Political Geography*, 25, 361-382.
Heikkila, T. (2004). Institutional boundaries and common-pool resource management: A comparative analysis of water management programs in California. *Journal of Policy Analysis and Management*, 23(1), 97-117.
IRBD. (2013). International River Boundaries Database. Durham University. Retrieved October cited 17, 2013 from https://www.dur.ac.uk/ibru/resources/irbd/.
Kane, L. (2011). Nuestro Rio. Retrieved February 10, 2014, from http://nuestrorio.com/?lang=english
Kraak, M-J. (2003). Geovisualization illustrated. *Journal of Photogrammetry & Remote Sensing*, 57, 390-399.

Kraak, M-J. (2004). The role of the map in a Web-GIS environment. *Journal of Geographical Systems*, 6, 83-93.
Krahmann, E. (2003). National, regional, and global governance: One phenomenon or many? *Global Governance*, 9(3), 323-346.
Kwan, M-P., & Ding, G. (2008). Geo-narrative: Extending geographic information systems for narrative analysis in qualitative and mixed method research. *The Professional Geographer*, 60(4), 443-465.
Leshy, J. D. (1982). Irrigation districts in a changing west: An overview. *Arizona State Law Journal*, 345, 345-376.
Lieberman, S. (2011). Water organizations in Colorado: A first look into water organizations' control of agricultural water rights and their transfer potential in the Colorado River Basin. *University of Denver Water Law Review*, 15, 31.
MacEachren, A. M., and Kraak, M-J. (2013). Research challenges in geovisualization. *Cartography and Geographic Information Science*, 28(1), 3-12.
McCool, D. (1987). Command of the waters: Iron triangles, federal water development and Indian water. Berkeley, CA: University of California Press.
Mulroy, P. (2008). Climate change and the Law of the River: A Southern Nevada Perspective. *West Northwest Journal of Environmental Law & Policy*, 14(2).
National Atlas. (2013). *Map Layers*. Department of the Interior. Retreived November 25, 2013 from http://nationalatlas.gov/maplayers.html.
National Geographic. (2013). *Change The Course*. National Geographic. Retrieved November 5, 2013 from http://environment.nationalgeographic.com/environment/freshwater/change-the-course/colorado-river-map.
NCWA. (2013). California Water Rights. The New California Water Atlas. Retrieved October 17, 2013 from http://ca.statewater.org/.
NMGAC. (2012). Geospatial Advisory Committee. Retrieved February 10, 2014, from http://www.gac.state.nm.us/index.html
Omernik, J. M. (1987). Ecoregions of the conterminous United States. *Annals of the Association of American Geographers*, 77(1), 118-125.
OSU. (2013). International River Basin Organization (RBO) Database. Oregon State University. Retrieved October 6, 2013 from http://www.transboundarywaters.orst.edu/research/RBO/.
Pacific Instiitute. (2014). Water to Supply the Land: Irrigated Agriculture in the Colorado River Basin. Retrieved February 10, 2014, from http://www2.pacinst.org/reports/co_river_ag_2013/map/
PBS. (2009). Interactive Map of Powell's Journey. *Lost in the Grand Canyon.* Retrieved February 10, 2014, from http://www.pbs.org/wgbh/amex/canyon/maps/index.html
SALB. (2013). Project overview. United Nations. Retrieved October 10, 2013 from http://www.unsalb.org/index.php?option=com_content&view=article&id=49&Itemid=60
Seaber, P. R., Kapinos, F. P., & Knapp, G. L. (1987). Hydrologic Unit Maps U.S. Geologic Survey Water Supply Paper (pp. 63): U.S. Department of the Interior, U.S. Geological Survey.
Starr, H. (2002). Opportunity, willingness and geographic information systems (GIS): Reconceptualizing borders in international relations. *Political Geography*, 21, 243-261.

Sternlieb, F., Bixler, R. P., Huber-Stearns, H. and Huasca, C. (2013). A question of fit: Reflections on boundaries, organizations and social-ecological systems. *Journal of Environmental Management*, 130, 117-125.

Stimie, C., Richters, E., Thompson, H., Perret, S., Matete, M., Abdallah, K., . . . & Mulibana E.. (2001). Hydro-institutional mapping in the Steelport River Basin, South Africa, Working Paper 17. In South Africa Working Paper No. 6. Sri Lanka: International Water Management Institute.

Sullivan, C., Vörösmarty, C., Caswell, E., Bunn, S., Cline, S., Heidecke, C., . . . & Meigh, J. (2006). Mapping the links between water, poverty and food security. Report on the Water Indicators workshop held at the Centre for Ecology and Hydrology, Wallingford, UK, 16-19 May, 2005. In GWSP Issues in GWS Research, No.1. Bonn: Global Water System Project-IPO.

Thompson, H., Stimie, C., Richters, E., & Perret, S. (2001). Policies, legislation and organizations related to water in South Africa, with special reference to the Olifants River Basin. Working Paper 18. In South Africa Working Paper No. 7. Sri Lanka: International Water Management Institute.

TNC. (2014). Colorado River Project: Conserving a lifeline for people and nature. Retrieved February 10, 2014, from http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/colorado/howwework/interactive-media-colorado-river-project.xml

Toset, H. P., Wollebaek, Gleiditsch, N. P., & Hegre, H. (2000). Shared rivers and interstate conflict. *Political Geography*, 19, 971-996.

Tufte, E. (2006). Beautiful Evidence. Cheshire, CT: Graphics Press.

UDWR. (2011). Maps. Utah Division of Water Rights. Retrieved February 10, 2014, from http://www.waterrights.utah.gov/gisinfo/maps/

USBR. (2012). Colorado River Basin Water Supply and Demand Study: Study Report. In Reclamation: Managing Water in the West. Boulder City, NV: Bureau of Reclamation, Department of the Interior.

USBR. (2013). Colorado River Basin Water Supply and Demand Study. U.S. Department of the Interior 2013. Retrieved October 17, 2013 from http://www.usbr.gov/lc/region/programs/crbstudy.html.

Vörösmarty, C., McIntyre, P., Gessner, M., Dudgeon, D., Prusevich, A., Green, P., Glidden, S. . . & Davies, P. 2010. Global threats to human water security and river biodiversity. *Nature*, 467, 555-561.

Wockner, G. (2010). Save the Colorado. Retrieved February 10, 2014, from http://www.savethecolorado.org/

Wolf, A. (1999). The Transboundary Freshwater Dispute Database Project. *International Water Resources Association*, 24(2), 160-163.

WRA. (2014). The Colorado River Basin. Retrieved February 10, 2014, from http://coriverbasin.org/maps/

WRI. (2013). Aqueduct: Measuring and Mapping Water Risk. World Resources Institute. Retrieved October 6, 2013 from http://aqueduct.wri.org/.

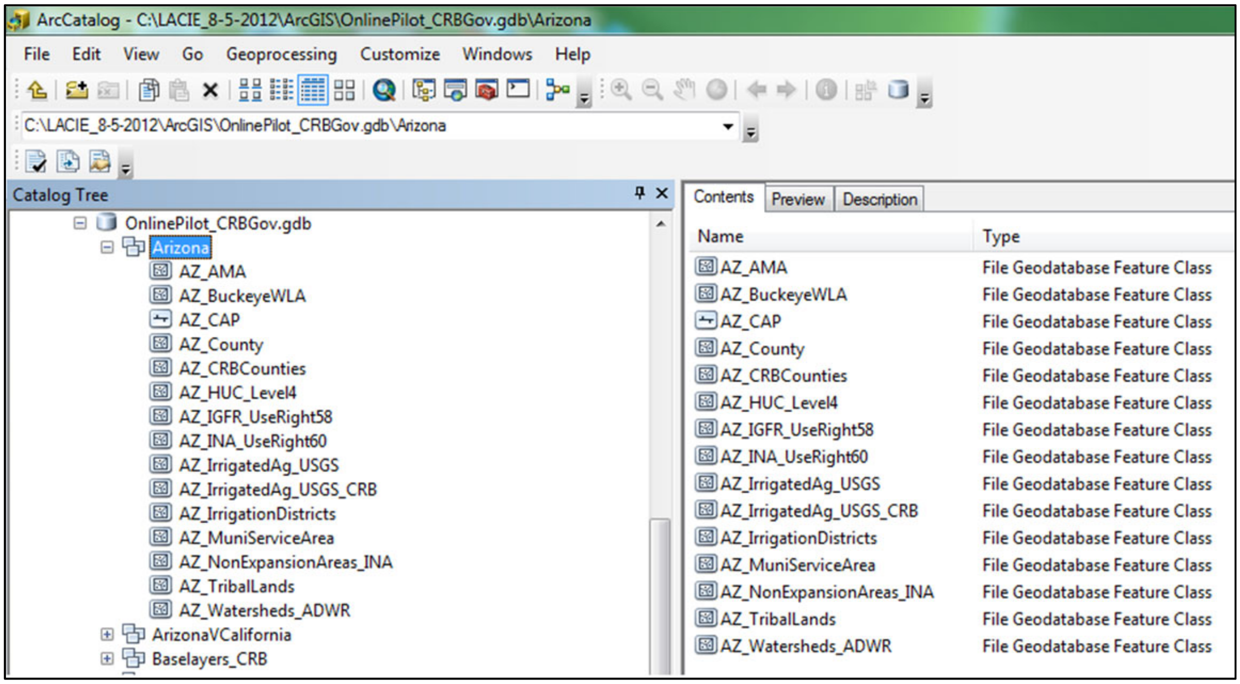
WWDO. (2010). Green River Basin Water Plan: GIS Products. Wyoming Water Development Office. Retrieved February 10, 2014, from http://waterplan.state.wy.us/plan/green/2010/gis/gis.html

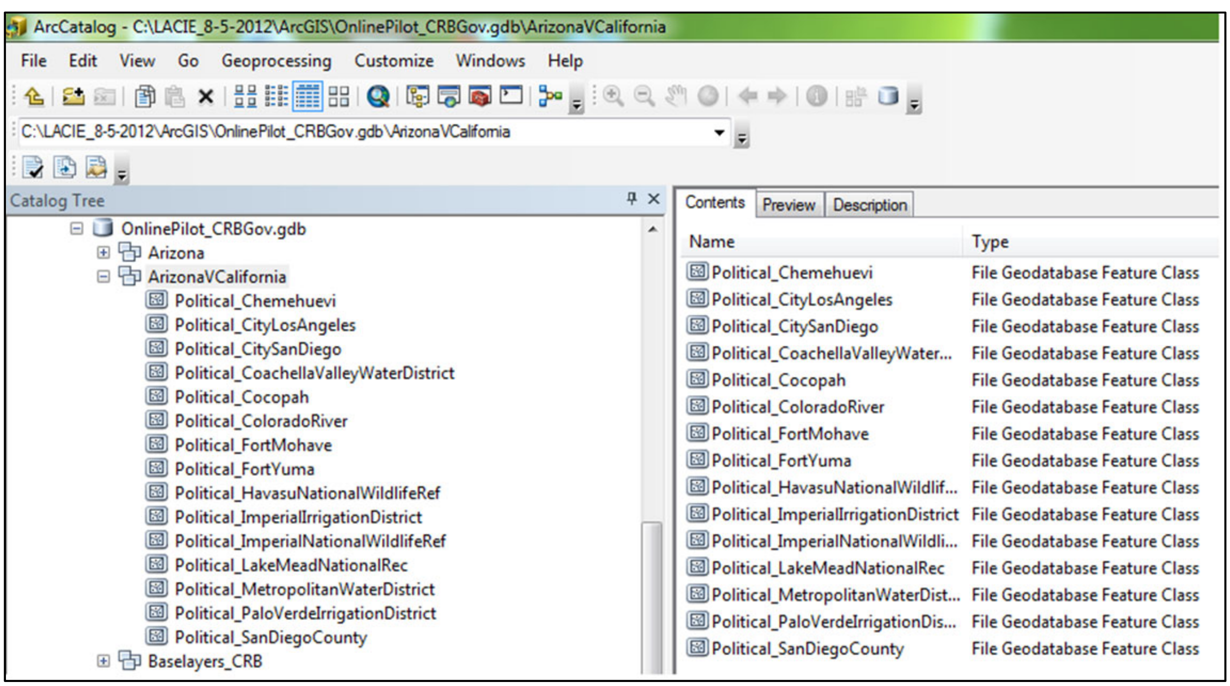
WWDO. (2014). Wyoming Water and Climate Map Server. Wyoming Water Development Commission. Retrieved February 10, 2014, from http://ims2.wrds.uwyo.edu/Website/Statewide/

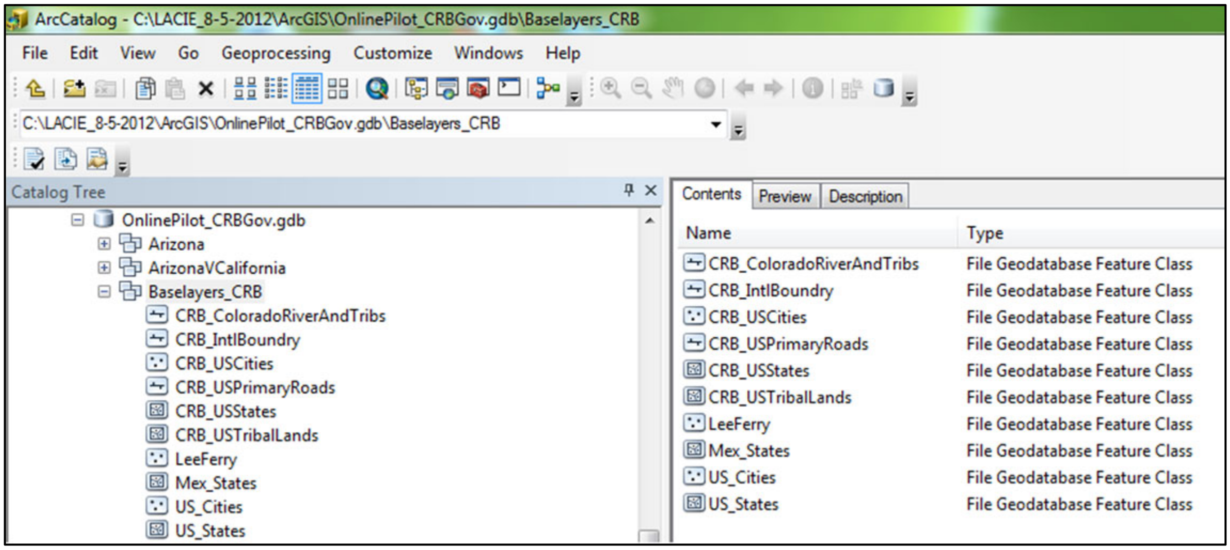
Yoffe, S., Fiske, G., Giordano, M., Larson, K., Stahl, K., & Wolf. A. (2004). Geography of international water conflict and cooperation: Data sets and applications. *Water Resources Research*, 40, 12.

Yoffe, S., Wolf, A., & Giordano, M. 2003. Conflict and cooperation over international freshwater resources: Indicators of basins as risk. *Journal of American Water Resources Association*, 1109-1126.

APPENDIX 3-I: GEODATABASE ARCHITECTURE



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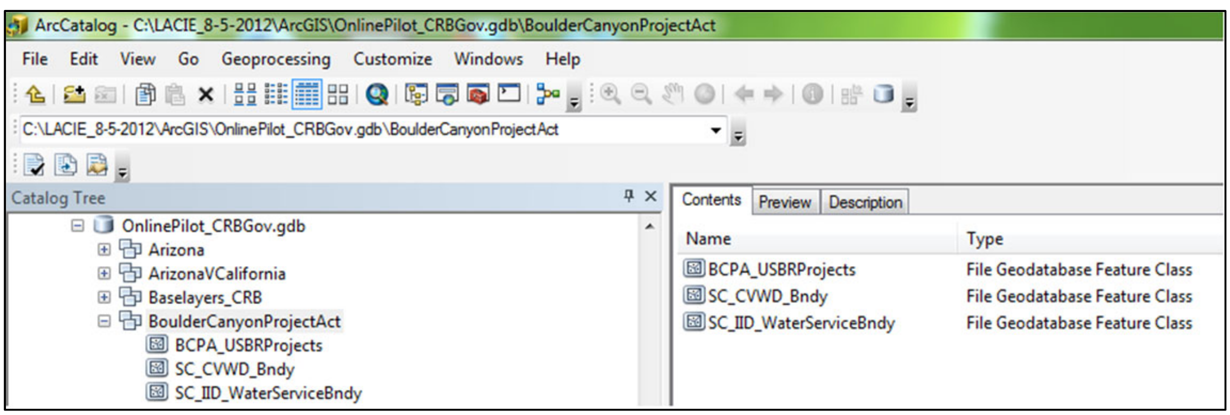
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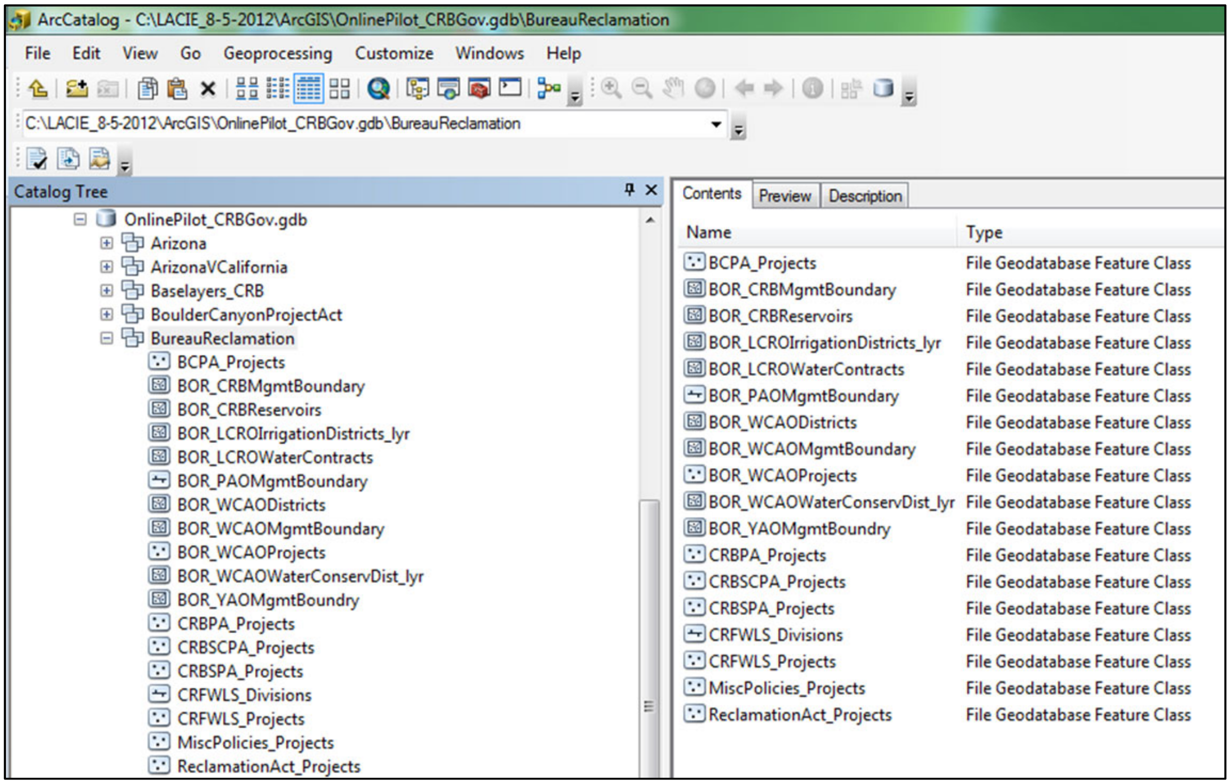
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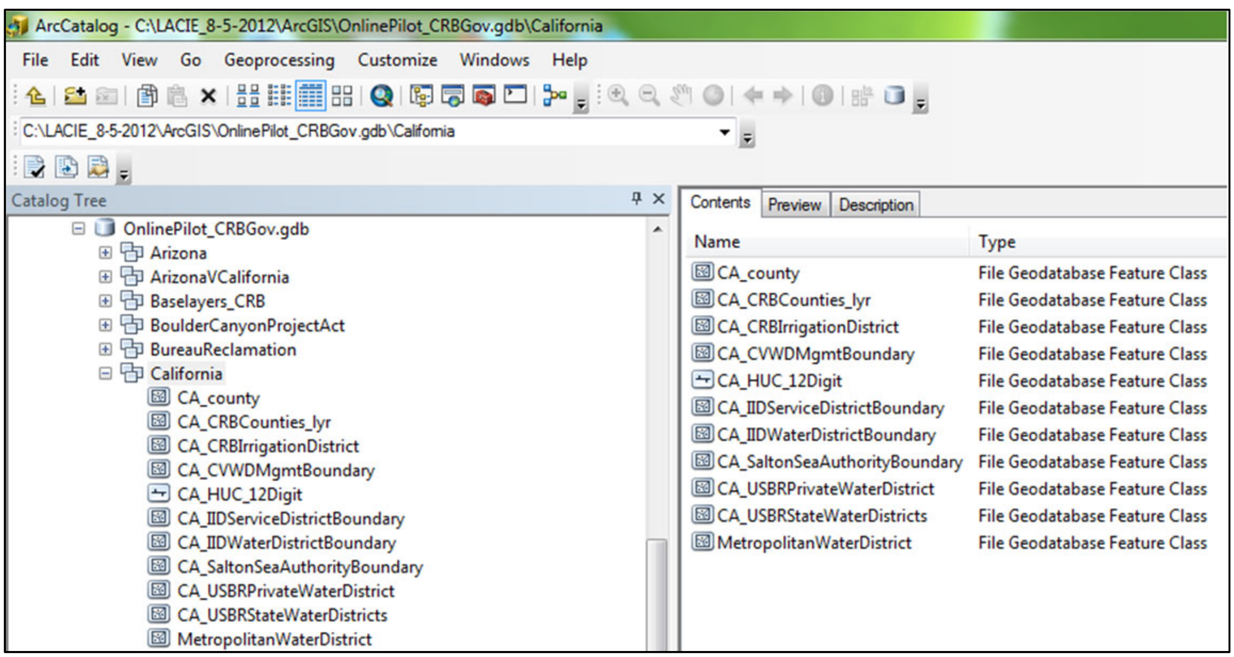
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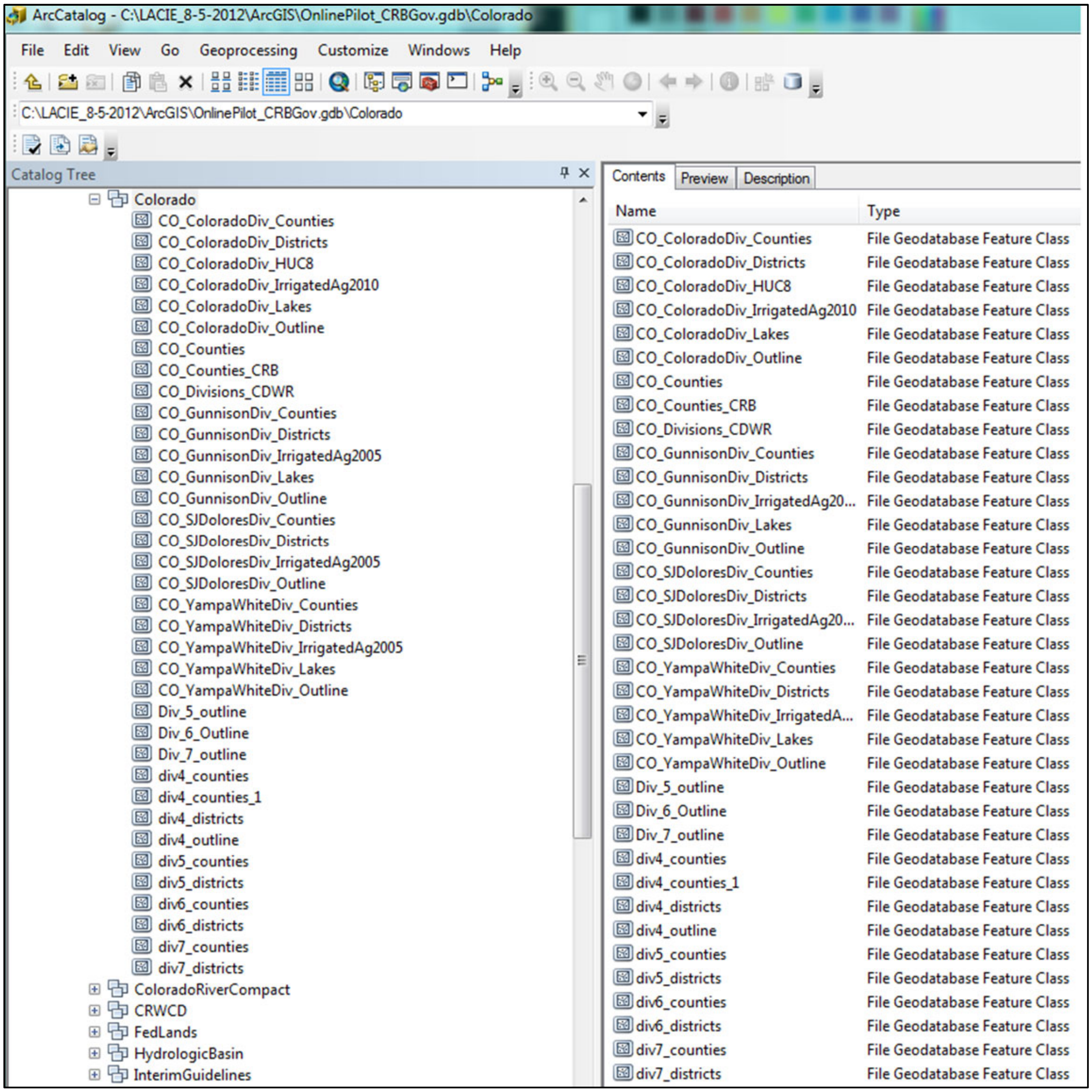
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CO_ColoradoDiv_Outline
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CO_Counties_CRB
CO_Divisions_CDWR
CO_GunnisonDiv_Counties
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CO_GunnisonDiv_IrrigatedAg2005
CO_GunnisonDiv_Lakes
CO_GunnisonDiv_Outline
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CO_YampaWhiteDiv_Counties
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CO_YampaWhiteDiv_IrrigatedAg2005
CO_YampaWhiteDiv_Lakes
CO_YampaWhiteDiv_Outline
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Div_6_Outline
Div_7_outline
div4_counties
div4_counties_1
div4_districts
div4_outline
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HydrologicBasin
InterimGuidelines
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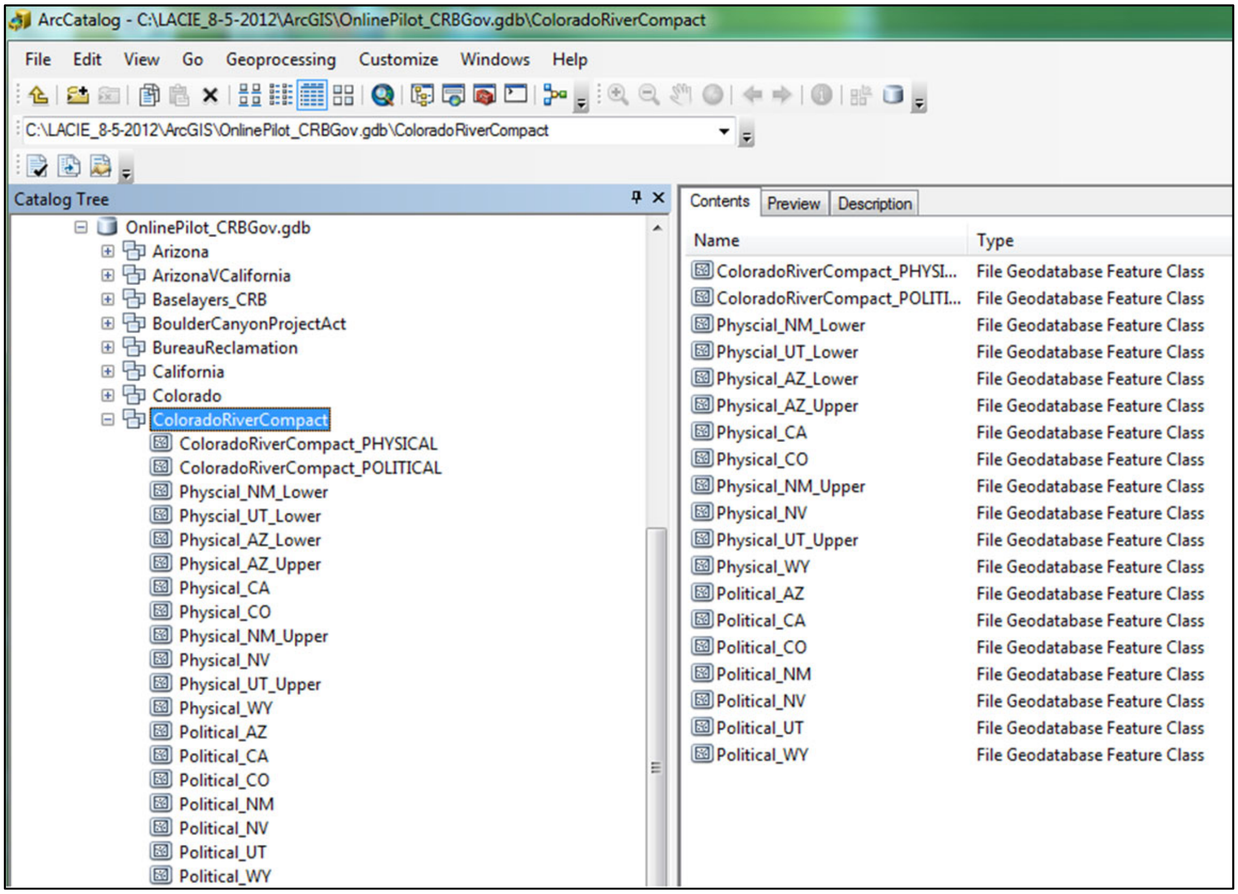
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ColoradoRiverCompact_POLITICAL
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Physcial_UT_Lower
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Political_NV
Political_UT
Political_WY
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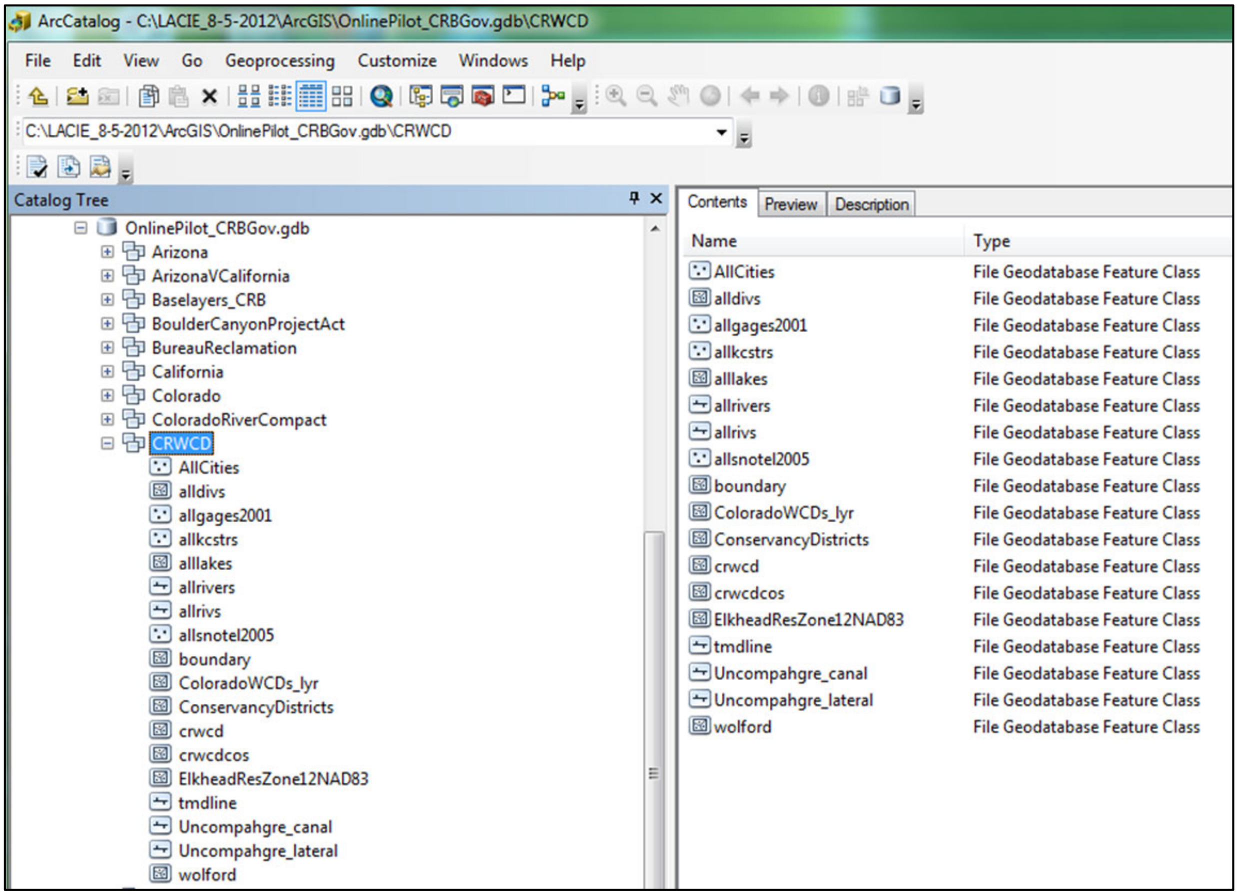
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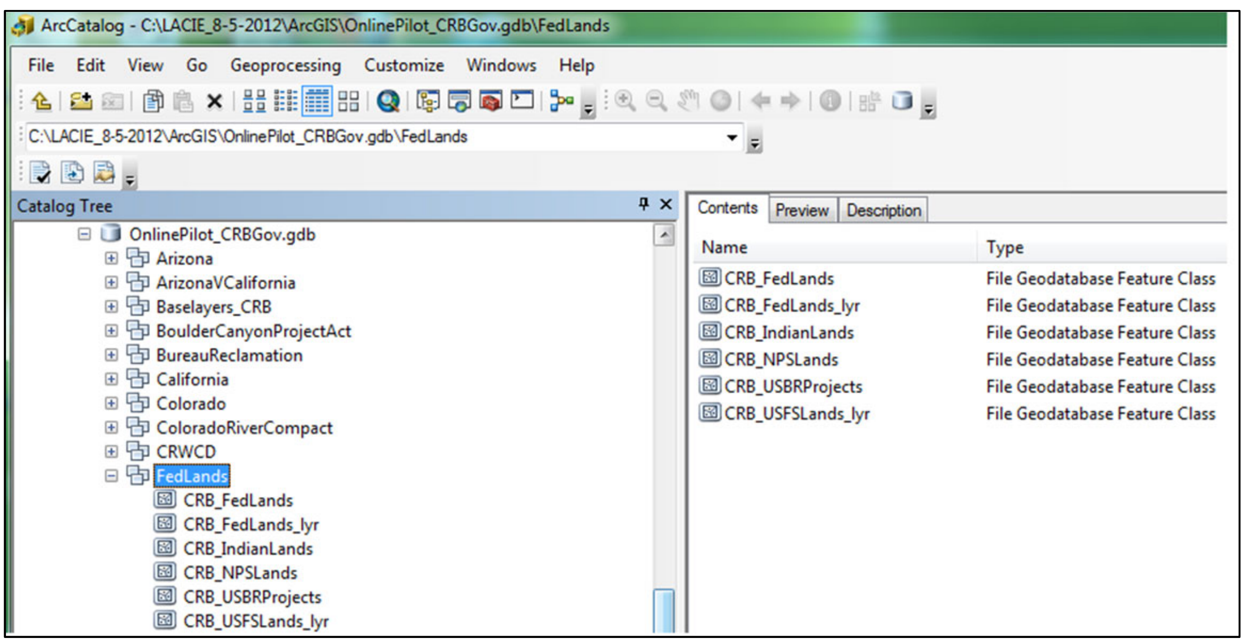
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CRB_FedLands_lyr
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Type
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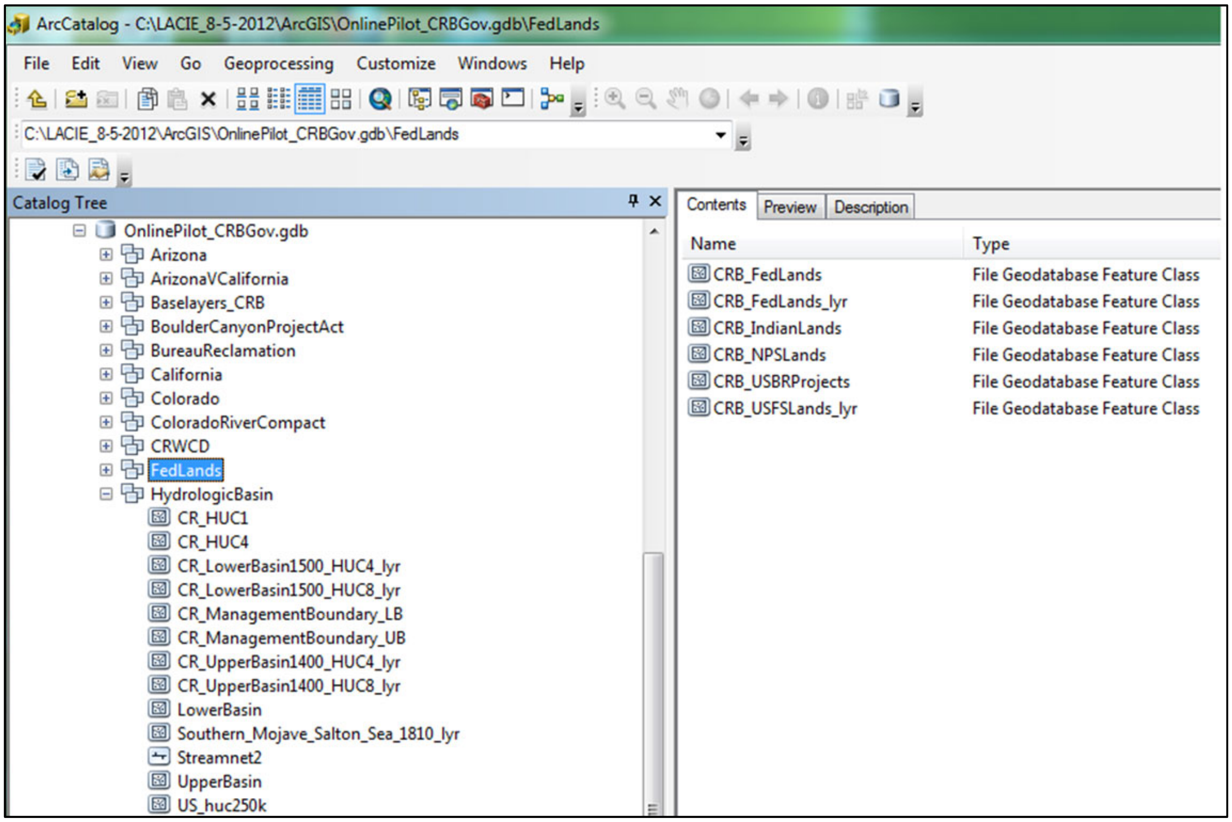
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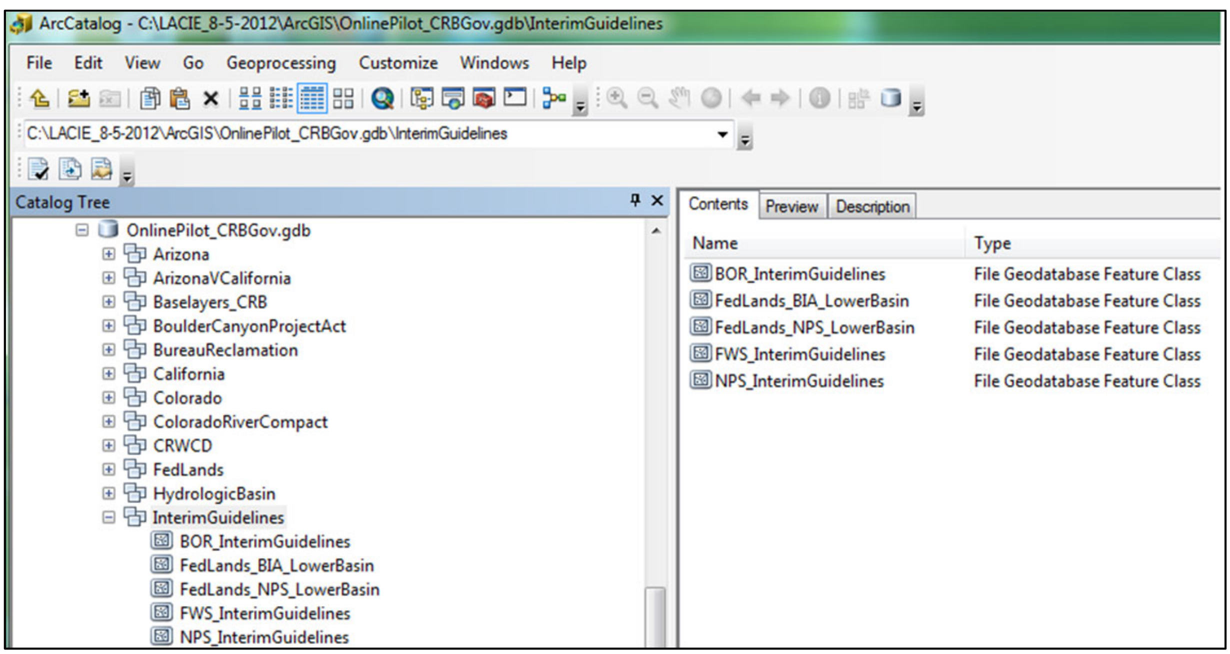
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FedLands_BIA_LowerBasin
FedLands_NPS_LowerBasin
FWS_InterimGuidelines
NPS_InterimGuidelines
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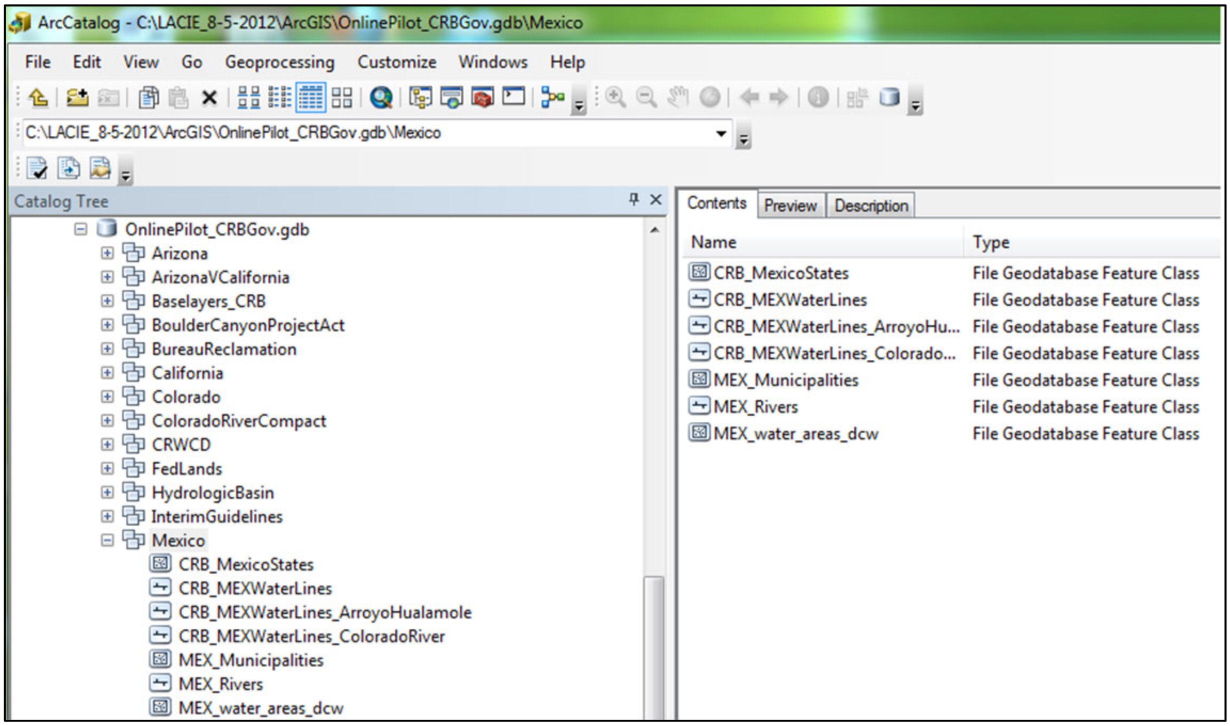
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MEX_water_areas_dcw
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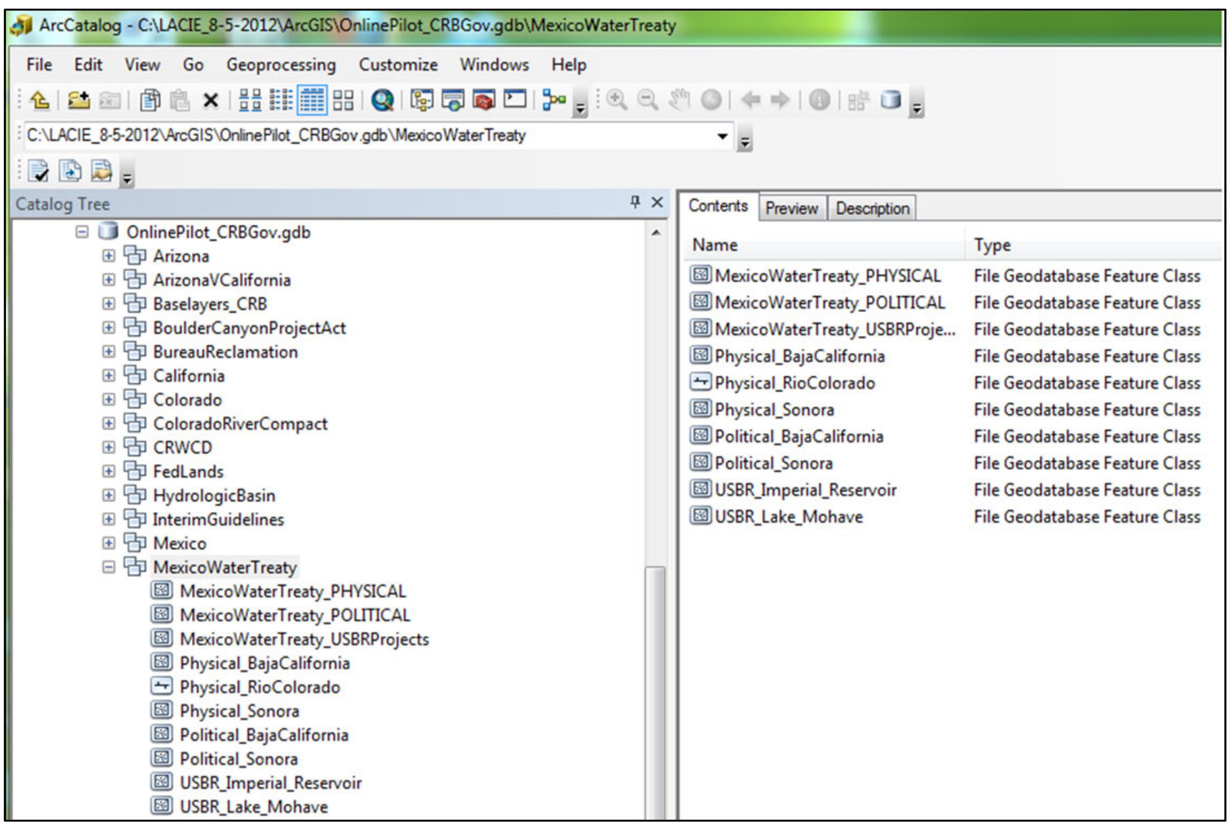
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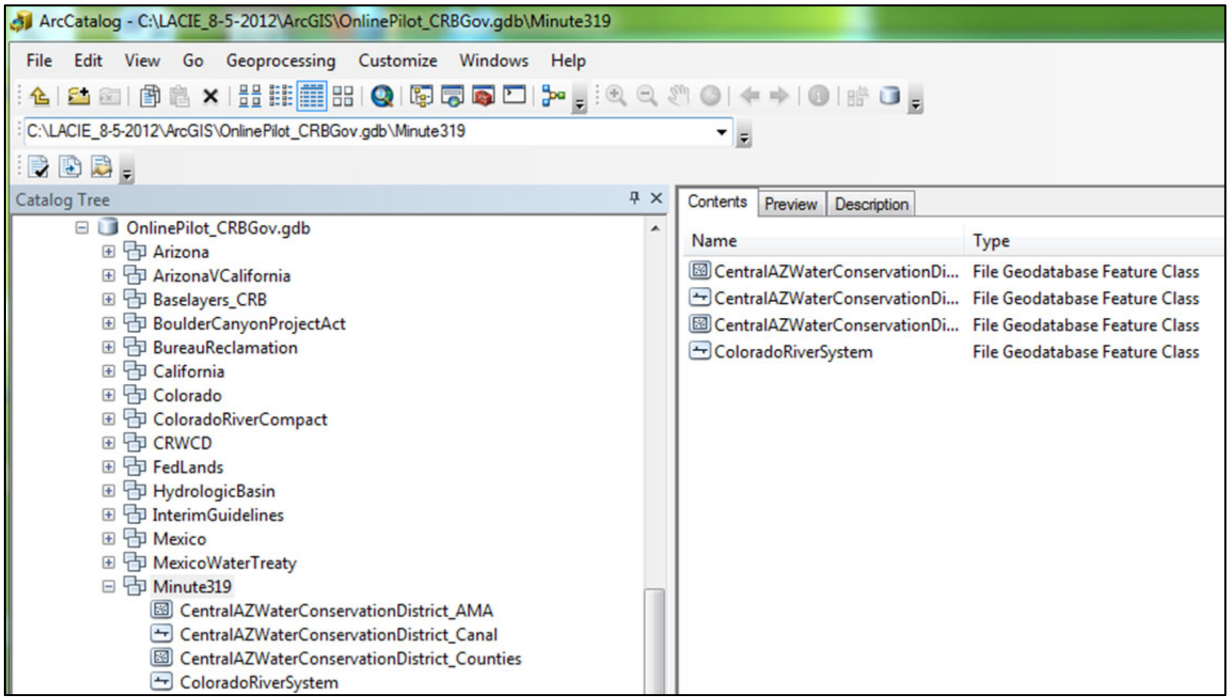
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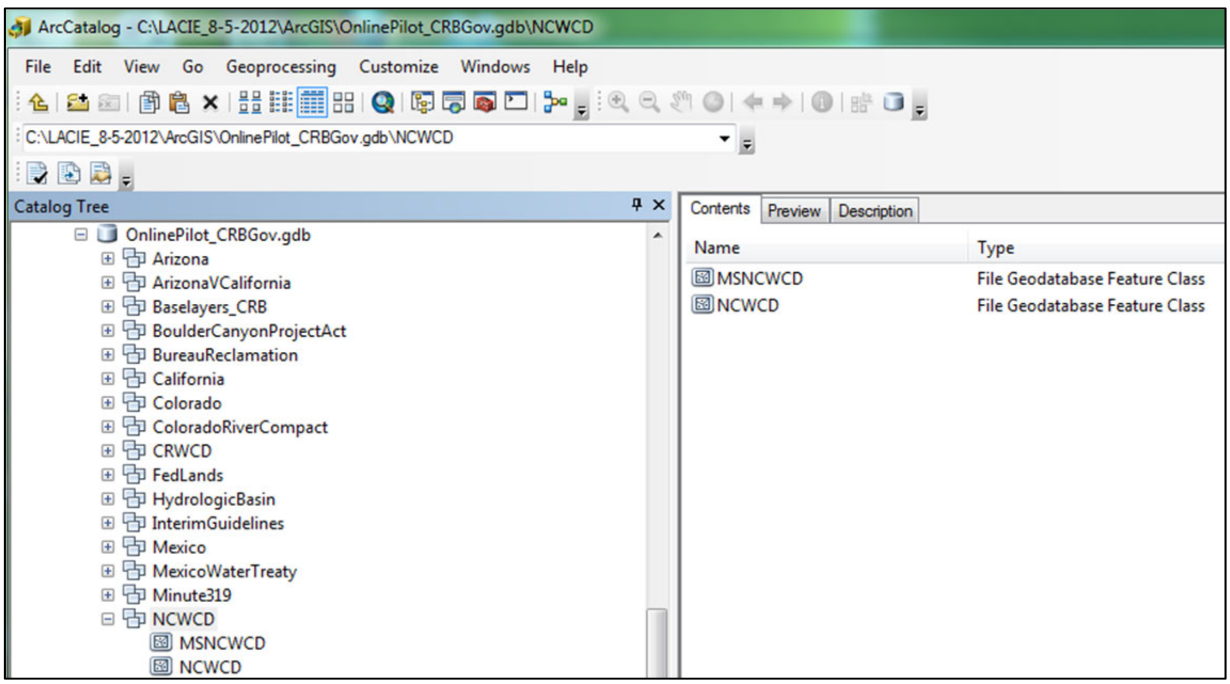
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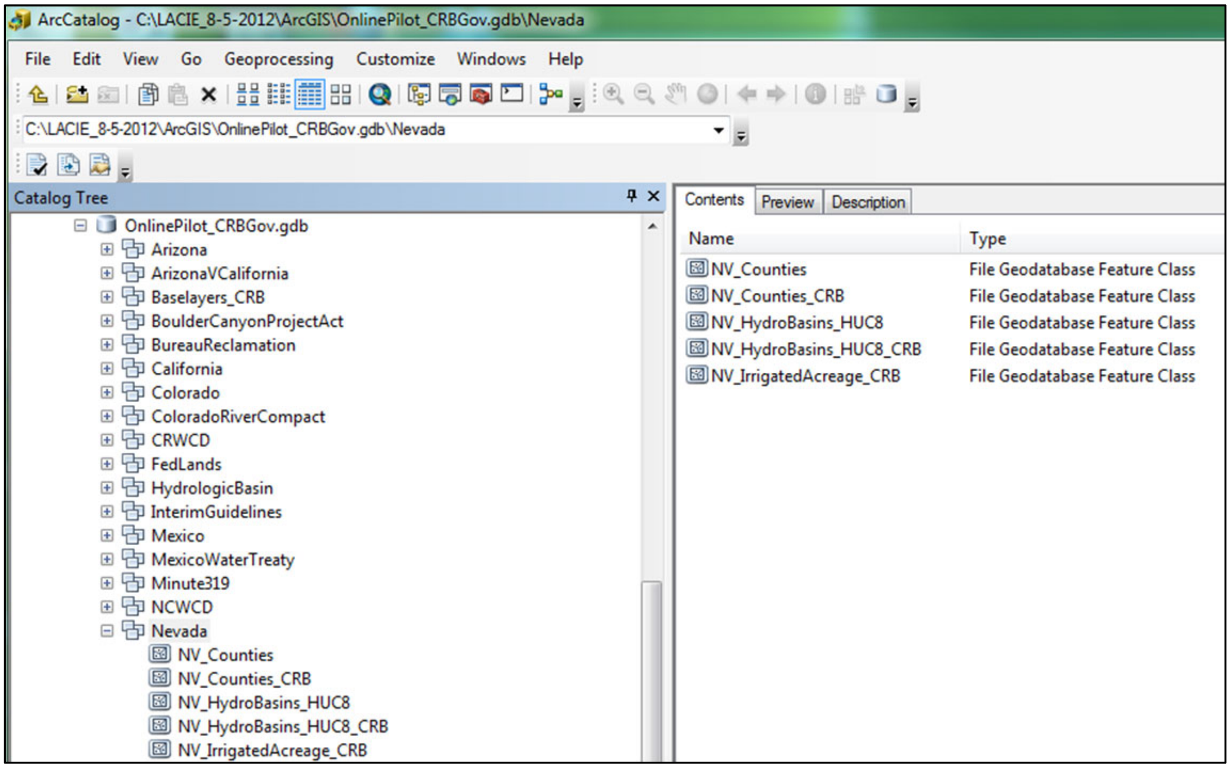
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NV_HydroBasins_HUC8
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NV_IrrigatedAcreage_CRB
Contents Preview Description
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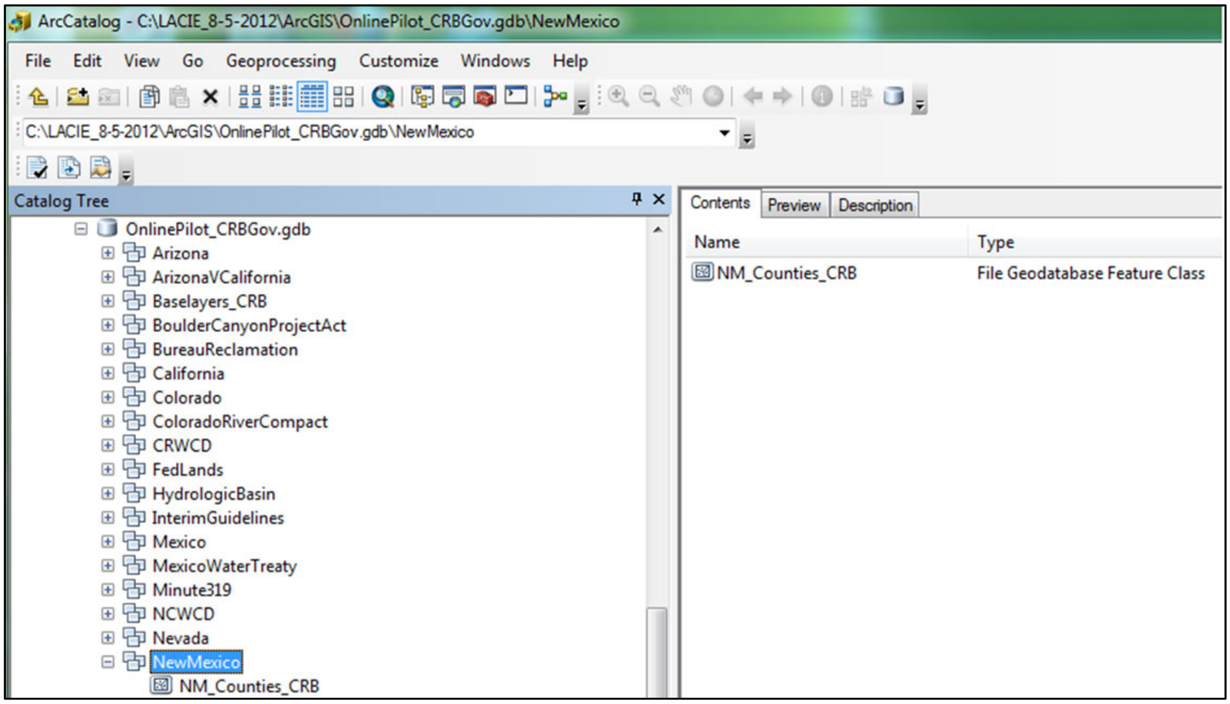
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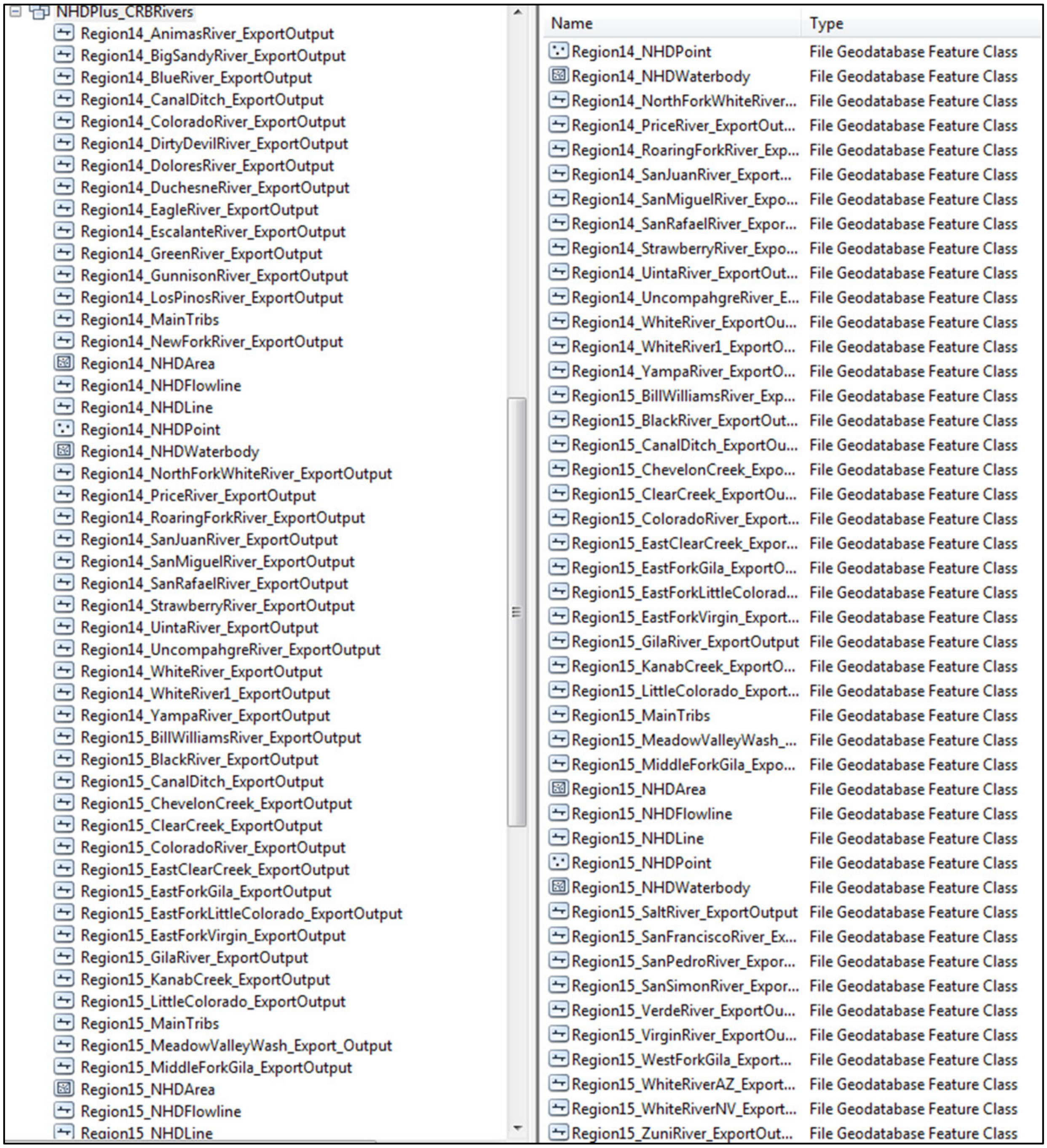
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Region14_EagleRiver_ExportOutput
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Region14_GunnisonRiver_ExportOutput
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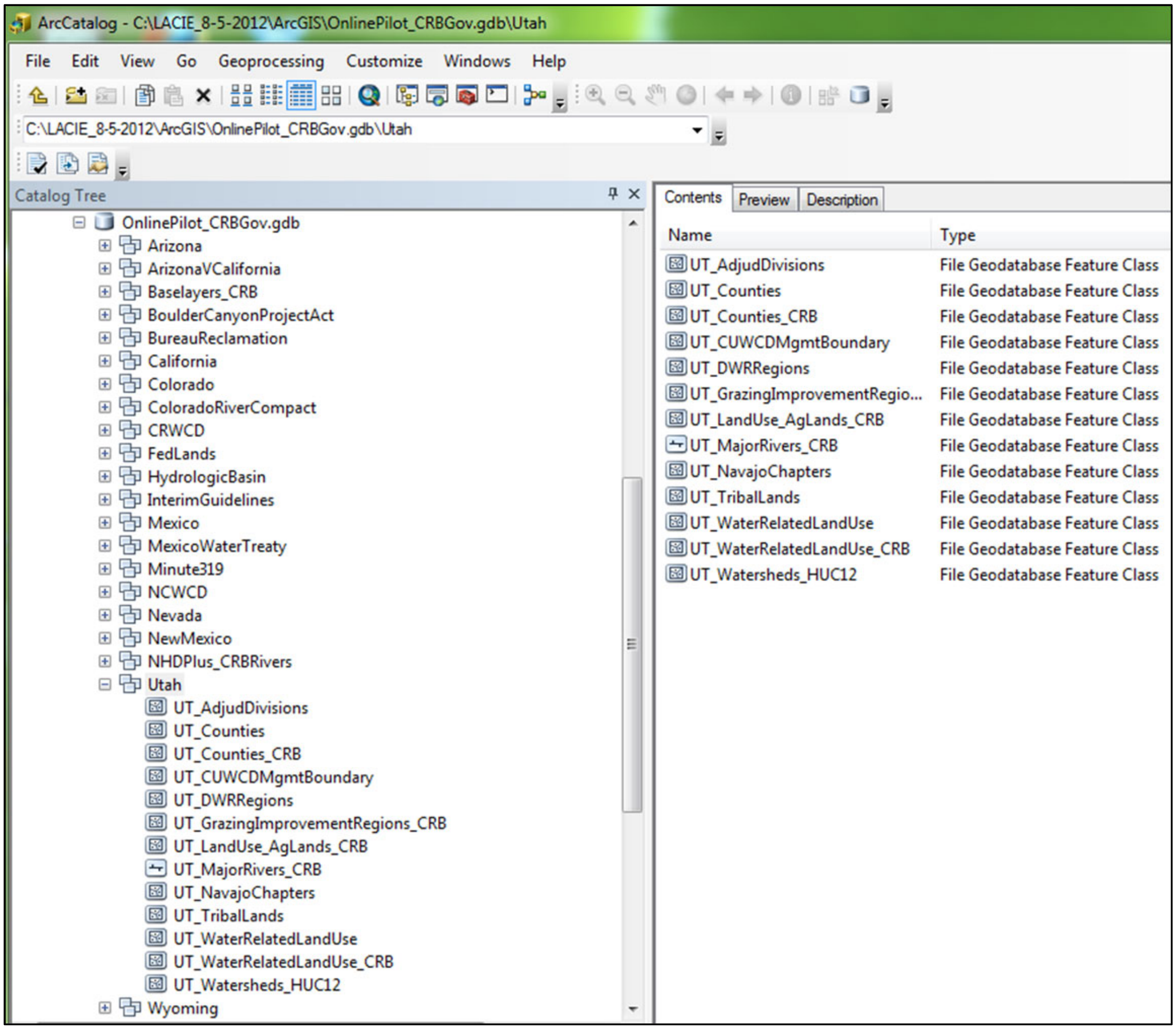
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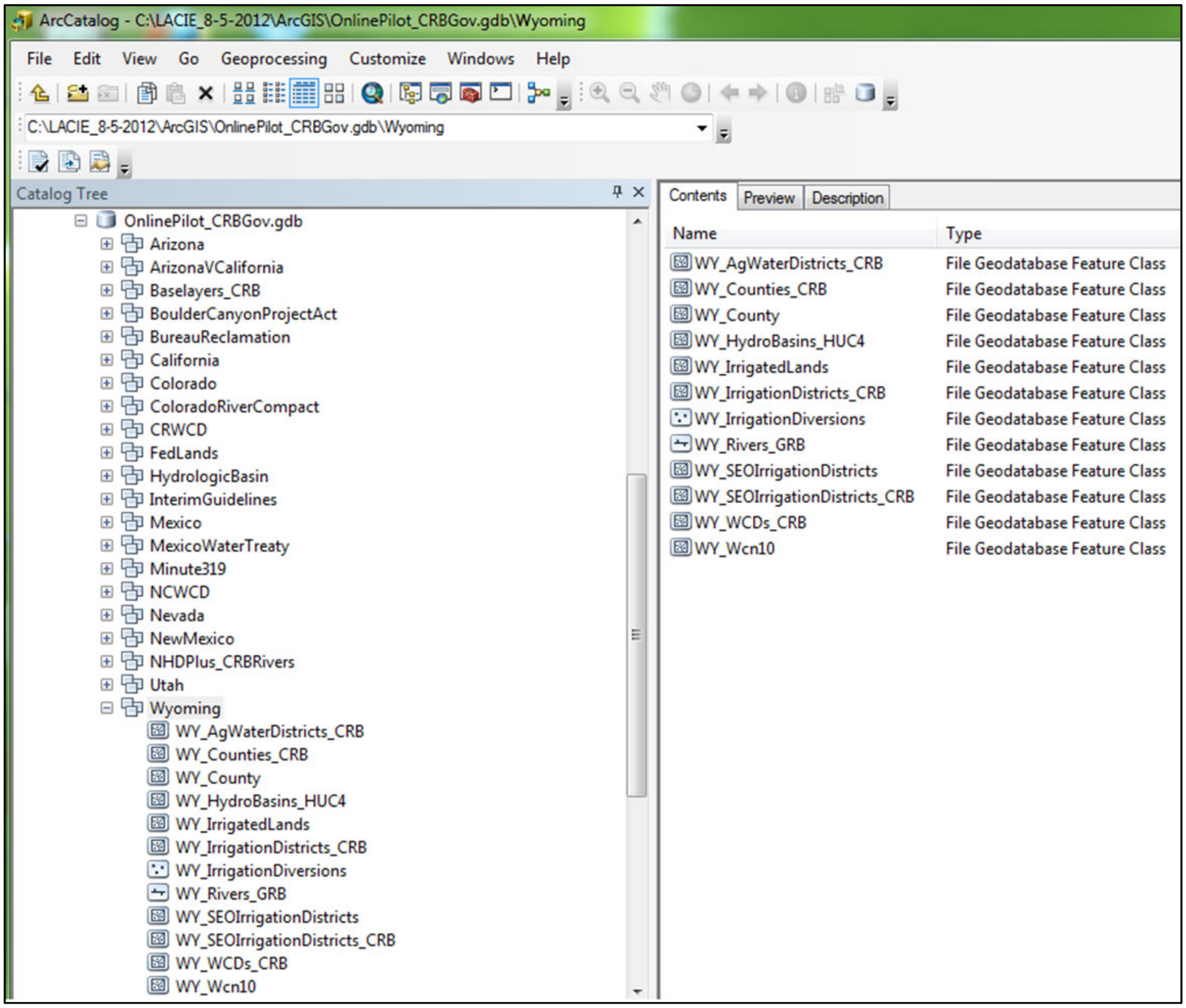
UT_DWRRegions
UT_GrazingImprovementRegions_CRB
UT_LandUse_AgLands_CRB
UT_MajorRivers_CRB
UT_NavajoChapters
UT_TribalLands
UT_WaterRelatedLandUse
UT_WaterRelatedLandUse_CRB
UT_Watersheds_HUC12
Wyoming
Contents Preview Description
Name Type
UT_AdjudDivisions File Geodatabase Feature Class
UT_Counties File Geodatabase Feature Class
UT_Counties_CRB File Geodatabase Feature Class
UT_CUWCDMgmtBoundary File Geodatabase Feature Class
UT_DWRRegions File Geodatabase Feature Class
UT_GrazingImprovementRegio... File Geodatabase Feature Class
UT_LandUse_AgLands_CRB File Geodatabase Feature Class
UT_MajorRivers_CRB File Geodatabase Feature Class
UT_NavajoChapters File Geodatabase Feature Class
UT_TribalLands File Geodatabase Feature Class
UT_WaterRelatedLandUse File Geodatabase Feature Class
UT_WaterRelatedLandUse_CRB File Geodatabase Feature Class
UT_Watersheds_HUC12 File Geodatabase Feature Class


ArcCatalog - C:\LACIE_8-5-2012\ArcGIS\OnlinePilot_CRBGov.gdb\Wyoming
File Edit View Go Geoprocessing Customize Windows Help
C:\LACIE_8-5-2012\ArcGIS\OnlinePilot_CRBGov.gdb\Wyoming
Catalog Tree
OnlinePilot_CRBGov.gdb
Arizona
ArizonaVCalifornia
Baselayers_CRB
BoulderCanyonProjectAct
BureauReclamation
California
Colorado
ColoradoRiverCompact
CRWCD
FedLands
HydrologicBasin
InterimGuidelines
Mexico
MexicoWaterTreaty
Minute319
NCWCD
Nevada
NewMexico
NHDPlus_CRBRivers
Utah
Wyoming
WY_AgWaterDistricts_CRB
WY_Counties_CRB
WY_County
WY_HydroBasins_HUC4
WY_IrrigatedLands
WY_IrrigationDistricts_CRB
WY_IrrigationDiversions
WY_Rivers_GRB
WY_SEOIrrigationDistricts
WY_SEOIrrigationDistricts_CRB
WY_WCDs_CRB
WY_Wcn10
Contents Preview Description
Name Type
WY_AgWaterDistricts_CRB File Geodatabase Feature Class
WY_Counties_CRB File Geodatabase Feature Class
WY_County File Geodatabase Feature Class
WY_HydroBasins_HUC4 File Geodatabase Feature Class
WY_IrrigatedLands File Geodatabase Feature Class
WY_IrrigationDistricts_CRB File Geodatabase Feature Class
WY_IrrigationDiversions File Geodatabase Feature Class
WY_Rivers_GRB File Geodatabase Feature Class
WY_SEOIrrigationDistricts File Geodatabase Feature Class
WY_SEOIrrigationDistricts_CRB File Geodatabase Feature Class
WY_WCDs_CRB File Geodatabase Feature Class
WY_Wcn10 File Geodatabase Feature Class

APPENDIX 3-II: COLORADO RIVER BASIN WATER GOVERNANCE RELATIONAL GEODATABASE METADATA

18 December 2012
OnlinePilot_CRBGov

Summary

This file geodatabase contains data collected on governance for the Colorado River Basin from multiple sources. The data dates from through to January 2011. The geodatabase is the result of contract between Environmental Defense Fund and Colorado State University. This database is intended for public use.

Software: ESRI ArcGIS 10.0

Projection: North America Albers Equal Area Conic

Datum: North American 1983

Contact: Dr. Melinda Laituri, melinda.laituri@colostate.edu; 970-491-0292

Description

This data has been collected from many sources including: the satellite offices of the Bureau of Reclamation of the Colorado River Region; the USGS National Hydrology Dataset; the states of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming; the Colorado River Water Conservancy District; the Northern Colorado Water Conservancy District; the Redlands Institute; The Nature Conservancy; the West Divide Water Conservancy District.

Credits

The development of the Agricultural Water Colorado River Basin Governance Geodatabase can be credited to Faith Sternlieb, PhD Candidate of the Geosciences Department of Colorado State University and Dr. Melinda Laituri, Department of Ecosystem Science and

Sustainability, Warner College of Natural Resources, Colorado State University, Fort Collins, CO. Funding was provided from the Environmental Defense Fund and the Colorado Water Institute at Colorado State University.

The geodatabase is organized based on the source of the data and the subject. The data for this project was collected from the Bureau of Reclamation and the area offices throughout the basin and from each of the Colorado River Basin states entities or departments that is in charge of collecting geospatial data:

- Arizona - Arizona Department Water Resources (http://www.azwater.gov/azdwr/GIS/)
- California - CAL-ATLAS Geospatial Clearinghouse (http://www.dot.ca.gov/hq/tsip/gis/datalibrary/gisdatalibrary.html)
- Colorado - Colorado Decision Support Systems (http://cdss.state.co.us/GIS/Pages/GISDataHome.aspx)
- New Mexico - New Mexico Resource Geographic Information System Program (http://rgis.unm.edu/)
- Nevada - Nevada Division of Water Resources
- Utah - Utah Automated Geographic Reference Center (http://gis.utah.gov/data/)
- Wyoming - Wyoming State Water Plan (http://waterplan.state.wy.us/plan/green/2010/gis/gis.html)

In addition, data was collected from entities that manage water demand and supply including the Colorado River District, Central Utah Water Conservancy District, and Northern Water Conservancy District. Data regarding administrative boundaries including federal lands came from nationalatlas.gov (U.S. boundaries) and the Global Administrative Areas Database (Mexico boundaries), http://www.gadm.org/.

The Ag Water Governance dataset is not comprehensive and only represents a small number of agricultural water supply organizations in the basin. Although the data in the geodatabase is projected in North America Albers Equal Area Conic projection, different people collected data, which served different purposes. Some data were projected while other data were not, causing minor discrepancies between shapefile boundaries.

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APPENDIX 3-III: AGRICULTURAL WATER SUPPLY ORGANIZATIONS IN THE CRB

Service and Supply Organizations can be classified in two types: (a) private, which are owned by shareholders, and (b) public, which are federal, state, or quasi-governmental. Private Service and Supply Organizations are water utilities, mutual water companies, carrier ditch companies and mutual ditch and irrigation companies. Public Service and supply organizations are municipalities, irrigation districts, conservancy districts, conservation districts, Reclamation districts, water control district, fresh water supply district and municipal Water Districts. "Water supply organizations such as irrigation and conservancy districts are formed primarily to raise revenue (by property taxation and bond sales) and to construct and operate irrigation projects. Some [organizations] contract with the federal government to administer government-financed reclamation projects" (Getches, 2009, p. 453).

Below is a summary table and list of the service and supply organizations whose central task is to deliver, manage, operate, store and build agricultural water mainly for irrigation in the Colorado River Basin, organized by state in alphabetical order. Those organizations in red font have been obtained as shapefiles. Many of the organizations in this list, especially the private districts, should be verified.

Summary Table

CRB State	**Ag Water Supply Org**	**Geospatial Data (shapefiles)**
Arizona	68	26
California	6	4
Colorado	45 quasi govt	20
	38 private	0
Nevada	5 Private	0
New Mexico	2 quasi-govt	0
	45 private	0
Utah	24 quasi govt	11

	19 private	0
Wyoming*	11 active	6
	12 inactive	5
Baja California, MX	1	0
TOTAL	276	62

*For a complete list of agricultural water supply organizations in Wyoming see Wyoming Water Development Commission, 2010 Wyoming Irrigation Systems Report

Arizona

1. 100 Coop
2. 200 Coop
3. Adaman Irrigation Water Delivery District #36
4. Aguila Irrigation District
5. Arabian Farms Association
6. Arcadia Water Company
7. Arlington Canal Company
8. Avra Valley Irrigation District
9. Buckeye Water Conservation and Drainage District
10. Central Arizona Irrigation And Drainage District – Lower Bureau Contract
11. Central Arizona Water Conservation District (CAP)
12. Chandler Heights Citrus Irrigation District– Lower Bureau Contract
13. Chino Valley Irrigation District
14. Cibola Valley Irrigation and Drainage District– Lower Bureau Contract
15. Citrus Glen Owner's Association, Inc.
16. Citrus Heights Ranch
17. Clearwater Farms Unit I
18. Clearwater Farms Unit II
19. Cortaro-Marana Water Users Association– Lower Bureau Contract
20. Country Farms Irrigation and Management Co.
21. Duncan-Virden Valley Consolidated Canal System
22. Estrella Meadow Water Coop
23. Franklin ID
24. Fredonia Consolidated Irrigation and Mfg. Co.
25. Harquahala Valley Irrigation District– Lower Bureau Contract
26. Hassayampa Water Coop
27. Hillander-C Irrigation and Drainage District
28. Hohokam Irrigation and Drainage District – Lower Bureau Contract but not listed in irrigation Districts Shapefile
29. Hohokam Irrigation District– Lower Bureau Contract
30. Maricopa-Stanfield Irrigation and Drainage Dist– Lower Bureau Contract
31. Maricopa Water District
32. Lake Havasu Irrigation and Drainage District– Lower Bureau Contract
33. McMullen Irrigation and Drainage District
34. Mohave Valley Irrigation and Drainage District– Lower Bureau Contract
35. Mohave Water Conservation District– Lower Bureau Contract

36. Navajo Indian Irrigation Project (Navajo-Gallup) – Lower Bureau Contract
37. New Magma Irrigation and Drainage District
38. New State Irrigation and Drainage District
39. North Gila Valley Irrigation and Drainage District - – Lower Bureau Contract
40. Orangewood Farms
41. Papago Butte Water District 4
42. Peninsula Ditch and Irrigation District
43. Pomerene Water Users Association
44. Queen Creek Irrigation District - – Lower Bureau Contract
45. Ranchos Jardines Irrigation Delivery District
46. Roosevelt Irrigation District– Lower Bureau Contract
47. Roosevelt Water Conservation District– Lower Bureau Contract
48. Saint Johns Irrigation District
49. Salt River Valley Water Users Association – Lower Bureau Contract
50. San Carlos Irrigation and Drainage District– Lower Bureau Contract
51. San Tan Irrigation District– Lower Bureau Contract
52. St. David Irrigation District Land
53. Sturgest Gila Monster Ranch
54. Suburban Irrigation District
55. Sun Valley Farms Coop III
56. Sun Valley Farms Coop II
57. Sun Valley Farms Coop IV
58. Sun Valley Farms Coop VII
59. Sunburst Farms Irrigation District
60. Tonopah Irrigation District– Lower Bureau Contract
61. Unit B Irrigation and Drainage District
62. Wellton Mohawk Irrigation and Drainage District– Lower Bureau Contract
63. Western Meadows Irrigation District
64. Yuma County WUA– Lower Bureau Contract
65. Yuma Irrigation and Drainage District same as? Yuma Irrigation District– Lower Bureau Contract
66. Yuma Mesa Fruit Growers Assocation– Lower Bureau Contract
67. Yuma Mesa Grapefruit Company– Lower Bureau Contract
68. Yuma Mesa Irrigation and Drainage District– Lower Bureau Contract

California

1. Coachella Valley Irrigation District, CA
2. Coachella Valley Water District, CA
3. Imperial Irrigation District, CA
4. Palo Verde Irrigation District, CA
5. Yuma Project
6. Metropolitan Water District of Southern California

Colorado

1. Carbon Water Conservancy District, CO (USBR)
2. Colorado River (Water Conservation) District

a. Basalt Water Conservancy District
b. Battlement Mesa Water Conservancy District
c. Bluestone Water Conservancy District
d. Bostwick Park Water Conservancy District, CO - – WCAO Project
e. Collbran Water Conservancy District – WCAO Project
f. Crawford Water Conservancy District – WCAO Project
g. Fruitland Mesa Water Conservancy District
h. Grand Mesa Water Conservancy District
i. Great Northern Water Conservancy District
j. Juniper Water Conservancy District
k. Middle Park Water Conservancy District
l. North Fork Water Conservancy District - – WCAO Project
m. Crawford Water Conservancy District– WCAO Project
n. Pot Hook Water Conservancy District
o. Rio Blanco Water Conservancy District
p. Silt Water Conservancy District– WCAO Project
q. Tri-County Water Conservancy District WCAO Dallas Creek Project
r. Upper Gunnison River Water Conservancy District
s. Upper Yampa Water Conservancy District, CO
t. Ute Water Conservancy District
u. West Divide Water Conservancy District, CO
v. Yellow Jacket Water Conservancy District
w. San Miguel Water Conservancy District (USBR?)
x. Southwestern Water Conservation District, CO (WIP)
    i. Animas – La Plata Water Conservancy District
    ii. Dolores Water Conservancy District– WCAO Project
    iii. Florida Water Conservancy District– WCAO Project
    iv. La Plata – Archuleta Water Conservancy District
    v. Mancos Water Conservancy District
    vi. Pine River Irrigation District – WCAO Project
    vii. San Juan Water Conservancy District
y. Grand Valley Irrigators, CO - WCAO Grand Valley Project
    i. Mesa County Irrigation District, CO
    ii. Palisade Irrigation District, CO
    iii. Grand Valley Irrigation Company, CO (Private)
    iv. Orchard Mesa Irrigation District, CO
    v. Grand Valley Water Users Association, CO – WCAO Project
z. Northfork Water Conservancy District (Crawford Dam/Paonia) – WCAO Project
aa. Orchard City Irrigation District– WCAO Fruitgrowers Project
bb. Mancos Water Conservancy District, CO
cc. Montezuma Valley Irrigation Company, CO
dd. Summit Irrigation
ee. Redlands Water & Power, CO (Rudeye Reservoir) – WCAO Project
ff. Uncompaghre Valley Water Users' Association – WCAO Project

Private Companies

1. Animas Consolidated Ditch Company, Durango
2. Bauer Lake Water Company, Mancos
3. Bona Fide Ditch Company, Delta
4. Bowen Ditch Company, Nathrop
5. CC Ditch Company (big ditch in Nucla off San Miguel)
6. Citizens Animas Irrigation Company, Inc., Durango
7. Elmwood Lateral Ditch Co., Inc, Fruita
8. Fire Mountain Canal and Reservoir Company
9. Florida Canal Ditch Company, Durango
10. Florida Canal Enlargement Ditch Company, Durango
11. Florida Co-op Ditch Company, Durango
12. Florida Farmers Ditch Company, Durango
13. Grand County Irrigated Land Company
14. Hartland Ditch Co.
15. Headgate 135 Lateral Inc, Grand Junction
16. Hermosa Ditch Company, Durango
17. Las Animas Consolidated Canal Company, Las Animas
18. Loma Ditch and Lateral Company, Loma
19. Mesa County Irrigation District
20. Minnesota Canal &Reservoir Co., Paonia
21. Missouri Heights - Mountain Meadow Irrigation Company, Carbondale
22. Missouri Park Ditch Company, Poncha Springs
23. North Delta Ditch Co.
24. Overland Ditch and Reservoir Company
25. Palisade Irrigation District, Clifton
26. Pine River Bayfield Ditch Company, Durango
27. Pioneer Ditch Company, Durango
28. Redlands Mesa Water Users, Hotchkiss
29. Redmesa Reservoir and Ditch Company, Hesperus
30. Relief Irrigation Co.
31. Riverside Ditch and Allen Extension Company, Buena Vista
32. Southern Ute Indian Tribe, Department of Natural Resources, Ignacio
33. Short Ditch Co. (not sure on name)
34. Spring Creek Extension Ditch Company, Ignacio
35. Stewart Mesa Ditch Company
36. Sullivan Wallace Ditch Co., Inc., Ignacio
37. Summit Reservoir and Irrigation Company, Dolores
38. Weber Ditch Company, Durango

Nevada

1. Bunkerville Irrigation Company, Virgin River
2. Moapa Valley Irrigation District, Muddy River Drainage
3. Mesquite Irrigation Company, Virgin River
4. Muddy Valley Irrigation Company, NV
5. Virgin Valley Water District, NV

New Mexico

1. Gila Basin Irrigation Commission
    a. Upper Gila Irrigation (Ditch) Association
    b. Fort West Irrigation (Ditch) Association
    c. Gila Hot Springs Irrigation (Ditch) Association
    d. Gila Farms Irrigation (Ditch) Association
    e. Riverside Irrigation (Ditch) Association
    http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nain
    f. Grandpa Harper Irrigation (Ditch) Association
    g. San Juan Agricultural Water Users Association
        i. Aztec Ditch
        ii. Bloomfield Ditch
        iii. Cedar Ditch
        iv. Cunningham Ditch c/o Don Nickles
        v. Eledge Ditch
        vi. Enterprise Ditch
        vii. Farmers Irrigation District
        viii. Farmers Mutual Ditch
        ix. Farmington-Echo Ditch
        x. Graves-Atteberry Ditch
        xi. Greenhorn Ditch
        xii. Halford Ditch
        xiii. Hammond Conservancy Ditch
        xiv. Helton Ditch
        xv. Highland Ditch
        xvi. Hillside Irrigation Dist
        xvii. Independent Ditch
        xviii. Jackson Ditch
        xix. Jaquez Ditch
        xx. Jewett Valley Ditch
        xxi. Kello-Blancett Ditch
        xxii. La Plata Conserv. Dist.
        xxiii. La Plata Indian Ditch
        xxiv. La Pumpa Ditch
        xxv. Left Hand Ditch
        xxvi. Lower Animas Community Ditch Co.
        xxvii. Manzanares-Turley Ditch
        xxviii. McDermott Ditch
        xxix. North Farmington Ditch
        xxx. Pioneer Ditch
        xxxi. Ralston Ditch
        xxxii. Ranchmans Ditch
        xxxiii. Sargent Ditch
        xxxiv. Stacey Ditch
        xxxv. Twin Rocks Ditch
        xxxvi. Willett Ditch (Mike Sims)

xxxvii. Wright-Leggett Ditch

2. Navajo Nation
    a. Shiprock Irrigation Project
        i. San Juan Dine Water Users Association
    b. NAPI – NIIP
        i. Fruitland Canal
        ii. Hogback Canal

<u>Private Companies</u>

3. Basin Pump & Supply Co. Farmington
4. Bloomfield Irrigation District
5. Ditch Company, Farmington
6. Jackson Canal And Ditch Company, La Plata
7. Sunset Canal Company – Virden Valley
8. New Model Canal Company – Virden Valley
9. San Francisco Ditch, Glenwood

Utah

1. Central Utah Water Conservancy District, Orem
2. Central Iron County Water Conservancy District, Cedar City
3. Carbon County Water Conservancy District, Helper
4. Duchesne County Water Conservancy District
5. Duchesne/Strawberry Water Users Association
6. Emery County Water Conservancy District, Castle Dale (Emery County Project)
7. Grand County Water Conservancy District, Moab
8. Kane County Water Conservancy District, Kanab
9. Moon Lake Water Users Association
    a. Dry Gulch Irrigation Company
    b. Farnsworth Canal & Reservoir Company
    c. Lakefork Western Irrigation Company
    d. Monarch Canal & Reservoir Company
    e. South Boneta Ditch Company
    f. T.N. Dodd Irrigation Company
    g. Uteland Ditch Company
10. San Juan Water Conservancy District, Blanding
11. Sanpete County Water Conservancy District, Mount Pleasant
12. Uintah Water Conservancy District
    a. Vernal Unit
    b. Jensen Unit
    c. Bonneville Unit
13. Washington County Water Conservancy District
14. Wide Hollow Water Conservancy District, Escalante

<u>Private Companies</u>

15. Ashley Central Irrigation
16. Ashley Upper Irrigation Co., Vernal

17. Ashley Valley Reservoir Company
18. Ashley Water Users, Vernal
19. Ashley Upper Irrigation Co. (Alta Ditch)
20. Basin Irrigation, LLC, Roosevelt
21. Blanding Irrigation Company
22. Dry Gulch Irrigation Company, Roosevelt
23. Duchesne Irrigation Company
24. East Side Irrigation Company, Green River
25. Green River Canal Company
26. Green River Irrigation Company
27. Intermountain Farmers Irrigation, Roosevelt
28. Moab Irrigation Company
29. New Escalante Irrigation Company
30. Operation and Maintenance Company, Duchesne
31. St. George Irrigation Div., St. George
32. Steinaker Canal and Irrigation Company, Vernal
33. Uintah Basin Irrigation Company
34. Uintah Irrigation Project
35. Uintah River Irrigation Company

Wyoming

Active

1. Boulder Irrigation District - Boulder, WY (District)
2. Eden Valley Irrigation and Drainage District – Farson, WY (District)
    a. District #1
    b. District #2
    c. District #3
    d. District #4
    e. District #6
3. New Fork Lake Irrigation District – Cora, WY (District)
4. Pine Creek Ditch Association Inc. – Pinedale, WY (Association)
5. Reservoir Ranch (formerly Sixty-Seven Reservoir Project)
6. Big Piney, WY (Private Company)

Inactive

7. Canyon Canal Inc. – Pinedale, WY
8. Bertrom Ditch Company – Boulder, WY
9. Cottonwood Irrigation District – Cottonwood Creek East Fork Canal Company – Boulder, WY
10. Fayette Canal Association – Pinedale, WY
11. Fremont Irrigation Company – Pinedale, WY?
12. Green River Irrigation District – Daniel, WY
13. Highland Irrigation District – Pinedale, WY
14. Paradise Canal Association – Boulder, WY
15. Silver Lake Irrigation District – Boulder, WY
16. Blacks Fork & Boulder

17. Blacks Fork Canal Company
18. Little Snake River Water Conservancy District

Mexico

1. Distrito de Riego 14 Rio Colorado in Baja California

APPENDIX 3-IV: RELATIONAL GEOSPATIAL DATABASE PROCEDURE

Below is the procedure implemented to create the *Colorado River Water Governance Geodatabase*. Data were compiled in a personal geodatabase in ArcGIS which contains feature datasets and feature classes arranged by water sharing arrangement and by state. Data were collected from a number of different state and federal agencies across the Colorado River Basin (CRB) including the Bureau of Reclamation, the Colorado River Water Conservation District, the seven basin states (Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming) as well as from National Atlas, a collection of data provided by the government. All of the data collected were available on the internet at no extra cost. Although the data come from different sources and have different geographic references, all of the data have been transformed to North America Albers Equal Area Conic projection and the GCS North American 1983 geographic coordinate system. This projection is used to accommodate the extent of the Colorado River Basin (estimated at 242,000 square miles), an international basin that covers the greater Southwestern U.S. and borders the U.S. and Mexico for 22 miles.

A transboundary analysis was conducted of water sharing arrangements in the *Law of the River*, a set of policies, court cases, laws and operational guidelines that set the political course for governing water in the CRB, a number of which can be classified as water sharing arrangements (WSAs). Subsets of WSAs were selected to demonstrate governance patterns that extend over geographic and temporal space (see list of WSAs below). Through a transboundary analysis, multiple overlapping boundaries (physical, political, and sectoral) in the Basin were identified and linked to geospatial data by *governance layers*. Governance layers are defined by two key components: 1) mandated or naturally occurring geographic boundaries and 2) decisions made based on those boundaries. Governance layers are also the key that links the transboundary analysis of the Law of the River, which is stored in a relational database (Microsoft Access) and the geospatial data stored in the personal geodatabase.

Because the boundaries in the Law of the River are configured in a temporally and spatially nested hierarchical pattern, it was necessary to identify all of the boundaries that applied to all the agreements, policies, laws and infrastructure upon which each water sharing arrangement was based. For example, in the text of the Mexico Water Treaty, specific reference was given to the Colorado River Compact. Thus, the jurisdictions within the Compact also apply to the Mexico Water Treaty and water sharing arrangements thereafter. The jurisdictions and all of the boundary information previously identified for the Compact was imported to the Mexico Water Treaty feature dataset. This same process was realized for all of the water sharing arrangements. In addition to the Colorado River Compact, other jurisdictions were referenced in the Mexico Water Treaty, such as Davis Dam and the All American Canal System. Although the Davis Dam was a result of the Mexican Water Treaty, the All American Canal (AAC) System was the result of the Boulder Canyon Project Act (BCPA) of 1928. Although the BCPA was not an original WSA in the analysis, the BCPA was added to the geodatabase in order to establish a political link between the Colorado River Compact and the Mexico Water Treaty feature datasets.

The procedure below demonstrates the development of both, how to create governance layers and the role of governance layers in spatializing water governance:

Procedure:

1. Identify water sharing arrangements (WSA) based on the transboundary analysis conducted in Chapter 1:
    - Colorado River Compact (1922)

- Mexico Water Treaty (1944)
- Upper Colorado River Basin Compact (1948)
- Arizona v. California (1963)
- Interim Guidelines (2007)
- Minute 319 (2012)

2. Within each water sharing arrangement, conduct a policy analysis to identify the jurisdictions to which the water sharing arrangement pertains
3. Collect the geospatial data that pertains to each agency and organizational jurisdiction
4. Create a file geodatabase in ArcGIS
5. Within the geodatabase, create a feature dataset for each WSA. The naming convention in this geodatabase is by Source, State and WSA. Supporting feature datasets include data that correspond to an agency or organization, where the name of the dataset indicates the source of the date as well as the general baselayers that might be added to each map for geographic reference.
6. From the baselayers (which are also categorized in the geodatabase as feature classes), additional individual feature classes may be created. For example, one feature class if named CRB_USTribalLands. In this feature class, the attributes are all of the individual tribal reservation in the CRB (this feature class was derived from NationalAtlas). In order to extract the individual tribal reservation that pertain to any on WSA, In ArcMap, create a layer from selected features and saved the layer as a shapefile with the naming convention WSA_[Jurisdiction] in the folder named after the source. In ArcCatalog, import the shapefile into the geodatabase as a feature class into the appropriate WSA feature dataset. Change the name of the feature class to reflect the appropriate type, based

on the boundary typology. For example, a state or tribe is a political boundary, while a hydrologic basin is a physical boundary.

7. Create four feature classes based on the boundary typology which requires appending all physical layers together and all political layers together. The feature classes are also linked to the boundary typology through the relational database (see below). The naming convention is based on this process. This step relates every attribute in the feature class to the appropriate boundary information in the relational database. For example, the feature data classes that demonstrate the Colorado River Compact (CRC) only relate to the data in the relational database that describe the CRC. The naming convention for the feature classes is:
   - Political/Physical_[feature class name]
   - WSA_PHYSICAL (physical extent)
   - WSA_POLITICAL (political extent)
   - WSA (subset of physical and political feature data classes)
8. For each Feature Class, add two fields to each attribute table: Policy_Name (name of the WSA), which is the field that is used to join the relational database to the geodatabase, and File_Name, the name of the feature class as it is in the geodatabase. This name will have changed from its original source name because it only represents a subset of the original data.
9. From the transboundary analysis, create a spreadsheet identifying all of the WSAs and the boundary information for each including: scale and jurisdiction and the boundary typology, which also includes the governance layers as well as the path to each feature data class. The spreadsheet field names are:

- Policy: name of the WSA within the Law of the River
- International Jurisdiction: the level of jurisdiction at the international scale (federal jurisdiction)
- Federal Jurisdiction: name of the agency that has jurisdiction over a particular geographic extent
- Regional Jurisdiction: name of the regional agency or organization that has jurisdiction over a particular geographic extent
- State_Tribe: name of the state or tribe with jurisdiction over a particular geographic extent
- Local Jurisdiction: name of the local entity with jurisdiction over a particular geographic extent
- Boundary Type: based on the boundary typology (physical, political, and sectoral)
- Governance Layer: based on Boundary Type (administrative, judicial, statutory, hydrologic, hydrographic, agricultural, environmental, municipal, industrial and recreational)
- Administrative Extent: based on boundaries defined in the Policy
- Path to GIS Layer: the source of each feature data class in the geospatial database

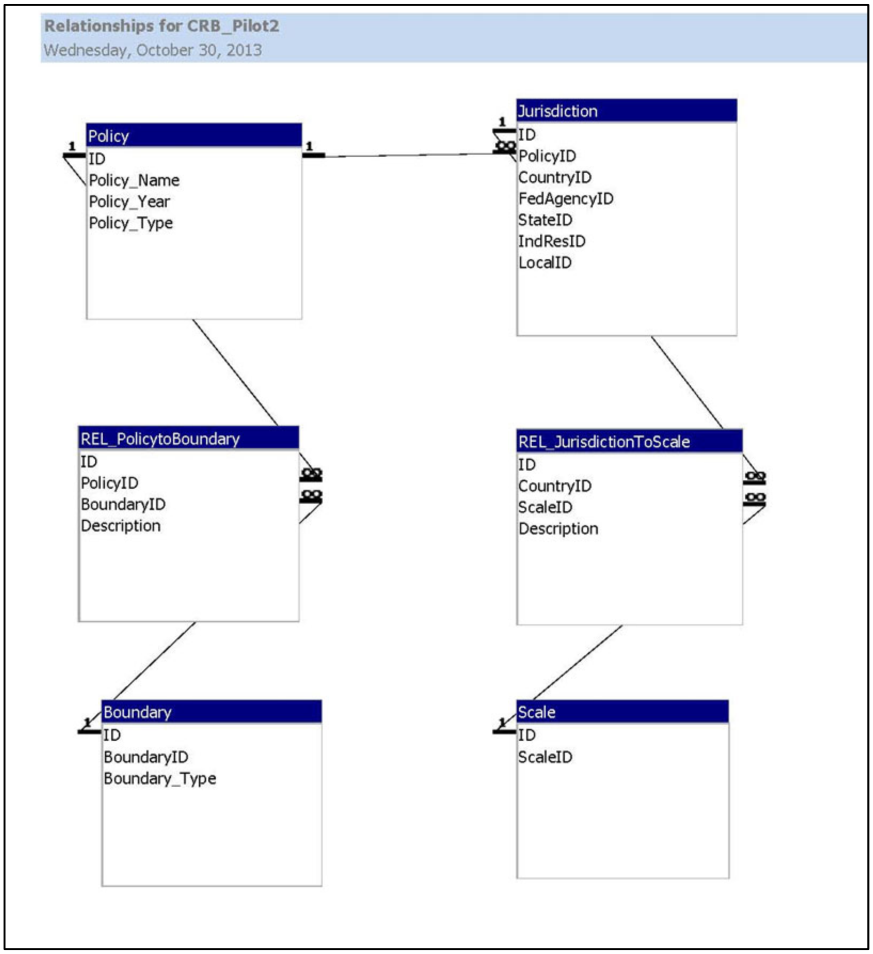
Joining a relational database to the geospatial database enables different types of data to be linked (such as geospatial data with qualitative data) and increases the query potential. This relational database, or CRB_Pilot, demonstrates the result of a transboundary analysis which is documented in tabular format in an Excel spreadsheet, and relates the spreadsheet into simplified tables through which relationships have been created. The architecture for the access database consists of classes which contain objects. In the schema:

- Classes describe a group of objects, for example: *Jurisdiction* is a class that describes the object *Federal or State*.
- Objects have a unique identity and may be transient (non-spatial) or place-based (spatial)
- Relationships can be classified as associations (between classes) and operations (between a class and an object). In the example shown here, the relationships between classes are defined, for example: *Policy* is associated to *Jurisdiction*.
- Relationships between classes and objects can be stated as: 1 to 1, 1 to many (∞), or many to 1.
- Associations and operations describe different types of relationships in an object-based model (Blaha and Premerlani 1998).

There are six tables (or objects) in the CRB_Pilot database, four LKU tables (look-up) and two REL (relationship) tables which explicitly relate the LKU tables, which categorize the policies, jurisdiction, the boundaries (from boundary typology) and scale defined by each of the fields in the excel table. The unique functionality of the relational database is the nature of the relationships created. Once imported into the geospatial database and joined with feature data classes to link attributes that are not part of the spatial file (not included in the attribute table) and in many cases, are different types of data.

In the geospatial database, create a like item and join the tables from the relational database to link the new attributes with those of the geospatial files. The 'like' item that links the geospatial table with the relational tables is Policy_Name. PolicyID is the like item to join the REL_PolicyToBoundary. And BoundaryID is the like item to join REL_ JurisToScaleToBounds. The relationship established in all of these relates is a many to one relationship where there are many Feature Classes in the geodatabase to one Policy. From the queries conducted, the policies, their related boundary information and governance patterns can be geovisualized.

APPENDIX 3-V: RELATIONSHIPS AND RELATIONAL DATABASE



CHAPTER 4 AGRI-CULTURAL GEOGRAPHIES: A BOUNDARY STUDY OF WATER SHARING IN THE COLORADO RIVER BASIN

Introduction

The relationship between the Bureau of Reclamation (USBR) and special interest groups (i.e., agriculture), has a rich, complex history. This relationship has defined the western landscape through the infrastructure that reaches from the rivers to small and large farms. Access to water in the Colorado River Basin (CRB) is determined by the doctrines of prior appropriation (or first in time, first in use) and beneficial use. The Colorado River is one of the world's most highly regulated river systems, where agriculture (Ag) uses up to 75% of the available water (USBR, 2012). Ag water in the CRB is currently under pressure due to projected increases in population, water demand and water use, as well as significant uncertainty in climate and future water supply. Organizations such as irrigation districts that manage the supply of Ag water to farmers and producers are situated at the center of these pressures.

The focus of this chapter is on geographic perspectives of Ag water users in the CRB. Geographic perspectives are the ways in which sections of society think about the geography of their home, culture, and general way of life. Ag water users are irrigation district managers and agricultural producers (which include farmers and ranchers), who live and work at the nexus of multiple, overlapping and intersecting boundaries. Their geographic perspectives are essential to understanding water for agriculture in the West precisely because it is possible their water supply is at risk due to competing claims for water (e.g. municipal needs and tribal claims). Reclamation projects are built and financed by the USBR where land is reclaimed for agriculture and water is harnessed through infrastructure for irrigation. Reclamation projects have facilitated traditional agricultural lifestyles from the time of the westward expansion. At the time of the Eleventh

Report of the United States Geologic Survey (1891), John Wesley Powell surveyed the territories surrounding the Colorado River with the aim to identify possible dam sites along the reach of the Colorado River, where water could be controlled for agriculture (Powell 1892).

This chapter summarizes research conducted for a USDA-NIFA project entitled *Addressing Water for Agriculture in the Colorado River Basin.* The research team conducted in-depth telephone interviews of agricultural producers and water managers across the CRB from the seven basin states: Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming (Appendix 4-I). The interviews focused on what farmers think about the changes regarding the pressures on Ag water, cooperation (or conflict) between farmers as well as between farmers and other interest groups, the future of water for agriculture, and decision-making at multiple levels. A subset of these interviews was extracted specifically to examine the movement of water in Reclamation projects across federal, state, and district boundaries.

Based on the assumption that Reclamation projects inhibit water sharing, the research presented here suggests that Reclamation projects actually facilitate local water sharing through contracts between the USBR and districts, both within projects and between projects and other irrigation enterprises. The geographic perspectives of farmers who work within Reclamation projects support this postulation. Sharing water can take on many forms such as water markets and banks, transfers, exchanges, sales, and other types of interactions (Chapter 1). Water sharing transactions occur between uses and users (e.g. Ag to municipal, Ag to environment, municipal to industry, etc.), involving overlapping jurisdictions across multiple geographic scales (e.g. international, interstate, and intrastate transactions) and are used to describe multiple facets of water quantity (e.g. shortages and excesses), as well as benefits and costs (Chapter 1). Water sharing policies and transactions are stipulated by both normative (*bonafied*) and physical (*fiat*) boundaries and can be represented geospatially (Chapter 3). In order to better understand water sharing, a boundary study was conducted to identify and map the dominant boundaries surrounding Ag producers who farm under the jurisdiction of Reclamation projects.

Boundaries, in the context of this project, are defined as the social, political, and physical similarities or differences between two or more groups that can be geospatially represented. Reclamation farmers and their geographic perspectives relay their four-dimensional position on time, place, space, and scale, in the context of (a) the boundary typology and its characterization of Ag water governance in the Colorado River Basin and (b) water sharing arrangements (WSAs) (Chapters 2 and 3). In short, boundaries are important because they influence where, when, and who can feasibly share water. Boundaries may be created by the *de jure* rules, policies, institutions and organizations (governance arrangements) and by the physical location of infrastructure or natural water flows. However, the perceptions of those boundaries are important because they signal the "in use" boundaries of those governance arrangements.

The first section of this paper addresses the early institutional endeavors, both formal and informal, that shaped the development of water for agriculture in the western U.S., and specifically the CRB. The second section describes the methods and criteria used to analyze the subset of interviews on Reclamation projects. The boundary typology (Chapter 2) was utilized to guide analysis of the interview data to answer the questions: (a) what are the prevailing boundaries in Reclamation projects based on the farmers' perspectives, (b) can those boundaries be geospatially represented, and 3) do they indicate the presence of water sharing?

The fourth section highlights the resulting *agri-cultural* geographies, in other words the geographic perspectives of farmers, with specific emphasis on the *culture of Ag*. Throughout the chapter, agri-culture refers to lifestyle based on farming and agriculture refers to the production of crops. Farmers reference geography through four dimensions: (a) places that are important to them in the CRB, (b) space (indicated by sectoral boundaries which are defined by local special interests), (c) scale (levels of jurisdiction) and (d) time (water rights are granted based on prior appropriation, first in time, first in right). By applying the boundary typology to analyze interviews, geographic perspectives such as time, place, space, and scale emerged as important geographic perspectives. The boundary typology provides a method to link identity to socio-spatial arenas (place) via spatial units and political scales (Cash et al., 2006; Pellow, 1996; Taylor and Spicer, 2007). The identification of boundaries at multiple scales provides insight into the farmer's identity, especially as they perceive their role in using, conserving, and developing water for agriculture in the CRB as well as maintaining their agri-cultural lifestyle.

Place, in the context of this study, "is an always-ready ongoing assemblage of geographically associated, ontologically co-constitutive elements and relationships" (Gregory, Johnston, Pratt, Watts, & Whatmore, 2009, p. 540). To illustrate this definition, rural CRB communities where agriculture is practiced symbolizes a cultural landscape (Sauer, 1963 [1925]), one that has been formed by the participants in this study and their predecessors, and the relationships there within, specific to a geographic location or region which can be identified and demarcated on a map. However, the nature of a cultural landscape is one that exhibits change over time, independent of the agri-cultural actors or agri-culture itself (Gregory et al., 2009; Sauer, 1963 [1925]), which in Reclamation projects, the cycle has been perpetual, at least since the Reclamation Service was born in 1902. However, even Reclamation farming is undergoing change as many of the projects now cater to multiple uses, still including agriculture. In agriculture in the CRB, place for farmers specifically pertains to the Federal government, as the

USBR created places in the CRB of water availability for use, empowering the farmer, and reifying the USBR-farmer relationship and enabling water sharing through infrastructure.

Finally, the discussion emphasizes insights from this study that can inform future research in testing and further developing the boundary typology as an analytical framework, in which boundaries link identity and scale. Conclusions point towards the need to better understand agricultural water governance, especially as it pertains to arid and semi-arid climates, in places where water is scarce.

Developing Water for Agriculture

Farming in the west was driven by manual labor that consisted of digging ditches in hard clay soil in a hot and dry climate. At the turn of the 20th Century, the U.S. Government encouraged westward expansion by selling parcels of land at low prices to those willing to farm. Farmers began to organize themselves in small private ditch companies to pool both water and money. These early enterprises were formed "as a mechanism to require all landowners in an area to join in the common *enterprise* of developing and delivering water for irrigation," such as the Wright Act, California, in 1887 (Leshy 1982, 353). Soon after passing the Wright Act, the 1888 Joint Resolution for an Irrigation Survey located possible storage sites appropriated under the 1878-79 Sundry Civil Appropriations Bill. At that time, enterprises were responsible for building their ditches and other infrastructure, eventually falling into disrepair. It became evident that organizations such as cooperatives and districts would need further government assistance to develop infrastructure for water storage and delivery to stay in business (Mead, 1903; Worster, 1985).

As a result of hard labor, death and loss of crops in their fields and a fear that westward expansion might fail (Rowley, 2006; Worster, 1985), agricultural interests collectively lobbied

Congress to provide assistance to farmers. Simultaneously, John Wesley Powell, who understood the predicament of water in the Arid Lands, was travelling to territories throughout the West, giving speeches and writing articles about the urgency to plan westward expansion for the sake of agriculture (deBuys, 2001; Schorr, 2012; Wilkinson, 1992; Worster, 1985). Congress responded and the Reclamation Service was born with the passing of the Reclamation Act (1902), also known as the Newlands Act. Three primary goals of the Reclamation Act was to (a) create federal projects that would irrigate family sized farms, (b) secure subsidies for water supplied by federal projects, and (c) limit private speculation and individual gains from federally subsidized water (Benson, 1997).

The Reclamation Service first contracted with farmers for the storage and delivery of irrigation water through ditches, canals, pipelines, and by building dams. Federal assistance further encouraged westward migration, and from 1900 to 1910, the population in the West grew 66.8%, the highest percent of growth from the period between that same period (Hobbs & Stoops, 2002; Mackun, Wilson, Fischetti, & Goworowska, 2011). Due to the rapid influx of people migrating to farm the West, administrative tasks and costs for managing contracts for water were becoming inefficient (Bretsen & Hill, 2006). New arrangements amongst farmers developed where many private enterprises (irrigation companies) transitioned to quasi-governmental entities, functioning as political subdivisions of the state called irrigation districts. Many of the historic rules and functions of an irrigation district hold true today, such as: (a) enforced cooperation and participation, (b) low interest or interest free loans, (c) the power to tax, and (d) state and Federal tax exemption (Howe, 2005; Leshy, 1982). The costs of reclaiming land in the 17 western states were high and a number of amendments were made (Reclamation

Law) upon which the relationship between farmers and Reclamation depend upon for irrigation water and infrastructure (Table 4.a).

In addition to Reclamation law, a series of policies, laws, rules, and doctrines govern the Colorado River Basin, referred to as the *Law of the River* (1922). The *Law of the River* is bound by physical, political, and sectoral boundaries, which were established by federal, state, and local policies and can be geospatially represented through governance layers (Figure 4.a), where each policy has a regional scale and each project has a local scale that pertains to a specific place and is based on the farmers' (or districts') water rights. For example, those projects authorized by the Reclamation Act are regionally located in both the Upper and Lower Basins, in three different states, and collectively have some of the oldest water rights in the basin. However, each project has a distinct affiliated local irrigation district and water rights that are dependent upon the time each project was authorized. The same principle applies to all Reclamation projects under each Act passed by Congress, based on the rules, policies, and court decisions of the *Law of the River*. Within Reclamation projects, irrigation districts have different levels of water rights (represented by temporal governance layers) that depend upon physical boundaries including direct flow rights (surface water) and storage rights (rights to stored water).

Water rights may be the single most important aspect that ties a farmer to their land, and therefore to a particular place. This is especially true in Reclamation projects where a prescribed amount of water can only be applied to specific plot of land. Once a farmer sells their land, they also give up their water right and thus any economic advantage to produce crops. Based on prior appropriation, the older the water right, the more valuable it is, tying a Reclamation farmer to place as well. Thus time is an important geographic dimension as it is an historical one. This is one example in which the boundary typology provided a means to ascertain the prominent boundaries and determine the geographic significance of place, space, time, and scale as seen by farmers' affiliated with Reclamation projects. Water sharing is another example.

Reclamation Projects: Old & New Boundaries

There are two perspectives in which to consider the relationship between boundaries and Reclamation projects. The first is through boundaries that constrain farmers from entering into WSAs either within or outside of Reclamation project boundaries, created by entities that establish federal (Reclamation law), state (prior appropriation), and local (irrigation district) rules. The second is through new boundaries that have been created by WSAs (e.g. informal water banking arrangements). Constraining boundaries are those that have been established by contracts between the USBR and districts. Contracts are one type of a local level WSA between farmers and the federal government. As with any WSA, boundaries may be imposed that both facilitate and constrain the movement of water. Through contracts, the USBR imposes boundaries on farmers and their irrigation districts because they have very specific allocation rules about how to use water and where the water can be used. Section 5 contracts (also referred to as repayment contracts) refer to the way in which water can be used under section 5 of the Boulder Canyon Project Act (BCPA) (for agriculture and municipal purposes), which is also a part of the *Law of the River*.

There are two different types of repayment contracts that address water for irrigation, both of which are executed under the authority of the Reclamation Project Act of 1939: 9(d) provide for complete repayment of construction costs within a specified period of time; 9(e) for projects not completed and costs have yet to be established (Candee, 1989). Repayment contract provisions between irrigation districts and Reclamation allow the delivery, storage, diversion, and release of project water (Benson, 1997; Sax, 1968). Contracts also prohibit the sale or transfer of water for individual or district profit. Independent of the repayment contract with the district, Reclamation must apply to the states for water rights on behalf of the project constituents, which include the federal government, the state, the irrigation district, and the farmer who owns Ag land in the project. The water rights holder determines the rights and responsibilities of the various parties, and the context (geographic, legal, and political circumstances) of how and where water is applied (Benson, 1997; Sax, 1968). The irrigation district has an important role in managing water use in that it, "acts as an intermediary between the United States and the ultimate user, contracting with individuals for allotments within the projects, administering the distribution of water, and collecting taxes and user fees to pay annual maintenance expenses as well as the capital repayment due to the United States" (Sax, 1968, p. 119-20).

In addition, several federal and state laws restrict water use by an irrigation district, where water in Reclamation projects is tied to the Ag land under the federal contracts and state law often prohibits transfers that cross Reclamation project boundaries (Leshy, 1982; Moore, 1991; Wahl, 1989). In other words, if water is tied to the land, the land and water rights are sold together and those water rights cannot be sold separately. The only state this rule applies, outside of Reclamation projects, is the state of Wyoming. Finally, new 'area-of-origin' protections are rules that limit the spatial extent of water sales and transfer to a particular district or watershed (Griffin, 2012; Griffin & Kelly 2012; Moore 1991) to limit third party impacts that may affect the rural communities dependent upon the agricultural economy (Mead, 1903; NRC, 1992; Saliba & Bush, 1987).

Although the imposition of contractual boundaries might have created rigid boundaries in terms of how, where, and when water can be used in the CRB, the *Law of the River* has also opened up new boundaries which include sets of agreements and WSAs that include long-time actors who have not previously had a voice (e.g. Tribes), new stakeholders (e.g. the environmental sector), and changes in water use and water users over time. Farmers are the principal water users, where agriculture consumes up to 75% of the water Basin-wide (USBR, 2012). The amount of water consumed by agriculture compared to municipal, industrial, environmental, and recreation sectors leaves Ag water at risk, evidenced in the number of transfers that have occurred from agriculture to these sectors (Bren School of Environmental Management, 2014). The question about what farmers think about these transfers and how they feel about the changing state of agriculture in the Basin was a central motivation for interviews. Through interviews, we were able to ascertain farmers' position on agricultural water in the Basin, their interest and willingness to cooperate, their ability to organize amongst themselves, and their views about the future of Ag, Ag water, its availability, and what is needed to sustain thriving rural, agricultural communities.

Boundaries are essential to understanding the changing agricultural climate due to the amount of water that is transferred out of Ag (Bren School of Environmental Management, 2014). Physical and social boundaries determine the extent of agriculture in the CRB, which is difficult to track due to seasonal plantings (temporal); multi-crop plantings per season per field; extent covered by irrigated versus dryland agriculture (dependent upon precipitation); the source of water, whether tributary, mainstream, ground or surface water; differences in crops and consumptive water use for each crop in the Upper versus Lower Basin; changes in water sharing arrangements including leases, transfers, and exchanges of land and/or water between and among the agricultural and other sectors; and inconsistencies between state and federal data reporting (Pritchett, 2011; Cohen, Christian-Smith, & Berggren 2013). Calculated irrigated acreage and types of crops estimates that 23% of irrigated acres are for alfalfa in the CRB (Cohen, Christian-Smith, & Berggren, 2013; Kallenberger, 2013). The highest percentages of crops grown and harvested in the CRB are forage and pasture (including alfalfa and hay) largely produced to support ranching and supply the livestock industry, an important voice of the agricultural sector (Cohen, Christian-Smith, & Berggren, 2013; Kallenberger, 2013) (Figure 4.b).

Methods

Twenty interviews (out of the original sixty interviews of farmers, ranchers, and water managers) were selected based on those who farm on Reclamation projects in the CRB, representing fourteen different irrigation projects.[1] The interviews were administered through a set of semi-structured questions, and each interview was conducted via telephone. Agricultural water users were identified based on geographic and political boundaries (states and districts where agriculture was prevalent). An informal interview was conducted with the Director of each state agency to identify the key agricultural areas in the Colorado River region of the State, the districts that manage agricultural water in those areas, and the managers and Ag producers who farm there. Interviewees included Ag water users who had senior and junior water rights of surface or groundwater or both with direct flow rights and/or storage rights and grew commodity crops and/or specialized crops Interviewees were mostly experienced, long term farmers, where the majority were third and fourth generation farming families.

Statistically, the small sample size was a limitation. However, for this study we were willing to accept a small sample to conduct a transboundary analysis and validate boundary

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[1] Interviewees often held multiple positions including farming and ranching. In addition, some managers farmed and ranched themselves. For this reason, it is difficult to decipher a number representative of each position. Although the boundaries that define positions are fuzzy, this is a boundary with which the community is comfortable crossing.

typology, a methodology that integrates geospatial and social sciences. Although the purpose of the larger study was to better understand perceptions, beliefs, and attitudes of farmers, the purpose of this study was to ascertain the farmers' geographic perspectives through interviews by validating the boundary typology. Due to the extensive geographic range, we were able to capture many boundary nuances such as upstream downstream users, senior and junior water rights holders as well as individuals from both the farming and ranching communities, variables that are key to the study of boundaries. The sample covers 32% of Reclamation projects in the CRB, of which three were with tribes and two of those were Reclamation projects (Table 4.b). Interviews took place in five out of the seven basin states, except for Wyoming and Nevada (Figure 4.c).

Although the USBR holds less than 1% of the total land area of the CRB (Sternlieb & Laituri, 2012), it serves roughly 10 million acres through water supply projects (Moore, 1991). There are a total of fifty-five Reclamation projects within and extending outside of the hydrologic extent of the Basin (including transbasin and transmountain diversions) covering seven states. *Interstate* transbasin and transmountain projects in the CRB include Hoover Dam, which straddles Arizona and Nevada and authorized by the BCPA, as well as the San Juan-Chama Project, which is a transmountain diversion that cuts across Colorado and New Mexico and authorized by the Colorado River Storage Act (CRSA). The CRSA is also responsible for authorizing Glen Canyon Dam, which is situated on the border Nevada and Arizona on the Colorado River.

This analysis is based on primary data from interviews that specifically relate to water sharing across Reclamation projects and boundaries identified by farmers who were interviewed. WSA(s) are agreement(s) made between two or more water users (or entities) where there is an initial appropriation (excluding water rights that are administered by a state or tribe) and/or a reallocation such as change of use, a change of location where the water is applied, and/or a change in user. A transboundary analysis was conducted to code interviews by applying the boundary typology. The boundary typology was instrumental in understanding boundary perspectives and transboundary relationships in water sharing across Reclamation projects in the Colorado River Basin. A methodological coding system based on boundary themes was accomplished through QSR* NVivo software (version 10), a qualitative research tool for coding interview data (Siccama & Penna, 2006). QSR* NVivo is used by social scientists to conduct qualitative research to answer questions, program evaluation, exploring perceptions, and understanding phenomena through content analysis of interviews, focus group, audio recordings, and images (Bazeley & Richards, 2000). One challenge inherent in qualitative research is transparency (Bringer, Johnston, & Brackenridge, 2004). However, QSR* NVivo is a tool that encourages the application of a strict methodology helpful in planning, documenting, analyzing, and reporting results (Bazeley & Richards, 2000). Most importantly, QSR* NVivo queries enabled cross reference between different types of water sharing arrangements by sector and state.

The boundary typology provides a way to identify opportunities and barriers in sharing water and representing that information geospatially. Coding was conducted applying the boundary typology. Three types of boundaries were coded as part of the boundary typology: physical, political, and sectoral (Table 4.c). The governance layers that pertain to physical boundaries are hydrologic and hydrographic. Hydrologic boundaries are those based on natural drainage systems defined by the National Hydrography Dataset of the U.S. Geologic Survey (Seaber, Kapinos, & Knapp, 1987), and hydrographic boundaries are hydrologic boundaries delineated by a state or tribal government. For these interviews, only hydrologic boundaries were coded: surface water and ground water. New physical boundaries are those created by infrastructure. Any inference to infrastructure was coded as a political boundary since water infrastructure is often mandated and managed by federal, state, local and/or private entities. Political boundaries, sometimes referred to as organizational or institutional boundaries (Heikkila 2004), are politically constructed and are formed by a combination of political, social, and cultural forces. Political boundaries are based on four governance layers (Chapter 2): statutory, judicial, administrative, and time. Sectoral boundaries are socially constructed and formed by social and cultural processes that delineate different types of water users as well as economic interests at local and regional scales (Fischhendler & Heikkila, 2010). Agricultural water policy has both formed and evolved from or initiated rules and norms on sharing water in the CRB (Sternlieb et al., 2013).

Maps were an integral component to the interview process. Prior to conducting the interviews, we conducted exploratory interviews with key state figures to identify names of managers of water conservancy districts and irrigation districts. Maps were created to locate potential interviewees and important Ag lands (identified by key state leaders). These maps were used to compile names of people, places, areas and districts that would be important for our interviews.

In addition to the maps created for each state, map documents of each state were prepared prior to the interviews to be conducted for that state. State maps were projected on the wall and shown to interviewers to show local areas within the state where interviewees were located. These maps provided baseline information about political jurisdictions, water ways and other geographical features that would both inform questions posed to the interviewees while informing the interviewers for reference regarding specific areas and locations during the interview. All of the basemaps were created from the Colorado River Basin Water Governance Database (Chapter 2). Natural and physical boundaries that identify geo-political locations such as states, counties, towns, hydrologic basins, as well as natural and physical features that include mountain ranges, rivers, dams and reservoirs, national natural areas such parks, and forests are of particular interest. Administrative boundaries that demonstrate patterns of governance such as organizations and agencies with specific jurisdictions at multiple scales were compiled per interview.

Due to the number of WSAs, their function, structure, and scale, criteria were developed to ensure systematic codification: all arrangements were political and either administrative, judicial, and/or statutory (if not specified, they were not classified); all arrangements were associated to one or more scales in order to better understand the scales at which arrangements were most frequent; all arrangements if specified had one or more sectoral boundaries (Figure 4.d).

Although all of the interviews were coded according to the boundary typology, boundaries that had not previously been considered due to their subtle geographic inference became apparent Table 4.d). Themes related to economics consistently arose, requiring a fourth boundary type, *pecuniary*, to capture matters regarding economic issues. Two additional categories that fell outside of the boundary typology were necessary in order to capture ‘place’ and WSAs. The resulting coding schematic used in coding interviews changed in two ways: (a) the boundary typology expanded with the addition of the pecuniary boundary and (b) the boundary typology was coded by cross-referencing boundaries with WSAs, place (geographic reference) and scale (Table 4.e). Scale was coded based on jurisdiction, which are boundaries that manifest on the political landscape. By cross-referencing the physical, political, and pecuniary boundaries with scale, I found that a nested hierarchical pattern resides within each boundary (except for pecuniary boundaries). This is important in identifying governance patterns (Chapter 1), providing possible explanations for changing governance regimes in the Basin.

Scale, both temporal and spatial, influences observed patterns, practices, and processes. According to scholars of political geography who study boundaries, scale is the "nested hierarchy of bounded spaces of differing size, such as the local, regional, national and global" (Delaney & Leitner, 1997; Howitt, 2003). Scales, like boundaries can be seen as a political and social constructs, as within indigenous societies (Howitt 2003; Marston 2000; Marston, Jones, & Woodward, 2005) or viewed as a mechanism for social transformation, as in potential for redistribution, recognition, and environmental sustainability (Howitt, 2003). It is within this context interviews were coded according to scale: the international, federal, interstate, state, tribal, intertribal, and local. Irrigation districts, as well as local environmental initiatives, roundtables, cities, and towns were all coded at a local scale. Reclamation projects were coded at the federal and local scale as well as within the political boundary, statutory governance layer. Project infrastructure and Reclamation districts were both coded at the federal and local scales, unless specific reference was made to infrastructure that served international agreements, such as the Mexico Water Treaty. In the resulting graph depicting water sharing arrangements at multiple scales (Figure 4.e); federal, state, and local scales have almost equal presence, based on farmers' perspectives.

Results

By correlating interview responses to the boundary typology, responses validate the boundary typology and that physical, political, and sectoral boundaries are explicit (as well as new boundaries not previously considered). In addition, they show that farmers in Reclamation projects think about Ag water in the context of place, space, time, and scale, which constitute four dimensions of geography. In fact, farmers do not only think about boundaries, responses support the hypothesis that boundaries are not prohibitive. In other words, the de jure boundaries, which they identify, do not necessarily constrain their ability to engage in water sharing. Translating boundaries that were explicit in the interviews through governance layers reveals the spatial dimension of the interviews, enabling geospatial representation of the policies that may either confine or facilitate transboundary relationships.

Settlements were a recurring type of arrangement that emerged from the interviews. Settlements were classified under political boundaries as judicial governance layers. According to the Oxford Dictionary, a settlement is "an official agreement intended to resolve a dispute or conflict . . . a formal arrangement made between the parties to a lawsuit in order to resolve it, especially out of court . . ." (Oxford English Dictionary, 2013). Other types of arrangements include water banks (coded at the state, federal, or local scale and coded as temporal and/or administrative governance layers); contracts (coded at the federal and local scales) as well as transfers and diversions (which were coded by scale only if specified in the interviews) (Table 4.f and Table 4.g). In reporting the qualitative results from the interviews, the new pecuniary boundaries were considered. The excerpts from the interviews mostly show interest in cooperation to share water. Out of fourteen projects, however, there was one specific example of an informal WSA within a federal project located in the Upper Basin, where reallocation of water from Ag to Ag was acceptable. They indicate that arrangements at multiple scales across the seven CRB states and tribes emerged and the nature of the arrangements show flexibility in the system, despite rigid rules (Mulroy, 2008). Different types of agreements mentioned in the interviews include the Quantification Settlement Agreement of California (state and multi-sectoral), the Intentionally Created Surplus (interstate between Arizona, California, and Nevada), the international Mexico Water Treaty, Historical Users Pool (inter-sectoral among senior water rights holders in Colorado), the Omnibus Act Public Law 111-11 (federal) are WSAs that make up the *Law of the River*.

Temporal governance layers are important because they embody the nature of water rights in all of the states within the CRB: the doctrine of prior appropriation or “first in time, first in right.” The temporal category was initially classified as its own boundary. In the interviews, water rights emerged under a number of different terms including prior appropriation, entitlement, and allocation. Because water rights rules in the CRB derived from the doctrine of prior appropriation, they were classified under political boundaries as temporal governance layers. Since states administer water rights, even to the federal government, water rights were classified at the state scale and were also classified under political boundaries as administrative governance layers.

Water rights (allocation and entitlements administered by the state) are not WSAs. Federal projects are able to operate in a particular state due to the water rights allocated by the state. Therefore water rights, the political common point in state water law, Reclamation projects and Districts, may provide the necessary mechanisms to transfer water in and out of project boundaries. The major obstacle is that water is tied to the land in Reclamation projects (as is the case for water law in the State of Wyoming). The *Principles Governing Voluntary Water Transactions that Involve or Affect Facilities Owned or Operated by the Department of the Interior* support water transfers and “conversions of project water in accordance with state and federal law from existing to new users and/or uses” (DOI, 1988, 1; DOI, 2001; NRC, 1992).

In the boundary typology, hydrologic and hydrographic governance layers fall under physical boundaries. However, during the interviews, farmers spoke about two different types of water: surface water and ground water. More importantly, they spoke of different types of ground and surface water having to do with return flows, drainage flows, storage (infrastructure), and salinity and selenium (water quality). Instead of using the hydrographic and hydrologic codes, each of these water aspects were coded as either surface or ground water. In cases where farmers talked about conjunctive management, both surface and ground water were coded. In the case of salinity and selenium where water quality was an issue, neither ground nor surface water was coded. They were coded under the environmental governance layer instead, as many interviewees referred to water quality as an environmental problem, referring to environmental programs, regulations and standards. In all instances where a specific river or tributary was mentioned, surface water was coded, and likewise where an aquifer was mentioned, ground water was coded.

There is a significant difference between ground water use in the Upper and Lower Basin, where the Lower Basin is more dependent on groundwater. However, results indicate that 85% of the water used in Reclamation projects is surface water[2]. The final anomaly with physical boundaries was that of time which was not captured by the boundary typology. The boundary typology recognized temporal governance layers in the form of water rights. However, the farmers spoke of other temporal issues such as those at the field scale where season impacts crops planted and number of plantings. In light of these interviews, the boundary typology is

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[2] Most of the groundwater used in Central Arizona is independent of Reclamation projects, however conjunctive water management, the co-management of surface and groundwater supplies, is common in the management of Colorado River water throughout the Lower Basin.

useful to better understand differences and similarities between locations throughout the Basin but should be adjusted to include ground and surface water as well as pecuniary boundaries.

Nuances for political boundaries also ensued for circumstances in which the interviewee referred to contracts, diversions, storage and transfers. Administrative boundaries accounted for water rights administration at the state level. Originally contracts were considered administrative, however it was not always clear from the interviewees if contracts were administrative and operational. Therefore, contracts were coded as arrangements and at the local and federal scales. Diversions are also political but it was not always clear what type of political boundary applied (administrative, judicial, statutory, or temporal) as diversions often were a result of an arrangement. Storage is also political; specifically in which a Reclamation project is a result of an Act passed by Congress and considered a statutory boundary. Unless specified, it was not safe to assume that storage referred to a Reclamation project (many storage units are locally and state funded) and was not coded as a sub-type of a political boundary. But if the storage in question refers to a water right, all water rights were coded as state or tribe, administrative and/or temporal, and surface water.

There were minimal distinctions within sectoral boundaries of the boundary typology. In the interviews, consumptive use appeared regularly as a common theme. Although consumptive use may refer to any one of the sectors, it was coded under the agricultural sub-type. Farmers generally described consumptive use of Ag water as a matter of water rights, conservation and efficiency, and general field management practices. Like the salinity and selenium matter, responses that referred to endangered species and native fish were coded as environmental, one of five governance layers under sectoral boundaries.

Discussion

Four geographic dimensions emerged from the interviews, which can be understood in terms of geographic perspectives and include scale, time, place and space. First, scale has an essential role in determining boundaries, especially in deciphering the extent in area and constituents to which a water sharing arrangement has impact. Second, scale points to patterns of nested hierarchy which helps identify those groups who are not present or who have limited presence. For Reclamation projects, from farmers' perspectives it is imperative that the federal (USBR), state, local (irrigation districts), and individual scales be considered equally (McCool, 1987; Sax, 1968) when it comes to water sharing opportunities. In reviewing WSAs at different scales, opportunities also exist at the intertribal, tribal, and international scales. Scale also impacts place. The location of each Reclamation projects will dictate what types of arrangements occur and with whom they transpire as it relates to the Upper and Lower Basins and between the two, at an interstate or intrastate level, and an intra- and intertribal scale. In order to capture all water sharing interactions, the boundary analysis indicates new scales that occur across and between cultures, or cultural scales.

Although it is not a big surprise that agriculture has a much higher presence than any other sector due to the nature of the interviews and expertise of the participants, water sharing arrangements between agriculture and the environmental and municipal sectors were very close in occurrence and significantly higher than industry (Figure 4.f). In the interviews conducted, there was not one reference to a WSA with the recreation sector in any state; however, this can be attributable to the fact that the recreation sector benefits from water shared with the environmental sector. Conversations about WSAs were evenly distributed among most of the states where interviews were conducted, except for Utah (Figure 4.g). These results may be attributed to the singular interview that was coded as a Reclamation project.

There are differences in references to the environment, industry, municipal, recreation, and even agriculture sectors for Reclamation projects in Arizona, California, and Colorado (Figure 4.h). Colorado referenced each sector more than any other state, except for industry, which showed only slightly higher results than recreation. Again, agriculture is expected to have higher incidence since we were talking to farmers. Reference to water sharing in a positive or negative light could suggest that farmers in Colorado are more likely to consider cooperation with other sectors, simply because they speak of water sharing much more frequently.

The agri-cultural geographic perspective helped illuminate the importance of place, space, time, and scale for farmers in the CRB. These perspectives were captured through the boundary typology and through the ability to link boundary information to geospatial data. However, new boundaries emerged that are not as easily mapped, such as pecuniary boundaries. Future research warrants the necessity to conduct a geographic study on pecuniary boundaries. Additional boundary themes arose, specifically those that pertain to fallowing, conservation, and efficiency; however more research must be conducted to warrant an addition to the boundary typology. There are three purposes of irrigation water conservation: economic efficiency of water allocation, improving environmental quality of western river systems, and satisfying outstanding Native American claims (Moore, 1991). Future transboundary research questions will address how water management at the field and local scales can be geospatially characterized. What types of boundaries do conservation practices represent? For the purposes of this study, conservation practices were coded under the agricultural sector.

The boundary typology generally represented the concerns, issues, opportunities, and barriers presented by the interviewees, especially in the case of sectoral boundaries. Sectoral boundaries are formed by the social and cultural norms, practices, and lifestyles of the rural agricultural West. These are the boundaries that were the easiest to identify, yet the most challenging to map, as they are more than just jurisdictions. Limitations to geospatial data are that they portray only one perspective of the social and cultural boundaries so important to the landscape. Recommendations for future research would suggest further analysis and refinement of cultural and social boundaries through satellite imagery such as those used in Israel to show the movement of new Jewish settlements in Palestinian territory (OCHA, 2007). In addition, further refinement of the boundary typology as a methodology to understand governance is necessary, specifically pertaining to political and physical boundaries.

Maps were essential to the larger goals of the interview process in three ways. The first is that *maps connected the interviewer with the interviewee*. Because interviews were conducted over the telephone and many of the interviewees were located in different states and within state but hundreds of miles away, maps provided the interviewer and interviewee a common point of reference[3]. The second is that *maps connected interviewees*. Although the interviews were confidential and were conducted individually, the interviewers were able to connect interviewees by exploring scenarios that may have been prevalent upstream and/or downstream (geographic reference), providing a basis for commonalities and/or differences between water users and their circumstances (lack of and/or prevalence of cooperation). This will support further analysis of

[3] Only the interviewers were looking at maps. In most cases, the interviewee explained and described point of importance and locations which the interviewers located and then verified. This process brought the interviewers and interviewees closer together through common understanding. In addition, some interviewees expressed their delight that the interviewers were so interested in the geography of their locales.

the interviews and help identify hotspots for future research. And finally, *maps connected interviewers*. As maps provided much of the baseline information for the state and for the interviewee in that state, geographic information was a key discussion point before and after the interview. Because of maps, we have a better sense of space that is occupied by the informants *and* their perception of that space.

Conclusion

At the turn of the 20th Century, the USBR offered water security to people who were migrating to the West, primarily for the reclamation of lands for agriculture. Coupled with early development efforts to put public water resources to beneficial use, irrigation districts became powerful entities. The power that has been vested to them by the state and federal government have further enhanced institutional strength, freedom from state and federal regulation, and protection by the state and federal government ensuring water delivery within broadly defined criteria such as amount of land irrigated, historical beneficial use, and status within prior appropriation (Leshy, 1982). At the time, agricultural interests created a powerful political constituency that used as much as 90% of the available water. Especially today, irrigation districts responsible for supplying water for agriculture across the Basin are positioned as central actors in water supply and demand in the CRB.

Since 1902, the USBR has become the largest wholesaler of water and second largest producer of hydroelectric power in the nation (USBR, 2013), a byproduct of the original mission. They deliver water to more than 31 million people, and provide one out of five western farmers (140,000) with irrigation water for 10 million acres of farmland that produce 60% of the nation's vegetables and 25% of its fruits and nuts (Moore, 1991). It is projected that in 2015 the population of the hydrologic basin that encompasses the Colorado River and the adjacent areas that receive Colorado River water will increase to almost 40 million people and will irrigate nearly 5.5 million acres of land (USBR, 2012). Increasing multiple demands on water in the Basin today and increases in population as well as changes in climate (resulting in higher temperatures) and federal law (leaning towards WSAs) have necessitated a change in the way water is managed. USBR became the entity that served the farmers' economic backbone for years to come by building projects and subsidizing water for farming and ranching through contracts. However, it is precisely because of dams and agreements like the Mexico Water Treaty, the U.S. and Mexico have been able to maintain transboundary relationships. The presence of dams has actually disintegrated rigid boundaries, enabling water sharing and the ability to move stored water through diversions to places, spaces and people in need in times of uncertainty.

Visible or not, boundaries reveal stories about people and their movement, development and inhabitation of a place. Hydrologic boundaries tell the story of geologic processes of uplift, erosion and climate. Political and hydrologic boundaries form regions that have shaped the CRB defining water development, such as those described and proposed by Powell and other early explorers. Political, cultural, physical, and social boundaries have redesigned the waterscape where complex natural freshwater systems have been modified by the infrastructure associated with Ag water management, such as canals, reservoirs and pumping stations that make up water delivery systems. For farmers in the CRB, most of the west and in arid and semi-arid environments all over the world, agriculture will be dependent upon water sharing to survive.

Tables & Figures

Table 4.a: Bureau of Reclamation Acts of Congress. Reclamation acts and amendments that reinforce the USBR-farmer relationship under Reclamation Law.

Year	Act/Amendment	Description
1902	Reclamation Act	Established the "reclamation fund" to be used in the examination and survey and the construction and maintenance of irrigation works for storage, diversion, and development of water for the reclamation of arid and semi-arid lands*
1906	Town Sites and Power Development	Congress authorized the sale of surplus power from water projects to towns and the crediting of the sale revenues to the repayment of irrigation costs
1910	Advances to Reclamation Fund and Requirement of Presidential Approval	Congress directed the U.S. Treasury to loan up to $20 million to the fund to finance completion of the construction of water projects
1914	Reclamation Extension Act	Congress extended the repayment period of water projects from 10 to 20 years
1922	Irrigation Districts Act	Congress authorized Secretary of the Interior to contract with irrigation districts in place of individual water users to recover the annual charges of joint liability
1926	Omnibus Adjustment Act	Congress further extended the repayment period for all water projects from 20 to 40 years and relieved some irrigators of parts of their repayment obligations due to nonproductive lands
1939	Reclamation Project Act of 1939	Projects could be authorized for multiple purposes, more local in scope and the construction costs would be allocated among the projects' various purposes: irrigation, municipal and industrial water supply, hydroelectric power generation, flood control, and navigation
1982	Reclamation Reform Act	Congress increased the number of acres that an individual or legal entity, such as a partnership or corporation, could irrigate with water from federal projects from 160 acres to 960 owned or leased acres

*From all money received from the sale and disposal of public lands in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming

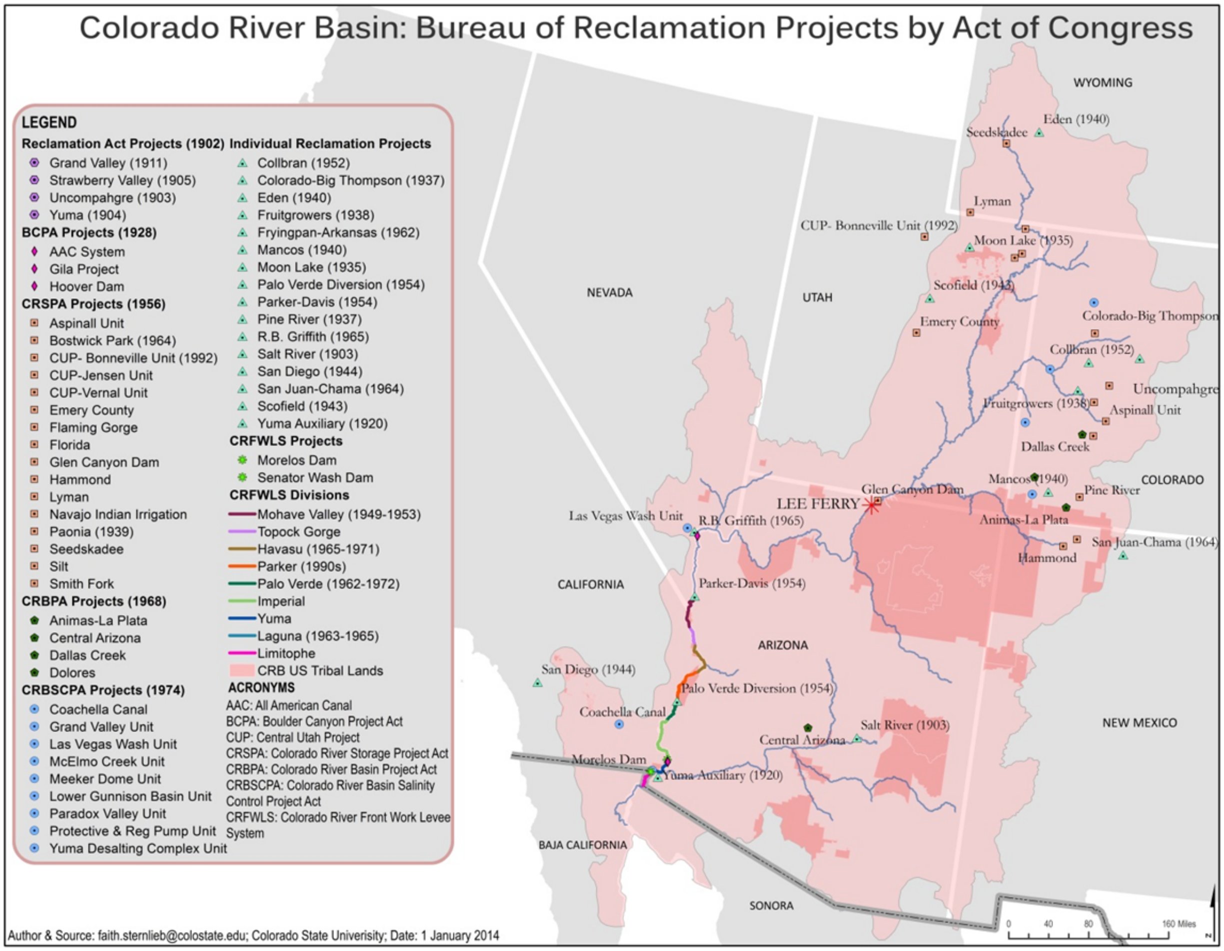


Figure 4.a: Distribution of Bureau of Reclamation Projects and Policies across the Colorado River Basin.

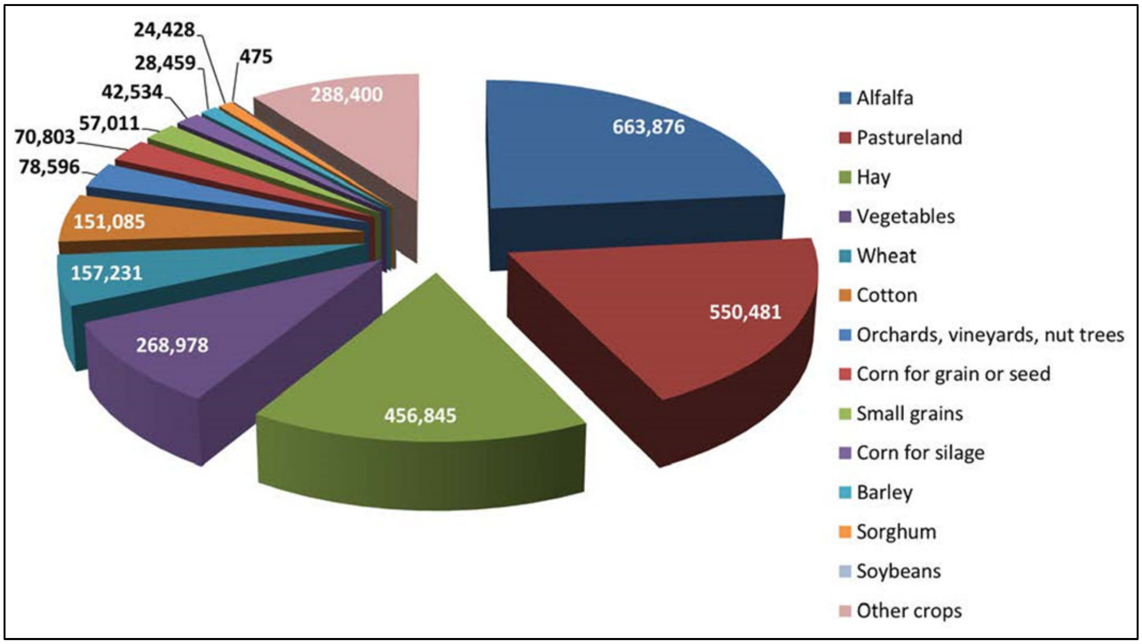
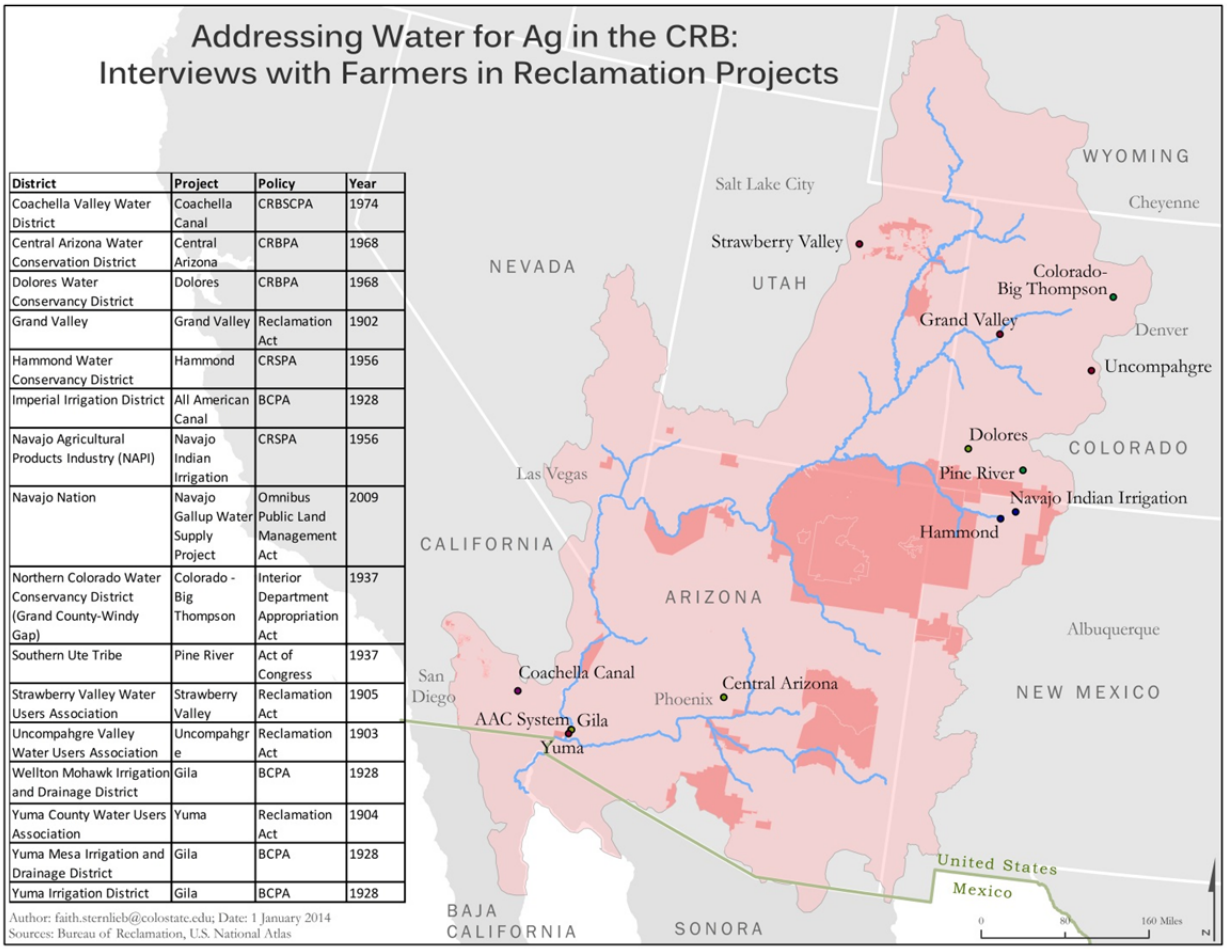


Figure 4.b: Crop Distribution across the Colorado River Basin in Irrigated Acreage based on USDA-NASS, Census of Agriculture, 2007 (Kallenberger 2013, p.5).



District	Project	Policy	Year
Coachella Valley Water District	Coachella Canal	CRBSCPA	1974
Central Arizona Water Conservation District	Central Arizona	CRBPA	1968
Dolores Water Conservancy District	Dolores	CRBPA	1968
Grand Valley	Grand Valley	Reclamation Act	1902
Hammond Water Conservancy District	Hammond	CRSPA	1956
Imperial Irrigation District	All American Canal	BCPA	1928
Navajo Agricultural Products Industry (NAPI)	Navajo Indian Irrigation	CRSPA	1956
Navajo Nation	Navajo Gallup Water Supply Project	Omnibus Public Land Management Act	2009
Northern Colorado Water Conservancy District (Grand County-Windy Gap)	Colorado - Big Thompson	Interior Department Appropriation Act	1937
Southern Ute Tribe	Pine River	Act of Congress	1937
Strawberry Valley Water Users Association	Strawberry Valley	Reclamation Act	1905
Uncompahgre Valley Water Users Association	Uncompahgre	Reclamation Act	1903
Wellton Mohawk Irrigation and Drainage District	Gila	BCPA	1928
Yuma County Water Users Association	Yuma	Reclamation Act	1904
Yuma Mesa Irrigation and Drainage District	Gila	BCPA	1928
Yuma Irrigation District	Gila	BCPA	1928

Figure 4.c: Interview Locations*, Irrigation Districts and Bureau of Reclamation Projects Across the Colorado River Basin. Policies include: Reclamation Act of 1902, Boulder Canyon Act of 1928 (BCPA), Colorado River Storage Project Act of 1956 (CRSPA), Colorado River Basin Project Act of 1968 (CRBPA), and the Colorado River Basin Salinity Control Project Act of 1974 (CRBSCPA).

*In many locations, more than one interview was conducted. The map only shows CRBSCPA projects which are under the authority of the Bureau of Reclamation. It does not include projects under the authority of the U.S. Department of Agriculture Colorado River Basin Salinity Control Program.

Table 4.b: Interviews and Reclamation Projects per State. Total Reclamation projects, Ag water projects, interviews, project interviews and coverage of projects through interviews per state.

State	Total USBR Projects	Ag Water Projects	Total Interviews	Project Interviews	Project Coverage
Arizona	11	4	12	5	3
California	4	3	8	6	2
Colorado	25*	25	16	5	5
Nevada	1	0	3	0	0
New Mexico	5*	5	6	3	3
Utah	7	7	10	1	1
Wyoming	2	0	5	0	0
TOTAL	55**	44	60	20	14

*There are three tribal projects in the CRB, two in New Mexico, the Navajo Indian Irrigation Project and the Navajo Gallup Water Supply Project, and one in Colorado, the Pine River Project of the Southern Ute Tribe. Although the Dolores Project is not considered a tribal project, it survived the federal cuts of the Carter administration because it served Indian lands of the Ute Mountain Ute Tribe in southern Colorado. Interviews for all three tribal projects are included in the Project Interviews column.

**This number may change depending on whether some projects are counted as one unit or individually.

Table 4.c: Boundary Typology Including Governance Layers and Description.

Boundary Type	Governance Layer	Description
Physical	Hydrologic	Based on natural drainage systems defined by the National Hydrology Dataset (USGS)
	Hydrographic	Based on drainage basin delineated by each state and tribe
Political	Statutory	Based on federal, state and tribal laws and policies
	Judicial	Based on US Federal/State, District and Appellate Court system
	Administrative	Rules and regulations based on governmental jurisdictions (federal, state, tribe, county, municipality, city)
	Temporal	Based on time/history largely due to sequential legal and political decisions
Sectoral	Agricultural	Based on special social and political interests and supported by organizations' bylaws and occasionally reinforced by state statute
	Environmental	
	Municipal	
	Industrial	
	Recreational	

Table 4.d: Criteria Used for Coding New Boundaries.

Arrangements	Geographic References (Place)	Pecuniary
Agreements	Valleys	Assessment
Transfers	Towns and cities	Payment
Diversions	Mountain Ranges	Costs
Contracts	Areas in a central location	Funds
Treaties	Direction, lengths and distances between two places	Sell, lease, purchase, charge
Settlement		Accounting
Water Banks		Price
		Credits
		Fee

Table 4.e: Coding Schematic Cross-referencing the Boundary Typology with Water Sharing Arrangements (WSAs), Place (geographic reference), and Scale. The governance layers under physical boundaries are ground and surface water; under political boundaries are administrative, judicial, statutory and temporal; under sectoral boundaries are agricultural, environmental, municipal, industrial, and recreation; pecuniary boundaries are a singular category.

Boundary Type	**Governance Layer**	**WSAs**	**Scale**	**Place**
Physical	Surface Water			
	Ground Water			
Political	Statutory			
	Judicial			
	Administrative			
	Temporal			
Sectoral	Agricultural			
	Environmental			
	Municipal			
	Industrial			
	Recreational			

Table 4.f: Interviews on Water Sharing within Reclamation Projects According to the Boundaries Typology. The interview quotes below are examples of responses from interviews regarding barriers and opportunities for water sharing arrangements for each of the boundaries and corresponding governance layers consistent with the boundary typology. Coded words are in bold-face.

Boundary Type	**Governance Layer**	**Interview Quotes**
Physical	Ground water	"We've identified an amount of water we'd like to acquire for **groundwater replenishment**. It might come from various sources, including Colorado River if anybody interested in talking." (Arizona)
	Surface Water	"There used to be big **flushing flows** because they didn't have a **storage system**. Now they have perennial flows and there are **small pools** which created barriers to some of the **tributaries** flowing into the **reservoir**." (Colorado)
Political	Administrative	"State Engineer doesn't recognize **water banking**. **Bank water** within the districts. [Our] attorney set up **water bank** . . . [You] have to sign a lease/form and the [manager] maintains/**administers the bank**. People give up their water rights and that water goes into the **water bank** so they can keep track of the water they have. [You can] lease water or put **water in the bank** from 1-5 years." (New Mexico)
	Judicial	*
	Statutory	The Indian Settlement agreed to in 1986, signed off in 1988 was handed off. Reclamation project was originally on the **Carter Hit list** but went through because it was opportunity to work on Indian water rights." (Colorado)
	Temporal	"They would like to have more water but they are dealing with **Colorado Water Law**. They have to put water to beneficial use. Irrigators understand if they mess around with **CO water law** they will lose. They are trying to protect the historic uses and the economy." (Colorado)
Sectoral	Agricultural	"Earlier, a water bank. Could trade, allocate between **fields**. Apportion water between **fields**." (California)
	Environmental	"**Endangered fish** agreement – **endangered fish water** will be perpetual regardless of the **fish**. It is all about tradeoffs and forming relationships." (Colorado)
	Municipal	"In the permanent-water dedication agreement, a farmer signs over [their] voting rights. The canal company delivers it to the **city**, then to the **city use**. Most of the water dedication agreement is undeveloped land." (Utah)

	Industrial	"In a Section 5 contract with the Bureau, if they want to change water use from ag to **M&I** they have created a process. **M&I** is worth more and should get more money for that water. They are talking about transfers both in and out of the district." (Arizona)
	Recreational	*
Pecuniary		"Tribes receiving **economic gain** by allowing use by others, for instance. Voluntary water transfers, for instance, could enhance instream flow on a Colorado River Basin level." (Tribal)

*There were no specific quotes from interviews that represented these boundaries and governance layers.

Table 4.g: Interviews on Water Sharing between Reclamation projects and other Enterprises According to the Boundaries Typology. Examples of responses from interviews regarding out-of-district barriers and opportunities for water sharing arrangements for each of the boundaries and corresponding governance layers consistent with the boundary typology.

Boundary Type	**Governance Layer**	**Interviews**
Physical	Ground water	"We've identified an amount of water we'd like to acquire for **ground-water replenishment**. It might come from various sources, including Colorado River if anybody is interested in talking." (Arizona)
	Surface Water	"We sent out letters to every ditch company in the SJB sent letters to all of the companies – 50 or 60 - and got less than 20 responses back. [We would] enter into a grant or cooperative agreement – automation, **lining canals**, anything that would improve efficiency systems. [We] have been relying on a pretty good **flow of water** to divert from the water will be stretched out. Everyone is going to get what they are entitled to but there won't be anything extra." (Tribal)
Political	Administrative	"there is no sharing between states with the exception of a recent development, mutual agreement and BOR caller **Intentionally Created Surplus (ICS)** – a state can use to store water in Lake Mead – sometimes the state cannot use their entire allotment – instead of losing it, they can store it in Mead and use it at another time – CA and AZ have been exercising the freedom to do that and it works really well" (Tribal)
	Judicial	"We are party to a series of agreements in 2003, Quantification Settlement Agreement (QSA). We agreed to a series of water transfers up to year 2045. The current base will be increased as a result of the QSA. Shortly after it was approved, several **lawsuits** were filed. Water agencies have faired well – some **lawsuits** have been consolidated." (California)
	Statutory	*
	Temporal	"**Junior rights** were being diverted before it got there - [Tribal] rights stored in **priority** only are available to those [tribes] who have a contract with BOR." (New Mexico)
Sectoral	Agricultural	"**Shortage sharing agreement**" (New Mexico)
	Environmental	"**Multi-species conservation** project. Some species listed in lower Colorado, we all pay into it. Gives them millions of dollars to do **habitat for species**, keeps them off their backs about return flows. Develop little backwater places, [etc.], 50 year agreement with 40 years left on it." (Arizona)

	Municipal	"Project 7 (7 different water companies) provides the **domestic water**. They fill Fairview Reservoir (state keeps track of that). Irrigation water comes from Ridgeview Reservoir. They exchange the water if the **subdivision** was built on ground that was tied to the water." (Colorado)
	Industrial	"**Gas/oil industry** has water rights and attorneys, supporting their own interests but on the same side as farmers." (New Mexico)
	Recreational	"Environmentalists will probably align themselves with state government. It doesn't matter what the priority date. [People] will still be able to **raft** and fish." (New Mexico)
Pecuniary		*

*There were no specific quotes from interviews that represented these boundaries and governance layers.

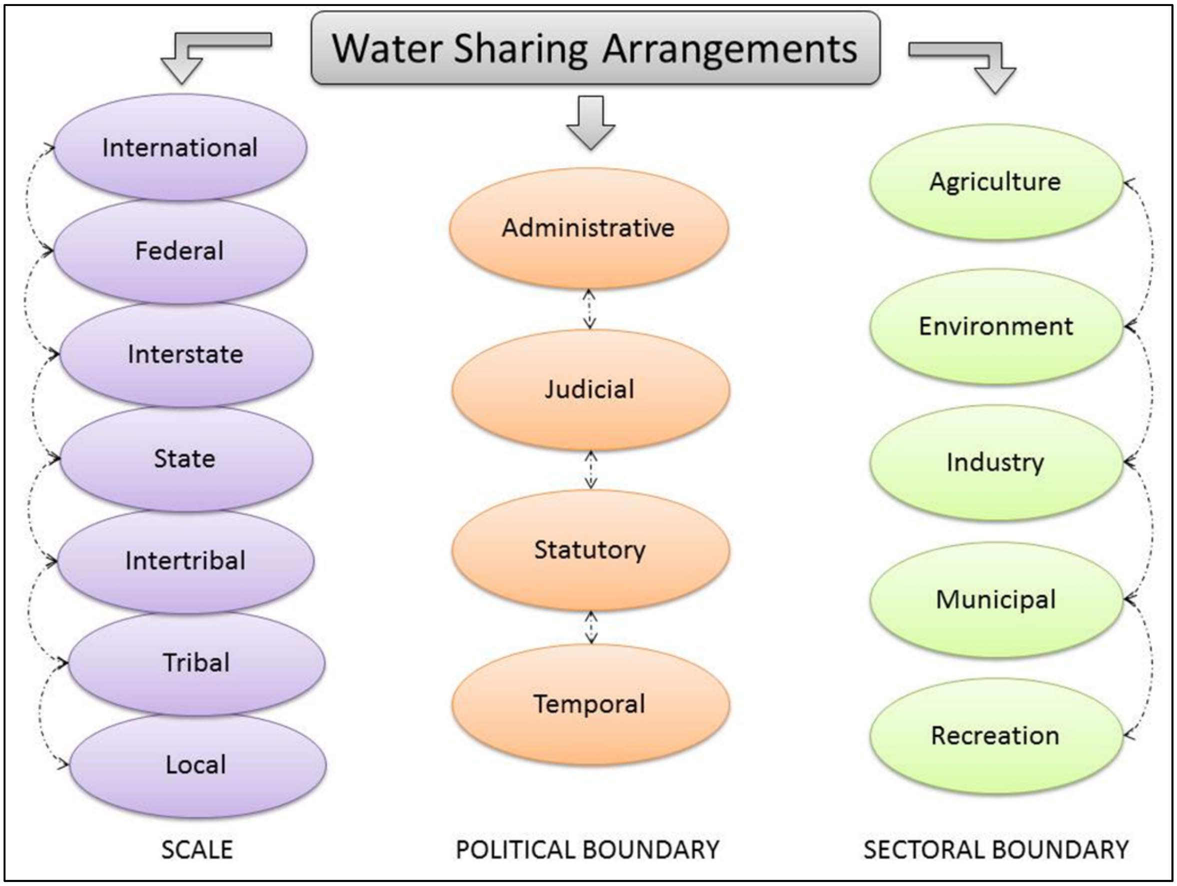


Figure 4.d: Flowchart for Coding Water Sharing Arrangements (WSAs) Based on the Boundary Typology. WSAs were coded based on scale and political and sectoral boundaries, the most prevalent and pertinent. Some WSAs were coded at multiple nodes across all three boundaries as well as within one boundary type. The dotted double arrows indicate that some boundaries are linked with others in some cases. For example, one WSA may include Ag, environment and municipal boundaries in addition to multiple scales and political boundaries.

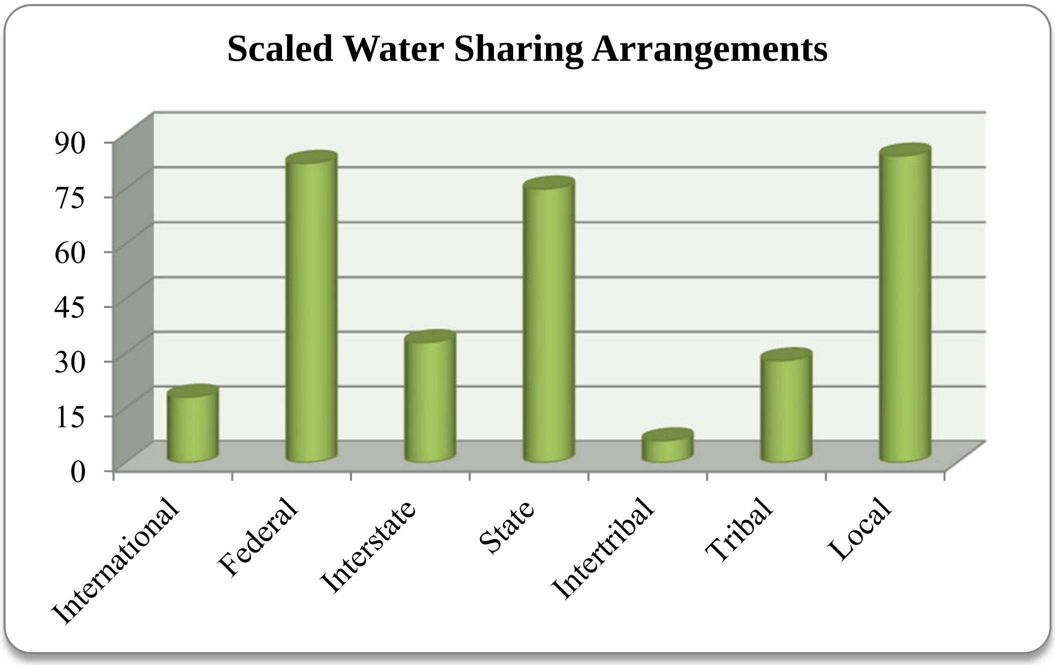


Figure 4.e: Scaled Water Sharing Arrangements for Reclamation Projects in the Colorado River Basin.

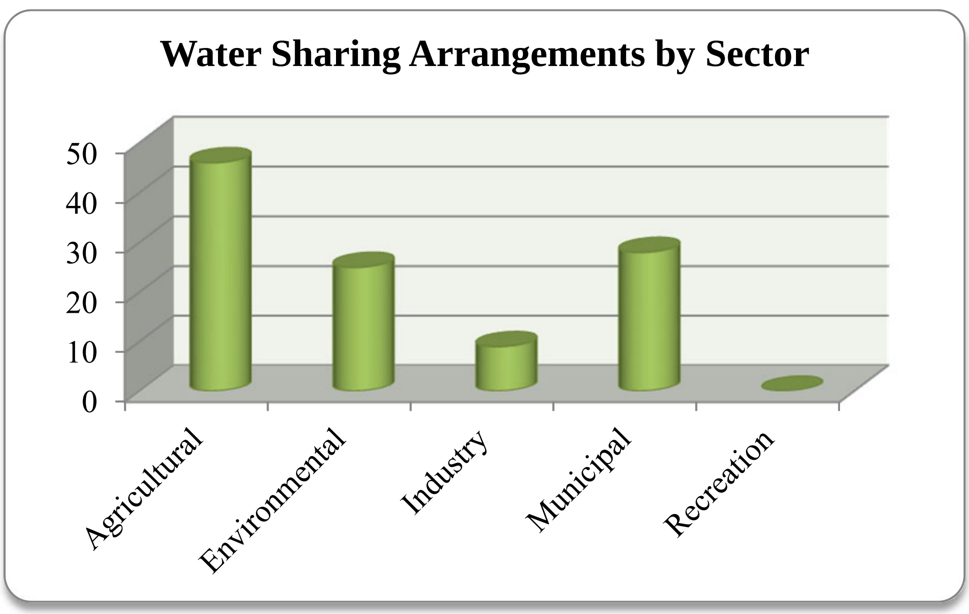


Figure 4.f: Water Sharing Arrangements by Sector for Reclamation Projects in the Colorado River Basin.

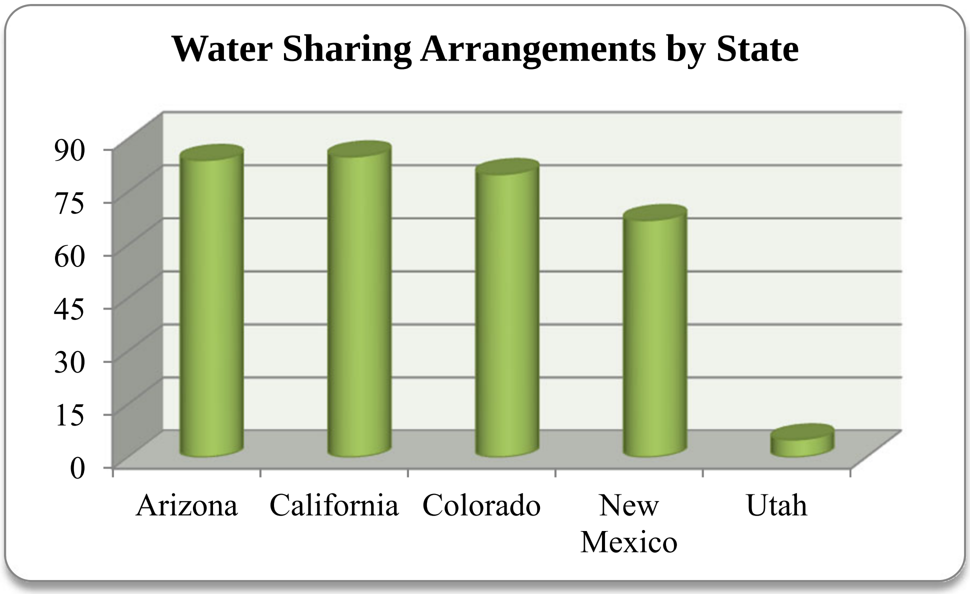


Figure 4.g: Water Sharing Arrangements by State for Reclamation Projects in the Colorado River Basin.

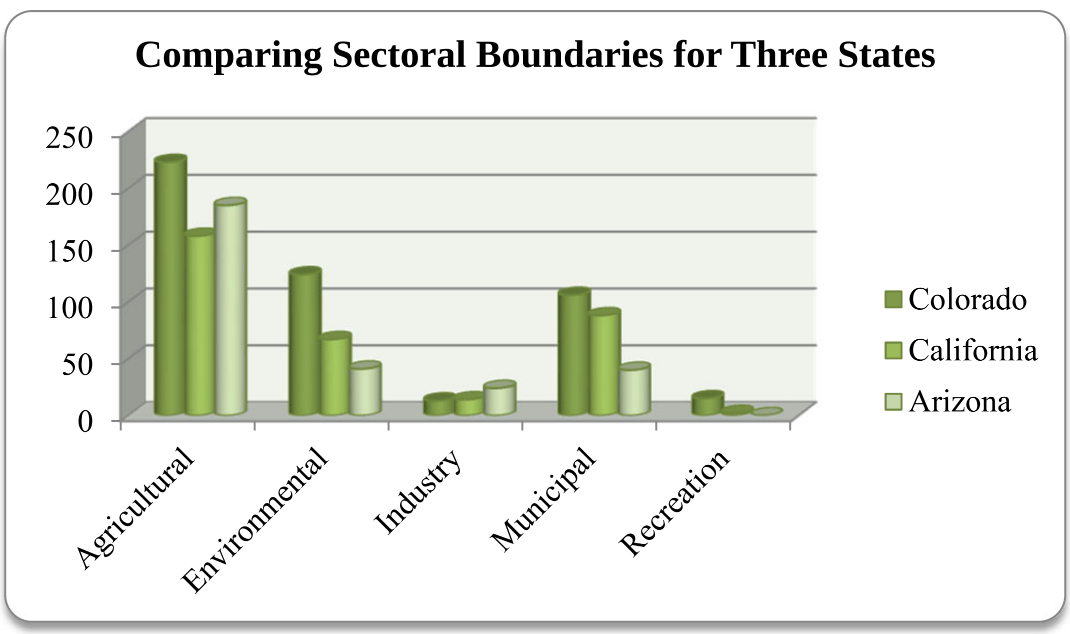


Figure 4.h: Sectors by State for Reclamation Projects in the Colorado River Basin.

REFERENCES

Bazeley, P., & Richards, L. (2000). The Nvivo Qualitative Project. Thousand Oaks, CA: Sage Publications.

Benson, R. D. (1997). Whose water is it? Private rights and public authority over Reclamation project water. *Virginia Environmental Law Journal* 16:363-427.

Bren School of Environmental Science and Management. (2014). *California Water Transfers Records*. University of California-Santa Barbara, Retrieved November 15, 2013 [cited 1 January 2014] from http://www.bren.ucsb.edu/news/water_transfers.htm.

Bretsen, S. N., & Hill, P. J. (2006). Irrigation institutions in the American West. *UCLA Journal of Environmental Law and Policy*, 25.

Bringer, J. D., Johnston, L. H., & Brackenridge, C. H. (2004). Maximizing transparency in a doctoral Thesis1: The complexities of writing about the use of QSR*NVivo within a grounded theory study. *Qualitative Research*, 4 (2), 247-265.

Candee, H. (1989). The broken promise of Reclamation reform. *The Hastings Law Journal*, 40, 657-685.

Cash, D. W., Adger, W. N., Berkes, F., Garden, P., Lebel, L., Olsson, P., Pritchard, L., & Young, O. (2006). Scale and cross-scale dynamics: Governance and information in a multilevel world. *Ecology and Society*, 11(2), 8.

Cohen, M., Christian-Smith, J. & Berggren, J. 2013. Water To Supply the Land: Irrigated Agriculture in the Colorado River Basin. Oakland, CA.

deBuys, W. (2001). *Seeing Things Whole: The Essential John Wesley Powell*: Island Press.

Delaney, D., & Leitner, H. (1997). The political construction of scale. *Political Geography*, 16(2), 93-97.

DOI. (1988). Principles Governing Voluntary Water Transactions that Involve or Affect Facilities Owned or Operated by the Department of the Interior. edited by Bureau of Reclamation. Washington, D.C.: Department of the Interior.

DOI. (2001). Voluntary Transfers of Project Water. edited by Bureau of Reclamation. Washington, D.C.: Department of the Interior.

Fischhendler, I., & Heikkila, T. 2010. Does integrated water resources management support institutional change? The case of water policy reform in Israel. *Ecology and Society*, 15(1),16.

Gregory, D., Johnston, R. Pratt, G., Watts, M. J. & Whatmore, S. eds. (2009). *The Dictionary of Human Geography*. 5th ed. Malden, MA: Wiley-Blackwell.

Griffin, R. 2012. Engaging irrigation organizations in water allocation *Natural Resources Journal* 52:277-313.

Griffin, R., and Kelly, M. (2012). The future of irrigation organizations in the Colorado River Basin. *The Water Report*, 95, 18-22.

Heikkila, T. (2004). Institutional boundaries and common-pool resource management: A comparative analysis of water management programs in California. *Journal of Policy Analysis and Management*, 23(1), 97-117.

Hobbs, F., & Stoops N. (2002). Demographic Trends in the 20th Century. In *Census 2000 Special Reports*. Washington, D.C.: US Census Bureau.

Howe, C. W. (2005). The return to the river basin: The increasing costs of "jurisdictional externalities." *Journal of Contemporary Water Research and Education*, (131), 26-32.

Howitt, R. (2003). Scale. In *A Companion to Political Geography*, edited by J. Agnew, K. Mitchell and G. Toal. Malden: Blackwell Publishing.

Kallenberger, J. (2013). Understanding Beliefs and Preferences of Irrigators Towards the Use and Management of Agricultural Water in the Colorado River Basin, Human Dimensions of Natural Resources, Colorado State University, Fort Collins, CO.

Leshy, J. D. (1982). Irrigation districts in a changing west: An overview. *Arizona State Law Journal*, 345, 345-376.

Mackun, P., Wilson, S., Fischetti, T., & Goworowska, J. (2011). Population Distribution and Change: 2000-2010. In *2010 Census Briefs*. Washington, D.C.: US Census Bureau.

Marston, S. A. (2000). The social construction of scale. *Progress in Human Geography*, 24(2), 219-242.

Marston, S. A., Jones, J. P., & Woodward, K. (2005). Human geography without scale. *Transactions of the Institute of British Geographers*, 30(4), 416-432.

McCool, D. (1987). Command of the waters: Iron triangles, federal water development and Indian water. Berkeley: University of California Press.

Mead, E. (1903). *Irrigation institutions: A discussion of the economic and legal questions created by growth of irrigated agriculture in the West*. New York: The Macmillan Company.

Moore, M. R. (1991). The Bureau of Reclamation's new mandate for irrigation water conservation: purpose and policy alternatives. *Water Resources Research*, 27(2), 145-155.

Mulroy, P. (2008). Climate change and the Law of the River: A Southern Nevada Perspective. *West Northwest Journal of Environmental Law & Policy* ,14(2).

NRC. (1992). Water transfers in the West: Efficiency, equity, and the environment. Washington, D.C.: National Academy Press.

OCHA, Office for the Coordination of Humanitarian Affairs. (2007). The Humanitarian Impact on Palestinians of the Israeli Settlements and Other Infrastructure in the West Bank. United Nations.

Oxford English Dictionary. (2013). *Definition of Settlement*. Oxford University Press. Retrieved December 25, 2013 from http://www.oxforddictionaries.com/us/definition/american_english/settlement.

Pellow, D. (1996). *Setting boundaries the anthropology of spatial and social organization*. Westport, Conn.: Bergin & Garvey.

Powell, J. W. (1891). Eleventh Annual Report of the U. S. Geological Survey, 1889-1890: Part II-Irrigation. In *Annual Reports to the Secretary of the Interior*. Washington, D.C.: U.S. Geological Survey.

Pritchett, J. (2011). Quantification Task: A Description of Agriculture Production and Water Transfers in the Colorado River Basin. Fort Collins, CO: Colorado State University.

Rowley, W. D. (2006). *The Bureau of Reclamation: Origins and Growth to 1945*. Vol. 1. Denver, CO: U.S. Department of the Interior, Bureau of Reclamation.

Saliba, B. C., & Bush, D. B. (1987). *Water Markets in Theory and Practice: Market Transfers, Water Values and Public Policy*. Edited by C. W. Howe. Vol. 12, *Studies in water Policy and Management*. Boulder, CO: Westview Press.

Sauer, C. O. 1963 [1925]. Land and Life: A selection from the writings of Carl Ortwin Sauer, edited by J. B. Leighly. Berkeley, CA: University of California Press.

Sax, J. L. (1968). Water law, planning and policy: Cases and materials. Indianapolis, IN: Bobbs-Merrill.

Schorr, D. (2012). The Colorado doctrine: Water rights, corporations, and distributive justice on the American frontier. New Haven, CT: Yale University Press.

Seaber, P.R., Kapinos, F.P., & Knapp. G.L. (1987). Hydrologic Unit Maps. In *U.S. Geologic Survey Water Supply Paper*: U.S. Department of the Interior, U.S. Geological Survey.

Siccama, C. J., & Penna, S. 2006. Enhancing validity of a qualitative dissertation research by using NVivo. *Qualitative Research Journal*, 8(2), 91-103.

Sternlieb, F., Bixler R.P., Huber-Stearns, H., & Huasca, C. (2013). A question of fit: Reflections on boundaries, organizations and social-ecological systems. *Journal of Environmental Management*, 130, 117-125.

Sternlieb, F., & Laituri, M. (2012). Mapping agricultural water governance in the Colorado River Basin. *Colorado Water*, 8-10.

Taylor, S., & Spicer, A. (2007). Time for space: A narrative review of research on organizational spaces. *International Journal of Management Reviews*, 9(4), 325-346.

USBR. (2012). Colorado River Basin Water Supply and Demand Study: Study Report. In *Reclamation: Managing Water in the West*. Boulder City, NV: Bureau of Reclamation, Department of the Interior.

USBR. (2013). *Colorado River Basin Water Supply and Demand Study*. U.S. Department of the Interior Retrieved October 17, 2013 from http://www.usbr.gov/lc/region/programs/crbstudy.html.

Wahl, R. W. (1989). Markets for federal water: Subsidies, property rights, and the Bureau of Reclamation. Washington, D.C.: Resources for the Future.

Wilkinson, C. F. (1992). Crossing the Next Meridian: Land, Water and the Future of the West. Washington, D.C.: Island Press.

Worster, D. (1985). Rivers of empire: water, aridity, and the growth of the American West. 1st ed. New York: Pantheon Books.

APPENDIX 4-I: INTERVIEW GUIDE FOR ADDRESSING AGRICULTURAL WATER IN THE COLORADO RIVER BASIN PROJECT

1. First, we would like to talk to you a bit about your own agricultural operations. Can you describe to us what kind of farming or ranching you do and how you get the water you need for your activities?

A. What crops/animals and other products do you produce?
B. To what extent do you irrigate? Where (and from whom) does your water come from?
C. How long have you been farming/ranching in this area?

2. On the basis of your experience, what would you say are the most important changes that have occurred in recent years or are now occurring in farming and ranching in your area? Do those changes have implications for how you use water?

A. What changes have you seen or are seeing in your production operations and where have those changes occurred? (market conditions, profitability issues, land values, other)
B. Would you say that your agricultural water is under pressure? What are these pressures and where are they coming from?
C. Have you seen important demographic changes in your area, with new kinds of people moving in?
D. Do these new groups have an impact on how you operate your farm/ranch and how you use your water?
E. Would you say that there have been important cultural changes in your area that affect how you operate your farm/ranch and how you use your water?

3. To what extent have you or other farmers in your area been able to organize and cooperate with each other to deal with the changes we've been talking about?

A. Are you active in your local irrigation district/ditch?
B. Do you know if your irrigation district/ditch company has been active in helping farmers/ranchers do with the changes we’ve been talking about? What strategies have they been pursuing?
C. How successful have farmers/ranchers been in working together cooperatively with each other to deal with important changes in agriculture in your area?
D. What challenges have farmers and ranchers faced in working cooperatively with each other? What brings people to the table and what keeps them away? (Upper and Lower basin, Colorado West Slope/Colorado Front Range; Junior/Senior water rights holders; groundwater/surface water users; different production strategies; full-time/part-time etc.)

E. At what level or scale do you think such cooperation might be most appropriate? (District, ditch, lateral, sub-basin, basin, statewide?)
F. Do you see any opportunities for cooperation among agricultural producers that aren't really being used much yet?

4. To what extent have you or other farmers in your area been able to organize and cooperate with other groups, such as urban, environmental, recreational and others, to deal with these changes?

A. Have there been efforts in your area to sell, exchange, lease, or share water between agriculture/ranching and other groups, such as urban utilities, environmental or recreation groups? Who have you cooperated with (what groups or government entities have you worked with or hope to work with in the future? From your perspective, how have those efforts worked out?
B. Have there been any efforts in your area to coordinate water management cooperatively with other water user groups? From your perspective, how have those efforts worked out?
C. From your perspective, to what extent do you think effective cooperation between agriculture and other water user groups can be successful? What might be the most important barriers to such cooperation, or reasons why it's hard for such cooperation to be successful? What brings people to the table and what keeps them away?
D. At what level or scale do you think such cooperation might be best appropriate? (District, ditch, lateral, sub-basin, basin, statewide?)
E. Do you see any opportunities for cooperation across different sectors that aren’t really being used yet?

5. How do you see the future of your own farm operation and agriculture more generally in your area, especially with respect to water?

A. Do you feel that your production operation is likely to change, either for better or for worse?
B. Do you or your children plan to continue your farming in future or do you think that you may want to retire and do something else?
C. Do you think how you are able to use water in your production operation is likely to change in the future?
D. What does the future hold, from your perspective, for agriculture and water more generally in your area?
E. Are you optimistic about the future, or pessimistic? How do you see the future?

6. Given the kinds of agricultural and water issues we've been talking about, what needs to happen, in your view, to make it possible for farmers and ranchers in your area to make the decisions related to water that are best for their farms and for their communities?

A. Would you say that certain things need to happen to help farmers/ranchers stay in agriculture?
B. Would you say that farmers/ranchers need to be able to sell their land and operations for a fair price, if they choose to leave farming/ranching?
C. What kinds of policy or legal, and/or administrative support are needed for farmers/ranchers?
D. What kinds of changes might be necessary in how water is handled to support farmers/ranchers appropriately?

7. On the basis of your experience, how might land-grant universities such as [fill in participating state land-grant institution] be supportive of farmers and ranchers and their water-related needs in your area?

A. What kinds of research, education and/or outreach might be most helpful to you and other farmers/ranchers in your area?
B. Are there pilot activities or experimentation that you think universities might carry out that would be helpful to you and other farmers/ranchers?
C. Could land grant universities provide education and training that would be useful to you and other farmers/ranchers?
D. Do you think land-grant universities could be a place where different agricultural water stakeholders might come together to discuss issues that both unite and separate them?
E. Have there been any land-grant University activities in your past experience that have been particularly interesting and helpful? For example?

8. Before we close, I would like to do a couple more things. One is to ask you if you have any questions to ask us. The second is to see if any of my colleagues here have any questions for you. And third, if we realize later that we forgot to ask you something, do you mind if we call back for a brief follow up?

CHAPTER 5 CONCLUSION

Contributions & Reflections

My scholarly and applied contributions from this dissertation are three-fold. They include an extensive exploration of the role of boundaries, both *fiat* and *bonafied*; leading to a deeper understanding of the machinations of not just environmental governance but of water sharing within an agricultural water governance context; and a new data set for federal, state, and local water managers in the Colorado River Basin. The literature review I conducted on boundaries and boundary studies opened a world of theoretical and practical possibilities for research. The boundary trajectory has revealed many of the anomalies and contradictions about the disciplines to which it is applied. Boundaries are a phenomenon because they are both tangible and intangible. The social, political, and cultural boundaries are those that are not obvious and therefore intangible unless observed through a very watchful eye. They move and fluctuate slowly over time through movement of people and their rules and policies, often times resulting from changes in the environment. It is only when the impact of these changes transforms the landscape that we are aware and fear the loss of a culture or a language on a grand scale. In the U.S. West, this has been a recurring issue. On a large scale, the "Old" West is one such example. It is an example of landscape change and the loss of a way of life, a culture, and a lifestyle. Today the ranchers, the farmers and those who have chosen rural lifestyle, one that is dependent on agriculture is slowly dying (Eichenberg, 2008).

Today in the CRB this is very much the case. Drought is nipping at the heels of municipal, agricultural, recreational, and industrial water managers across the Basin. The tangible boundaries, physical boundaries that are visible to the naked eye, are easier to locate, understand, and measure making data collection and analysis a much more manageable task.

Once there were reports that agriculture was using up to 90% of water in the Basin. Today agricultural water use is estimated at 75% (USBR, 2012). More and more land is being fallowed as indicated by farmers through interviews. Exchanges and sales of water rights are gravitating from agriculture to municipal and industrial use. On a local, state and federal scale, more people and higher uncertainty in water supply mean increased demand and less available water in the river system. Some districts are barely able to deliver the amount of water for farmers to make it through an entire planting season (personal communication). Conditions such as these indicate loss, both physical and social. The key is to tie these changes to the landscape and one way to do that is through a better understanding of boundaries.

Boundaries link the geography and governance literature, particularly governance of water resources, while the boundary typology provides the tool to systematically analyze the union between both. The union and/or division between disciplines is in itself a boundary, one that has been acknowledged and practiced by many inter- and transdisciplinary academic communities, including the scholars of ecosystem services (Hartig & Drechsler, 2010; López-Hoffman, Varady, Flessa, & Balvanera, 2010), social-ecological systems (Berkes, Colding, & Folke, 2003; Young et al., 2006), science and technology (Eden, Donaldson, & Walker, 2006; Sarewitz, 2004), sustainability sciences (Komiyama & Takeuchi, 2006) and transdisciplinarity (Hirsch Hadorn et al., 2008). The geography and environmental governance literatures complement each other, especially when looking through a watershed or river basin lens (Feitelson & Fischhendler, 2009; Fischhendler & Feitelson, 2003; Lebel & Daniel, 2009; Mumme & Aguilar, 2003; Wolf, 1999). In fact an entire special issue of Annals of the Association of American Geographers was dedicated to Geographies of Water, with five articles specific to water governance (Bakker, 2013; Brown, 2013; Doyle, Lave, Robertson, & Ferguson, 2013; Scott et al., 2013; Swyngedouw, 2013), not to mention other articles in that special issue which treat governance indirectly as well as countless journals that focus on water policy with expressions of geography interspersed. In fact it is very difficult to talk about water governance without geography. But it is not just the geography of water and governance that share an intimate connection. Maps and geospatial representations are crucial to scholarship regarding both tracks (Vörösmarty et al., 2010). In a conversation with a Professor of Law at the University of Boulder, we were discussing one of his many Colorado River books. I told him how refreshing it was to see maps depict places, spaces, and people's interest in water. He responded that *you just can't talk about water law without maps*. It is the lines on maps that show boundaries – the physical and social – and the boundaries that unite and divide us, lines that espouse cooperation or instigate conflict.

However, boundaries are not just about geography and they are not just about environmental governance. The most fascinating aspect of boundaries is the nexus at which they intersect, hence their transboundary nature, especially in places, over space and *in nature*. What happens where physical and social boundaries cross? Do such intersections cross in any place or in one particular place? What happens when the intersection takes place? Does conflict ensue, or cooperation? In attempting to delineate boundaries through the boundary typology, locate them in a geospatial environment through governance layers and then interview those who safeguard them, such as farmers do for the agricultural cause, is to take one step closer to answering these questions.

The Colorado River Basin is an iconic region. The CRB holds mystique for those who live in the Basin, those who live outside of the Basin but are dependent on the water, and academicians, scholars, and researchers around the world who are interested in the anomalies that make it so remarkable. In fact, the “Old” West and the transformation from the “Old” West to an agri-cultural geography is part of the mystique. Is it a lifestyle that we are trying to save or discard? Or is this agri-cultural landscape the outcome of a lifestyle to which we are accustomed – one where demand exceeds supply, in every aspect of the word demand? The simple truth we discovered in our interviews is that farmers feel responsible for producing the goods and products upon which we (in the West as much as global societies) depend upon. “Who is going to feed the world?!” they argued (personal communication). It just so happens that the Colorado River provides the water to grow tens of millions of dollars’ worth of vegetables, specialty crops and pasturelands that support our demand including a taste for beef, fruit and vegetables and products that fill our grocery stores in the winter. Based on our interviews, farmers feel they have a civic responsibility to the deliver to the public. As drought blankets the region, their limitations to provide these services increase. Boundaries, including pecuniary ones realized in the third chapter, can help answer these questions.

Boundaries are also about data, particularly geospatial data. I spent two years on a data collection mission only to find a gaping hole in the existence of geospatial data relating to sectoral boundaries – those depicting the agricultural sector. Geospatial data for physical boundaries are relatively easy to find or construct based on measurements, distances, and tabular data. Because social boundaries are much more difficult to measure, I chose to begin from an organizational/administrative perspective (governance). This was helpful in trying to capture space together with place but the approach made me aware that people do not think of social boundaries in a spatial way. I found many maps online of the irrigation district boundaries. These were practical maps showing jurisdiction and coverage primarily for their constituents. Because maps are required by state statue, they were available for public use and my research.

I decided that maps depicting irrigation districts and agricultural organizations could demonstrate agricultural interest, and therefore the local sector. This was truly a factor of scale. Together, these areas are a representation of the agricultural sector in the Basin (the same could be accomplished for the municipal sector as well as the other sectors). The interviews show, however that despite common interests, there are very different sentiments about water use, development, and conservation, just as there are many differences relating to upstream and downstream water users, junior rights and senior rights holders, Upper Basin and Lower Basin constituents. These are the anomalies that have been brought to the surface through the boundary studies presented in this manuscript.

I have thought long and hard about the nature of my research and the disciplines that I have come to question and appreciate. I realized the course I have taken throughout my education has led me to this place in time. Boundaries are a symbol to me and yet, despite their symbolism, they are very real. Boundaries define the way I live my life and my relationships within both spatial and temporal confines, considering both the abundance and lack thereof. I understand the world we live in *that* much better through my study of boundaries. And so, this dissertation is truly an extension and expression of myself. It has inspired me. And hopefully, my contribution has likewise enhanced the discipline.

REFERENCES

Bakker, K. (2013). Neoliberal versus postneoliberal water Geographies of privatization and resistance. *Annals of the Association of American Geographers, 103*(2), 253-260.

Berkes, F., Colding, J., & Folke, C. (2003). *Navigating social-ecological systems : building resilience for complexity and change*. Cambridge, New York: Cambridge University Press.

Brown, J. (2013). Can participation change the geography of water: Lessons from South Africa. *Annals of the Association of American Geographers, 103*(2), 271-279.

Doyle, M. W., Lave, R., Robertson, M. M., & Ferguson, J. (2013). River Federalism. *Annals of the Association of American Geographers, 103*(2), 290-298.

Eden, S., Donaldson, A., & Walker, G. (2006). Green groups and grey areas: scientific boundary-work, nongovernmental organisations, and environmental knowledge. *Environment and Planning A, 38*(6), 1061-1076.

Eichenberg, B. (2008). Fighing for a way of life: Public lands and the ranchers who own them. *West Northwest Journal of Environmental Law & Policy, 14*(2).

Feitelson, E., & Fischhendler, I. (2009). Spaces of Water Governance: The Case of Israel and Its Neighbors. *Annals of the Association of American Geographers, 99*(4), 728-745.

Fischhendler, I., & Feitelson, E. (2003). Spatial adjustment as a mechanism for resolving river basin conflicts: the US–Mexico case. *Political Geography, 22*(5), 557-583.

Hartig, F., & Drechsler, M. (2010). Stay by thy neighbor? Social organization determines the efficiency of biodiversity markets with spatial incentives. *Ecological Complexity, 7*(1), 91-99.

Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., . . . Zemp, E. (Eds.). (2008). *Handbook of Transdisciplinary Research*. Online: Springer Netherlands.

Komiyama, H., & Takeuchi, K. (2006). Sustainability science: Building a new discipline. *Sustaiability Science, 1*, 1-6.

Lebel, L., & Daniel, R. (2009). The governance of ecosystem services from tropical upland watersheds. *Current Opinion in Environmental Sustainability,* 1(1), 61-68.

López-Hoffman, L., Varady, R. G., Flessa, K. W., & Balvanera, P. (2010). Ecosystem services across borders: a framework for transboundary conservation policy. *Frontiers in Ecology and the Environment, 8*(2), 84-91.

Mumme, S. P., & Aguilar, I. (2003). Managing Border Water to the Year 2020: The Challenge of Sustainable Development. In S. Michel (Ed.), *Binational Water Management Planning* (pp. 51-94). San Diego: San Diego State University.

Sarewitz, D. (2004). How science makes environmental controversies worse. *Environmental Science & Policy, 7*(5), 385-403.

Scott, C. A., Meza, F. J., Varady, R. G., Tiessen, H., McEvoy, J., Garfin, G. M., . . . Montaña, E. (2013). Water security and adpaptive management in the arid Americas. *Annals of the Association of American Geographers, 103*(2), 280-289.

Swyngedouw, E. (2013). Into the Sea: Desalination as hydro-social fix in Spain. *Annals of the Association of American Geographers, 103*(2), 26.

USBR. (2012). Colorado River Basin Water Supply and Demand Study: Study Report *Reclamation: Managing Water in the West*. Boulder City, NV: Bureau of Reclamation, Department of the Interior.

Vörösmarty, C., McIntyre, P., Gessner, M., Dudgeon, D., Prusevich, A., Green, P., . . . Davies, P. (2010). Global threats to human water security and river biodiversity. *Nature, 467*, 555-561.

Wolf, A. (1999). The Transboundary Freshwater Dispute Database Project. *International Water Resources Association, 24*(2), 160-163.

Young, O. R., Berkhout, F., Gallopin, G. C., Janssen, M. A., Ostrom, E., & Leeuw, S. V. D. (2006). The globalization of socio-ecological systems: An agenda for scientific research. *Global Environmental Change-Human and Policy Dimensions, 16*(3), 304-316.