

DISSERTATION

THE ALLOCATION OF INTERSTATE GROUND WATER:  
EVALUATION OF THE REPUBLICAN RIVER COMPACT AS A CASE STUDY

Submitted by

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In Partial Fulfillment of the Requirements

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## ABSTRACT OF DISSERTATION

### THE ALLOCATION OF INTERSTATE GROUND WATER: EVALUATION OF THE REPUBLICAN RIVER COMPACT AS A CASE STUDY

Management of water resources is a demanding and complex challenge. The complexity is magnified when the source of water supply transcends local jurisdictions and extends across state boundaries to include multiple political interests, management authorities, and legal parameters. Interstate river compacts are used in the United States as an effective legal and administrative instrument to equitably distribute water within a multi-state river system. Of the forty-five interstate river compacts in the United States that focus upon the distribution of water supplies, only six include ground water within the distribution system – even though ground water is an important and often the dominant source of water supply that is used within an interstate river basin.

The goals of this dissertation are to examine the reasons *why* ground water is not included within an interstate river compact allocation system and to identify factors that show *how* this omission may be rectified. The primary research objective is to identify and examine the quantitative and qualitative data necessary to construct a template of factors and issues that warrant consideration in the decision-making process of compact administration officials who are contemplating the inclusion of ground water within a compact's allocation system.

The research uses a case study and program evaluation methodology to systematically analyze the integrated processes associated with complex interstate river compact administration in a comprehensive manner. The Republican River Compact is examined as an institutional model because it is representative of most other interstate river compacts that allocate surface water supplies only. Evaluation of the Republican River Compact also provides unique insight into the decision-making processes, and consequences, that pertain to the consideration, deferral, and ultimate inclusion of ground water within an interstate river compact allocation system. Although the use of a case study in engineering research differs from traditional quantitative approaches, it offers a distinct and valuable research design to address the non-numeric and qualitative data that is used in the decision-making process by water resources engineers.

The research findings clearly indicate that ground water may be successfully incorporated within the allocation system of an existing interstate river compact. The findings also indicate the Republican River Compact Administration has been effective in promoting the efficient and beneficial use of water within the Republican River Basin since 1943. The research shows the use of a case study and program evaluation methodology is an appropriate and effective approach for addressing the complex problems and decision-making processes inherent in interstate river compact administration.

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THE ALLOCATION OF INTERSTATE GROUND WATER:  
EVALUATION OF THE REPUBLICAN RIVER COMPACT AS A CASE STUDY

CHAPTER 1

INTRODUCTION

In most interstate river compacts the water allocation system is limited to surface water and does not address the hydrologic or legal impacts of ground water. The goals of this dissertation are to examine the reasons why ground water is not included and to identify factors that may rectify this omission in interstate river compact administration through examination of a case study, the Republican River Compact, as an institutional model.

The historical focus of water resources engineering was upon exploitation, or use of water in the most economically efficient manner possible. Prior to the 1960's, the policy-making process for water management was exemplified by federal economic water decisions that were embodied in the Flood Control Act of 1936, which adopted the benefit-cost ratio as the primary criterion for federal project financing (Hobbs, *et. al.*, 1989; Adams, 1998). The benefit-cost analysis and efficiency criteria became problematic and less favored for application in water management decisions because they

do not reflect the institutional decision-making structure that must be considered in policy formulation (Anderson, 1983). As competition for water advanced, the complexity of water management increased to meet the additional demands and prompted a shift toward a more effective use of water that moved beyond the simplistic output over input efficiency ratio to include economic, social, and environmental considerations (Grigg, 1985; Anderson, 1983). The complexity of water management and engineering becomes more acute as water management practices transcend local areas to regional or interstate boundaries with multiple jurisdictions (Adams, 1998; Barton, 1967). As the complexity and competition for water resources escalate, the potential for conflict also increases in frequency and magnitude (Grigg, 1985; Barton, 1967). Therefore, through professional experience previously referenced, it is evident that pragmatic policy makers already recognize the need and value of incorporating a mechanism for the equitable distribution of water within current water resource engineering practices to assure a measure of justice and fair treatment to all beneficial users of this precious and vital natural resource.

The Republican River Compact is an exceptional model of an interstate compact to study because the allocation system typifies other interstate river compacts that cite surface water only. It is also representative of many river systems in the western United States where ground water pumping surpassed streamflow diversions by the mid-20<sup>th</sup> century (Anderson, 1983). Ground water is the dominant source of water supply in the Republican River Basin (McGuire, 2003; Luckey *et.al.*, 1981). Although the compact administrators deferred including ground water within the allocation system for almost 60 years after compact ratification, ground water was successfully incorporated into the allocation and compact administration system after being prompted to do so by a

preliminary judicial order in 2000 by the Special Master appointed by the United States Supreme Court to hear the case *Kansas v. Nebraska and Colorado*, No. 126 Original. The Republican River Compact case study provides cogent insight into the successful, and non-successful, factors and decision-making processes employed by the Republican River Compact Administration (RRCA) in performance of its duties as the compact's administrative body and the inclusion of ground water within an interstate allocation system.

Review of the available literature indicates there is a void in the research on the inclusion of ground water as a supplemental source of water in the allocation system of an interstate river compact. In contrast, there is much information available about the general aspects of water management. There are also many technical, political, and legal treatises about water administration and endangered species or other natural resources issues. Most of the research that focuses upon water administration, which is in context of interstate river compacts, is related to the history, general water administrative practices, and political implications of specific compacts such as the Colorado River Compact (1922), Rio Grande River Compact (1938), or Delaware River Basin Compact (1961). This dissertation also provides additional insight into a non-traditional methodology used to research water resources engineering and interstate river compact administration issues, through a case study and performance evaluation of the Republican River Compact.

This research focuses upon ground water because it is a major source of water supply in many river basins that are subject to regulation through an interstate river compact. However, most interstate river compacts allocate surface water supplies only

and do not include ground water within the formula or system that equitably distributes water resources among adjacent states. Therefore, the primary objective of this research is to identify the factors necessary for analysis by interstate compact decision-makers, who are contemplating the inclusion of ground water within a compact's allocation system, through examination of the technical and legal criteria that determine how much ground water is available for distribution from tributary aquifer systems. Subsequent to the assessment of ground water supplies, the focus of this dissertation considers the elements and actions necessary to modify an interstate river compact allocation system to include ground water within an equitable distribution system and the importance of an enforcement clause or alternative dispute resolution process to address contentious issues and to assure all participatory states adhere to the provisions of the compact.

This dissertation advances the state of knowledge in water resources engineering because it addresses the dual and complementary requisites in interstate river compact administration – the engineering and scientific foundation that leads to understanding of ground water as a natural resource; and the non-technical social, political, and institutional parameters that influence the equitable distribution of interstate rivers that cross jurisdictional boundaries. It is appropriate to include the study of the cause and effects of the decisions that impact interstate compact administration in engineering research because the roles and decisions of engineers continue to evolve in water resources management (Grigg, 1993a).

## Background and Context of the Republican River Compact

In the United States there are 45 interstate river compacts, of which 29 cite water supply/allocation as the principal purpose. Only six of those compacts include ground water within the sources of supply and the allocation system (Bear River Compact, 1978; Upper Niobrara River Compact, 1962; Delaware River Basin Compact, 1961; Susquehanna River Basin Compact, 1970; Big Blue River Compact, 1971; California-Nevada Interstate Compact, 1971).

The Republican River Basin Compact is representative of current interstate river compacts because its provisions are contained within other compacts, such as the eight that were enacted in the 10-year period 1941 through 1950 (Republican River Compact, 1943; Belle Fourche River Compact, 1943; Arkansas River Compact, 1948; Pecos River Compact, 1948; Upper Colorado River Compact, 1948; Snake River Compact 1949; Canadian River Compact, 1950; Yellowstone River Compact, 1950). These focused upon sharing limited water supplies in an equitable manner and protecting the state's ability to fully develop water in the future. Typical of compacts enacted during the World War II era, the technical experts and negotiators of the Republican River Compact focused on the development and distribution of natural surface water supplies and not the limited use of ground water. A copy of the Republican River Compact is provided in Appendix A.

Subsequent to its adoption in 1943, the officials charged with administration of the Republican River Compact became aware of the increasing ground water development in the basin and the perceived impact to streamflows. However, they repeatedly deferred inclusion of ground water in the allocation system. There are two

hypotheses that seek to explain why the Republican River Compact administrators repeatedly postponed including ground water within the allocation system. The first is a lack of knowledge or understanding of the clandestine resource. The Republican River Compact does not contain specific language that recognizes ground water as a source of water supply – this omission indicates the compact negotiators were not fully aware of the existence, amount, location, or long-term sustainability of ground water resources within the basin, which prompted successive investigative studies in an attempt to bridge the breach in knowledge. The second hypothesis is the absence of cogent enforcement authority. The Republican River Compact does not include an enforcement provision in the compact text – which raised the issue of the authority of the compact administrators to include ground water within the allocation system, and if so, how it will be integrated with surface waters to measure compliance.

During the course of almost five decades since adoption of the compact, the State of Kansas became increasingly concerned about advancing ground water development, which they perceived as adversely impacting the Republican River streamflows and diminishing the amount of water available to their water users. Stifled by inaction by the representative compact administrative authority to account for ground water depletions, Kansas sought recourse through the judicial process and in 1998 initiated the interstate lawsuit *Kansas v. Nebraska and Colorado*, No. 126 Original to protect their interests and to seek a final determination of whether or not ground water should indeed be included within the Republican River Compact allocation system. The lawsuit was eventually dismissed because the three states that are represented in the Republican River Compact negotiated a mutually acceptable settlement that focused upon

the inclusion of ground water in the compact allocation system. This research provides valuable insight into the causes and factors that warrant consideration by interstate river compact decision-makers to address the contribution of ground water within the equitable division of interstate water resources – before suffering through the peril of litigation.

### Problem Context

During the pre-World War II era when the first interstate river compacts were created, surface water supplies predominately served the domestic, industrial, and irrigation demands for water in the United States. In the arid southwestern states, streamflow diversion through ditches, canals, and pipelines were used to supplement natural precipitation to meet crop irrigation demands on relatively small acreages on family farms. Releases of water from reservoirs supplemented the delivery of water for municipal use and late-season irrigation. As the American population increased and vast amounts of new lands came under farming production through advanced mechanization and farming corporations, surface water supplies became increasingly inadequate to keep pace with additional demands for water (Anderson, 1983).

The development and use of ground water resources increased dramatically in the United States in the mid-20<sup>th</sup> century to meet the advancing demands (U.S. Water Resources Council, 1978). New supplies were necessary to serve an increasing population, expanded irrigated acreage, recreational use, environmental protection, snowmaking, and other new competitive uses for water that were not even contemplated until the late 1960's. Additional advancements in farming practices, water well drilling,

and pump technology have further enhanced the availability and attractiveness of developing groundwater supplies as an economically viable source of water to irrigate new croplands. In the arid western region of the United States that is generally described as being west of the 97<sup>th</sup> Meridian, groundwater often surpasses surface water as the principal source of supply for domestic, municipal, and industrial uses due to its availability and water quality attributes (Anderson, 1983; McGuire, 2003).

Since the Colorado River Compact was adopted as the first interstate river compact in 1922, compacts have been employed throughout the United States as an effective management instrument for the equitable allocation of a shared river system. As previously indicated, 23 interstate river compacts base their distribution systems exclusively upon surface water supplies, including the Colorado River Compact. This research seeks to identify the factors and decisions that focus upon the dilemma of integrating ground water as an additional source of water supply within the water allocation system in an existing interstate river compact. As a case study, the Republican River Compact offers a unique opportunity for research because it is representative of many interstate river compacts that recognized the tributary impact of ground water upon natural streamflows, but did not include ground water within the allocation system. This dissertation researches the several factors and decision-making processes that are relevant to the cause and effect of this omission.

The first reason for not including ground water within the allocation system in an interstate river compact is a fundamental lack of understanding or quantification of the resource itself. Opposed to natural streamflows that are visually discernable, the amount, location, and physical accessibility of ground water are not readily apparent and are

difficult to measure. It is therefore problematic to include ground water as a contributory source of water supply in the allocation system if the amount available for distribution is unknown or difficult to measure with the reasonable degree of confidence that is necessary in interstate compact negotiations.

Another factor for consideration is the proximity of the ground water aquifers to state boundaries. Rivers or creeks flow within relatively defined natural channels from higher elevations across varied topography toward confluences with other rivers and ultimately to the oceans. Streamflows may easily be monitored at discrete points along their "thread" or corridor, including sites at the state boundaries. In contrast, ground water aquifers are unconsolidated and vary greatly in depth and expanse that exceed the geographic regions of the states contemplating an interstate compact. For example, the Republican River traverses across the States of Colorado, Kansas, and Nebraska. The ground water tributary to the Republican River is part of the Ogallala aquifer formation that underlies a portion of five additional states (South Dakota, Wyoming, Oklahoma, New Mexico, Texas) in the western United States (Luckey *et. al.*, 1981).

Legal recognition of ground water is a third factor that warrants consideration. The United States Constitution, Article X, mandates a federalist system of government that provides a division of authority between the federal government and the states. One of the principal components of this separation of powers is an intent to delegate authority over local issues, including natural resources, to individual states. Although this delegation of authority to administer water resources is highly valued by state governments, it does not assure a uniform or consistent application of laws. Succinctly, each individual state has unique surface water and ground water laws within their

respective boundaries that may, or may not coincide with those of their neighboring state(s) that shares a mutual water resource.

Succeeding the legal or statutory recognition of ground water is the ability to regulate the resource, particularly in context of timeliness. Streamflows that are subject to an interstate river compact are readily measured at gaging stations that describe the instantaneous amount of flow at that particular location along a river corridor. Compilation of these measurements and an annual record of streamflows are used to quantify the total amount of water available for distribution to the participatory states or the amount of compact obligation to be delivered to a downstream state at the state boundary. Applying the information gained from the river gaging stations, water officials may regulate diversions or storage of natural streamflows within their respective states on a daily or other short-term basis to manage the amount of water needed to meet compact delivery requirements. Curtailment of ground water pumping or withdrawals from an aquifer may have dramatically different timing affects to meet the compact delivery obligations. Since ground water moves through a subterranean consortium of sands and gravels, ground water depletions may not affect the tributary stream system for hours or decades, depending upon the distance, hydraulic gradient, and type of geologic materials the water flows through.

Political influences are a significant factor in the administration of an interstate river compact, including the consideration of including ground water within the allocation system. Any potential adjustment to the allocation system of an existing compact that would affect the water supply to a participatory state in an interstate compact is fraught with consternation and peril. Intra-basin water users within each state will justifiably be

concerned that the water supply they have become dependent upon, in time, amount and location, will be diminished in quantity, quality, or both. Negotiations that seek to alter the amount and/or source(s) of water supply in an interstate river compact are typically laced with allegations of hoarding, greed, and mistrust by “the other” state. Political influence will thereby be exerted upon the representative water administration officials to secure as much water as possible to meet their individual needs in perpetuity.

Interstate river compacts are legal contracts that are difficult to change. Although minor refinements may be accomplished through the governing authority or compact commission, substantive refinements are typically rare because they usually require a unanimous agreement of all participatory states. When the issues are elevated in complexity to the extent that they contemplate the use of a new resource such as ground water, that is not readily understood or measurable, it often results in deferment of the issue or may lead to litigation to pursue finality if the compact administrators cannot reach resolution on their own accord. The purpose of this research is to study these effects and develop findings that advance the integration of ground water within an allocation system in an interstate river compact.

### Research Approach

Water resource problems are complex and obscure. The complexity of water resource management is further magnified when the natural resources transcend local or state jurisdictional boundaries to include multiple management authorities and legal parameters (Adams, 1998). In the pursuit of resolving interstate water administration

and engineering problems, professional experience and numerous interstate river compact lawsuits have proven the exclusive reliance upon scientific reasoning or application of numeric quantification is inadequate to resolve the complex water problems that culminate in a conflict among different state water compact administration authorities (examples of interstate river compact lawsuits include: *Kansas v. Colorado*; *Texas v. New Mexico*; *Nebraska v. Wyoming*, *Kansas v. Nebraska and Colorado*). Water resource engineers are required to serve in two roles in interstate river compact administration that are inextricably intertwined – technical expert and decision-maker. Engineers are particularly adept in the application of mathematics and science in solving practical water resource management problems associated with the technical aspects of measurement, control, and accounting of interstate river waters (Grigg, 1993a). Water resource engineers are also vested with decision-making and policy development responsibilities in compact administration that require the application of social sciences, economics, politics, and sound management principles (Grigg, 1993a; Adams, 1998). To address and resolve the uncertainty of data, conflicting legal authorities, and other complex water management issues that are inherent with compact administration – a systematic analysis is required (Grigg, 1993a). This research applies a case analysis methodology that represents a true systems application because it takes a holistic approach and allows the full complexity of a water resources engineering problem to be considered beyond numeric quantification (Adams, 1998). As a qualitative tool, the case analysis method is designed to explain how and why events occurred. The case methodology provides a procedure to organize and evaluate the non-numeric and unstructured data or legal, social, and political variables in complex water resources problems that cannot be

quantified or modeled. The advantage of case-based reasoning, used in engineering design, is it adapts previous solutions to meet new demands (Kolodner, 1993). In perspective of advancing the knowledge base in water resource engineering and applicability to interstate river compact administration, the case analysis methodology enables the study of the context in which problems emerge and offers a mechanism to apply knowledge gained from historical conflicts in water resources management as a template for resolving future controversies (Kelley, 1993; Adams, 1998).

The analytical instrument used to develop the case analysis for this dissertation is a program-evaluation methodology that systematically determines if administration of the Republican River Compact has succeeded and is adaptable to inclusion of ground water as a supplemental source of supply in the allocation system. The knowledge gained from studying a failed process is also valuable in application to future situations (Adams, 1998). The intent of the research is to identify and evaluate the indicators associated with deferring the inclusion of ground water within the allocation system that led to interstate conflict. As described in further detail in Chapter 3, the program evaluation method consists of several steps: determination of program objectives; establishing outcome measures to gauge the success of achieving the stated objectives; identification of actions or variables that influence the outcomes, and use of research designs to measure program effectiveness. Having demonstrated the consideration of ground water in the Republican River Compact, the study is poised to suggest how ground water can be considered in other interstate compacts.

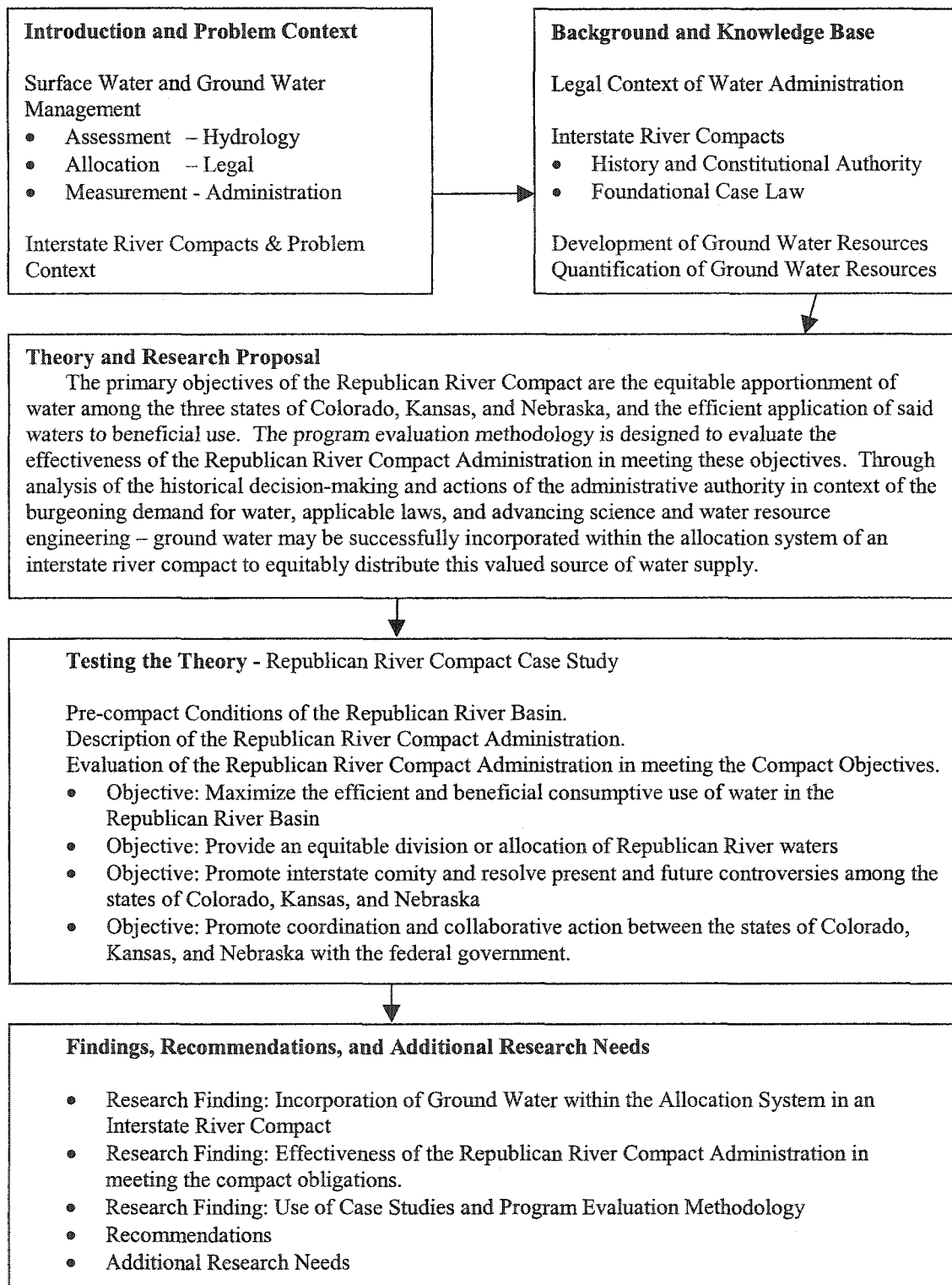
Two research designs are used. A pre- and post-test analysis is used as the primary research design to compare conditions before ratification of the Republican

River Compact in 1943 to present-day conditions in 2004 and a trend analysis over the same period to prove the two hypotheses that explain why the inclusion of ground water in the allocation system was repeatedly deferred.

The dissertation is presented in seven chapters. The first chapter presents the introduction, background and context of the Republican River Compact, problem context, and a general narrative of the research approach. Chapter 2 provides the technical and legal background information on ground water administration and interstate river compacts in the United States. The research methodology and design are detailed in Chapter 3. Chapter 4 describes the pre-compact conditions of the Republican River Basin and is followed by a description of the Republican River Compact and its administrative authority in Chapter 5. Chapter 6 evaluates the effectiveness of the Republican River Compact in meeting its objectives and adaptability to include ground water as a supplemental source of supply in its allocation system. The research findings, recommendations, and suggestions for additional research are outlined in the concluding Chapter 7. To outline the sequence of the presentation, the problem statement and flow diagram for the research methodology are provided below:

Problem Statement: The primary purpose of most interstate river compacts is the equitable apportionment of tributary waters, however, the allocation system employed in these compacts do not include ground water even though it is often a significant source of supplemental water supply.

Figure 1. Flow Diagram for Research Methodology



## CHAPTER 2

### BACKGROUND, WATER LAW, INTERSTATE RIVER COMPACTS, GROUND WATER DEVELOPMENT, AND GEOGRAPHIC SETTING

#### Surface Water and Ground Water Management

In order to effectively evaluate the inclusion of ground water as a source of water supply in an interstate river compact, it is necessary to first consider management of surface and ground water resources in a broader context. For foundation, there is ample evidence that surface water management activities have occurred for several millennia. Since natural streamflows and waters retained in reservoirs or ponds are visually discernable, they are relatively easy to manage and quantify. The first evidence of ancient irrigation practices that diverted water from natural streamflows dates to 4000 B.C. as found in the Hammurabi Code of Laws (2004). Serving as a dramatic example of historical surface water management, consider the water supply infrastructure in the ancient city known as Machu Picchu that was developed prior to the 15th century in the high Peruvian Andes Mountains. Machu Picchu became the pinnacle of religion, culture, and ruling government for the Inca Empire (Means, 1964). Its citizens were provided with ample domestic and agricultural water supplies through a complex water system composed of an integrated series of spring diversions and aqueducts that delivered water

for direct application to use or for temporary retention in small reservoir storage vessels (Rhein, 2004).

Because natural streamflows are visually apparent and readily accessible, they historically have been applied as the primary source of water supply in the form of diversions from the natural streams and the subsequent conveyance through ditches or canals to domestic, agricultural, and industrial needs. As civilization developed with a commensurate increase in competition for limited surface water supplies, often at locations a considerable distance from the natural stream channel, it became necessary to manage or regulate surface waters in a logical and equitable manner.

Traditional surface water management is based upon a three-step process: (1) assessment; (2) allocation; and (3) measurement or monitoring. The initial assessment step is undertaken to determine the amount, location, and timing of surface water supplies available for distribution and application to beneficial use(s). The particular form of assessment is often driven by the need or demand by water users and varies in geography and time scale. For example, farmers using water for irrigation are concerned with the amount of streamflows available on a daily basis at their specific diversion structure during the crop-growing season. In contrast, municipalities typically focus upon the historic minimum amount of streamflow recorded at their points of diversion or storage and develop their management objectives upon the reliability or firm-yield of water supplies. Municipal water suppliers direct their primary water management operations upon serving life-dependant uses such as drinking water or fire protection as the baseline or critical water service demand. Subservient water supplies are managed to serve commercial businesses, irrigation of lawns, or other water consumption activities.

Owners of reservoirs or storage vessels that impound water behind artificial dams manage toward a capture of excess waters in the winter months or during spring runoff and storm events. They also reserve a portion of their total reservoir holding capacity to retain peak streamflow events for flood protection. Reservoir operators release water later in the year to serve irrigation, commercial and other demands that are not being satisfied from declining streamflows. Reservoir or storage water management relies upon the total yield of a water basin above a potential dam site on an annual time scale.

The allocation of surface water supplies integrates a consortium of legal parameters, technical expertise, and water administration experience. In the United States there are two principal legal doctrines that dictate the allocation of surface water supplies. The Riparian Doctrine is predominant in the more humid areas of the nation with relatively abundant water supplies and its general precept allows an individual or entity to apply a reasonable amount of water to the intended beneficial use, as long as the water diversion does not harm the interests of others. The Doctrine of Prior Appropriation is applied in the arid western states and gives superiority to the early water users who diverted water from a natural stream for application to a beneficial use, over those water users that developed their interests later in time. A fuller description of the two principal legal doctrines for water distribution in the United States is provided later in this chapter. Working within the established legal parameters, it is the twin pillars of technical expertise and experience that attest to the success, or failure, of allocating limited water supplies to meet competitive water demands on a daily basis. The amount of water available for allocation among competitive water demands is highly dependent upon both natural and human-induced activities. Variance in topography, riparian

vegetation, geology or soil types, tributary inflows, precipitation, temperature, and other changes in the natural environment directly influence the amount of water available for use at any location throughout the river corridor. Compounding the natural phenomena, human induced activities such as diversion from the natural stream channels, temporary storage in reservoirs, and return flows from irrigated lands are examples that add to the complexity of determining the amount of water available for use at any particular location at an instantaneous point in time. Succinctly, the allocation of surface water resources requires a holistic perspective and technical analysis of the amount of water available in time, amount, and location in context of all competitive demands along a stream corridor and the physical environment.

Measurement or monitoring of surface water supplies is relatively easy to accomplish. Streamflows may be measured using a variety of flow meters or electronic devices to quantify the instantaneous amount of flow in a river or stream at a particular location. Streamflow gaging stations are also equipped with recording devices that are able to continuously register the amount of streamflow and many contain satellite or other telemetry equipment that allow water resource administrators to access streamflow information at remote sites at any time. Measurement and monitoring of water diversions is typically accomplished through visual observation of the amount of water flowing through calibrated flumes, weirs, or other water control structures. The amount of water retained in reservoirs or other storage facilities is also relatively easy to quantify by visually inspecting the height of water measured on a staff gauge that was calibrated in conjunction with an area-capacity table to instantaneously determine the amount of water held in the storage vessel. Compilation of the daily diversion and reservoir storage

records is used to quantify the total amount of water available at different locations.

Analysis of the annual diversion and storage records over a period of time is also useful in calculating the hydrologic yield of a river basin over time, in perspective of an average or firm water yield that depicts the lowest amount of flow for the period of record.

Annual streamflow records are particularly insightful when used in conjunction with climatic, population census, water use demands, or other information in long-term trend analyses.

### Ground Water Management

Ground water management has proven to be more problematic than surface water management. The inability to visually observe the depth to ground water below the earthen surface or to easily quantify the volume available for extraction from aquifers delayed extensive development of ground water resources until the mid-20<sup>th</sup> century. Due to its clandestine nature, the use of ground water was predominantly confined to relatively small wells that served domestic needs, stock watering, and limited irrigation of crops. Although surface waters management dates to the colonial era in the United States, ground water eluded incorporation within the management and regulatory systems of tributary river basins until recently. In a seminal case involving ground water in the United States, Justice Ellsworth captured the early essence of ground water management through the statement:

“The laws of its existence and progress, while there, are not uniform, and cannot be known or regulated. It rises to great heights, and moves collaterally, by influences beyond our apprehension. These influences are so secret, changeable and uncontrollable, we cannot subject them to the regulations of law, nor build upon them a system of rules, as has been done with streams upon the surface.”[Roath v. Driscoll, Conn. Sup. Ct. (1850)].

The recorded development and use of ground water wells dates to ancient biblical times. However, the assessment of ground water resources is much more difficult to quantify than surface water resources – in large part due to its elusive and clandestine nature. Ground water flow through the subterranean geologic materials is highly variant and difficult to accurately calculate. In general terms, the rate of ground water movement varies significantly and is highly dependent upon the hydraulic gradient and the type of sands, gravels and other unconsolidated material the water courses through (McWhorter and Sunada, 1988). The volume of water stored in subterranean aquifers is somewhat analogous to storage in surface water reservoirs because both forms of storage vessels capture and retain water for potential release to the stream systems or application to beneficial use at a later time. In contrast to the homogenous nature of water stored in a surface reservoir, ground water storage in a subterranean aquifer resides within the interstitial voids between the sands, gravels, and other unconsolidated geologic materials. Because the sand and rock material is heterogeneous, the amount of water available for extraction may vary significantly in relatively short distances. Although imprecise, the amount of ground water retained in the aquifers is often determined through interpretation of geologic maps and measurement of static water levels and saturated thickness in ground water monitoring wells.

The allocation of ground water supplies varies significantly in the United States and is predominantly based upon the ground water and land ownership laws in each individual state. The allocation system is also somewhat dependant upon the hydraulic connection or interaction with the river systems. For example, alluvial or tributary ground water that has a direct hydraulic connection with the stream is fully integrated and managed in a conjunctive manner with river systems in Colorado. In contrast, the allocation of ground water in Colorado that is retained in bedrock aquifers with negligible recharge from natural precipitation or hydraulic connection with the stream systems is based upon the calculated amount of water retained in the aquifer underlying specified land ownership [Colo. Rev. Stat. § 37-90-137(7)]. In other states, the “right of capture” or ability to pump ground water and apply it to beneficial use is vested exclusively to ownership of the overlying land without any regard to the interaction with the stream system (Texas). Other states such as Oklahoma and Michigan do not regulate or allocate the amount of ground water that may be withdrawn, but only require limited notification and water well construction procedures.

Similar to the diversion of natural streamflows, the measurement of ground water pumping is relatively simple to accomplish at individual wells. The flow rate of ground water pumping may be measured by use of a flow meter that indicates the instantaneous flow rate or calibrated to reflect the cumulative flow through the meter. Ground water withdrawals may also be calculated through empirical derivations. The first example of these mathematical relationships is the power conversion coefficient (PCC) method that calculates the amount of ground water withdrawal based upon a measured calibration of the mechanical efficiency of a specific ground water pump to the volume of applied

electrical energy. Another method to calculate the volume of ground water withdrawal from a specific source is calculation of the total amount of ground water applied to an irrigated crop from that well through empirical crop irrigation requirement relationships such as Blaney-Criddle or Penman-Monteith that correlate specific crop type, irrigated acreage, and climatic information with assumed irrigation practice efficiencies.

Measurement of the total ground water withdrawal from a ground water aquifer system is difficult to quantify due to the uncertainty of all inflows and outflows to the aquifer, in both amount and location. To estimate the amount of water retained in aquifer storage or the net change over a prescribed time period, two methods are employed. The first method calculates the net change in storage by comparison of the change in static water levels measured at a series of monitoring wells. The measurement of static water levels is typically performed during the winter months, or non-irrigation season, to mitigate the effects of large-scale ground water pumping in aquifers that are a significant source of agricultural water supply. This method is dependent upon a number of variables, principally the number of monitoring wells and is most applicable for consideration in trend analyses. It is not applicable for local ground water management decisions where there is an absence of monitoring wells. The second method to estimate the amount of water available in an aquifer system or the net change in storage is computation through a water budget. The reliability and application of this method is again directly dependent upon the quality of data and information. Inflows to the ground water aquifer include stream losses, canal or ditch leakage, recharge from irrigation, and most significantly – recharge from precipitation. Outflows in a ground water budget include evapotranspiration from phreatophytes, pumping for irrigation or other uses, streamflow

gains, and discharge as springs or to constant head boundaries. The net change in ground water storage is simply calculated as the difference between inflows and outflows for a defined aquifer system. Although calculation of the amount of water available for extraction from a ground water aquifer is always of importance and interest, the difficulty in measuring all the dependent variables and the application of those measurements over a broad domain prompts a measure of caution in using total water storage calculations in the management system for ground water resources. In the alternative, a trend analysis that depicts the net change in storage over a sequence of years is often much more applicable in ground water resources decision-making.

### Interstate River Compacts

As civilization and its correlative need for water supplies developed, and artificial state or territorial boundaries were established to govern geographical regions, surface water management evolved to address the need to share limited river waters among competitive demands and various government entities. In the United States, the predominant legal instrument that allocates the limited resources of a tributary river system that courses across state boundaries is an interstate river compact. To establish a basic understanding of the extent and purpose of interstate river compact administration within the United States, the primary water administrative authority in each state was surveyed and a search of applicable interstate river compact lawsuits and judicial decisions was conducted to develop a comprehensive database of all water-related compacts in the United States. The content of the tabulation includes, but is not limited

to, the name of the compact, participatory states, date of enactment, source of water supply, method of allocation, and lawsuits relevant to each interstate river compact. The tabulation and a copy of the survey are provided in Appendix E.

To assess the amount of water available for distribution among different states that share a common river and are parties to an interstate river compact, it is necessary to first determine the total amount of water available for distribution within the natural watershed on an annual basis. Review of the 29 interstate river compacts that were composed for the primary purpose of allocating water supplies among participatory states indicate the first step in the assessment process was identification of the virgin water supply available for distribution, which is defined as the total amount of water naturally available to a river system without affect from the activities of humans. The engineers and hydrologists who were charged with quantifying the virgin water supply available for distribution during the initial technical analyses in an interstate river compact negotiation relied upon historic streamflow gaging records that were typically collected at the confluence of major creeks with the dominant river and also at interstate boundaries. The streamflow records were compiled for the entire period of record available to indicate the minimum amount of water yield in dry years, maximum volume during years of excess precipitation, and the average annual yield produced at each river gaging station. In a similar manner, the diversion of streamflows, return flows of water back to the stream system after application to beneficial use, temporary storage in reservoirs, and other contributory actions that affected the amount and timing of the natural river hydrology were also quantified and integrated into the streamflow records to calculate the total virgin water supply. It is interesting to note the amount of ground water available for

distribution was not quantified in any of the aforementioned 29 interstate river compacts as a discrete source of water supply.

The allocation system is the cornerstone of an interstate river compact because it is the formula or prescribed procedure that is designed to accomplish the equitable distribution of water among neighboring states. The allocation system often mirrors the complex integration of applicable laws, hydrology, and water administrative practices of the individual states. Upon determination of the virgin water supply, it is necessary to craft an allocation system that optimizes the use of water in all participatory states and delivery obligations from upstream to downstream states. Consistent through all compacts, the two primary objectives of an interstate compact allocation system are to provide an equitable and quantifiable method for said distribution.

Research of the 29 water supply/allocation compacts indicates there are three dominant methods used in the design of an interstate river compact allocation system – consumptive use, delivery targets, and allocation that is based upon applicable legal doctrine. The consumptive use allocation system is predicated upon a quantification of the net consumptive use of water within each respective state by irrigation and all other beneficial uses at the time of compact formulation. In the most simplistic concept, the annual amount of water allocated to each participatory state is the product of the average annual virgin water supply compiled within the subject river basin multiplied by that states' percentage of the total beneficial consumptive use of water from the relevant river system.

Other compacts require delivery of a specific amount or percentage of computed streamflows that are measured at an upper index river gaging station near the headwaters

of the river in the upstream state. The compact delivery obligation to the downstream state is measured at a river gaging station located at the interstate boundary. The time step for the delivery target may vary from daily obligations to annual volumes. For illustrative purposes, during the irrigation season of February 16 through November 30 the La Plata River Compact (1922) requires the State of Colorado to deliver one-half of the streamflow measured at the upstream river gaging station near Hesperus, Colorado to the State of New Mexico at the state line the following day. The Rio Grande Compact (1938) is a three state agreement between the States of Colorado, New Mexico, and Texas that imposes an annual volumetric compact obligation on the upstream states of Colorado and New Mexico to deliver a sliding percentage of the water measured at upper index river gaging stations to the respective state lines. The delivery obligation percentage in the Rio Grande Compact increases with a corresponding increase in total water virgin water supplies measured at the upper index river gaging stations.

The allocation systems in other interstate river compacts are based upon applicable legal doctrines and do not specify a percentage or mathematical formula for water distribution. Distribution of water in these compacts follows the legal doctrine used to administer water within each respective state and the relative priority of individual water rights within the watershed, without regard to the artificially imposed state boundaries. It is important to note that all participatory states in a compact with an allocation system based upon legal and water administrative practices must employ the same type of legal doctrine to distribute water within their own respective boundaries. For example, the Costilla Creek Compact (Amended 1963) was ratified by the States of Colorado and New Mexico, both of which distribute surface waters within their own

boundaries in accordance with the Doctrine of Prior Appropriation. The allocation system in the Costilla Creek Compact does not recognize volumetric deliveries from one state to another at the interstate boundary. Rather, the limited streamflows are delivered on a daily basis to individual ditches and canals in both states based solely upon the priority date of each discrete structure within the integrated river system.

In perspective of interstate river compacts, a common practice is to measure the amount of streamflow at key locations throughout the basin that quantifies the amount and timing of contributory flows from individual tributaries to an interstate river system and also at a location near or at the state boundaries. Monitoring and measurement of interstate river compact delivery obligations is again relatively simple because it is based predominantly upon streamflow measurements, compilation of annual streamflow records that depict the total amount of water delivered at the state lines, reservoir storage, evaporation calculations, quantification of irrigated acreage, and reporting of total streamflow diversions for application to beneficial use.

### Legal Context of Water Administration

Interstate river compacts are legal instruments that are based upon fundamental bodies of English common contractual and water law used to govern the administration and allocation of shared water resources among different states. A full and detailed description of the different types and applications of pertinent water law that are applied throughout the United States, and their integration to ground water management or within interstate river compacts, is beyond the scope of this research. However, the fundamental

concepts of water law are provided herein to serve as the foundation for inclusion of ground water within the allocation system of an interstate river compact.

### Riparian Doctrine

The historical foundation for the riparian doctrine of water law rests within early English common law. Before the Industrial Revolution, the use of water was limited to small withdrawals for domestic needs and by the owners of small gristmills that were dependent upon running water from a stream to power their water wheels. As the use of hydraulic energy for powering industrial machinery advanced, new and larger mills were built. Larger mills required the construction of proportionally larger dams to create an increased hydraulic head that was necessary for operation – often to the detriment of others located near the expanded mills that relied upon the unimpeded natural streamflow. When the streamflow velocity diminished to the point of hampering the use of water by other landowners along the river corridor, litigation ensued by those neighboring water users to protect their interests. From these lawsuits came the underlying principle of riparian water law: each riparian proprietor has a right to use the stream as it passes through his/her property, but no riparian proprietor has a right to use water that would cause injury to another (Trelease and Gould, 1986). The new American colonies, which enjoyed abundant precipitation, adopted the English common law in practice to protect riparian property rights. As the American populace and industry grew, the corresponding increase in economic and social demands prompted additional

streamflow diversions to meet the burgeoning demands of industry, municipal water supplies, and irrigation of newly cultivated lands.

This increased demand transformed the basic tenet of English riparian law from protection of the stream *flow* to protection of the *use* of water. As a result, the common law of riparian rights split into two fundamentally different theories, the natural flow theory and reasonable use theory (Trelease and Gould, 1986). Under the natural flow theory, the primary or fundamental right of each riparian proprietor adjacent to a river or lake is to have the body of water maintained in its natural state, not sensibly diminished in quantity or impaired in quality (Radosevich, *et. al.*, 1976). Although this doctrine served its historic purpose of assuring sufficient streamflows passed downstream from one mill to the next, it is not utilitarian in modern practice. Strict application of the natural flow doctrine requires an undiminished streamflow, thereby prohibiting additional streamflow diversions for municipal, industrial, and other beneficial uses of water – even though the depletions from those uses may not be causing harm or injury to another riparian user.

The reasonable use theory places emphasis on applying the waters from a stream or lake to a full and beneficial use. This theory grants the fundamental right to each riparian proprietor on a watercourse or lake to fully utilize the resource, up to a reasonable amount necessary to accomplish the intended beneficial use, without causing injury to other riparian proprietors (Trelease and Gould, 1986). The reasonable use theory is distinct from the natural flow theory by allowing a riparian landowner to transfer water to non-riparian lands for beneficial use. Still maintaining the standard protection of no injury to other riparian proprietors, this flexibility expands the location

of irrigation, municipal, industrial, and other beneficial uses beyond those lands that are immediately adjacent to a river or lake. Although the riparian doctrine is the prevalent water allocation system among the 31 States that are east of the 97<sup>th</sup> Meridian and are situated in a humid environment, it is also applied in dryer regions of the country. Some courts in the western United States have recognized the reclamation of barren lands is only possible through irrigation and have applied the reasonable use theory to the extent of allowing the entire streamflow to be diverted and thereby causing the streambeds to be dried up completely (Trelease and Gould, 1986). Presently, in States that adhere to the riparian doctrine for the allocation of water supplies, the reasonable use theory is the predominant system applied. Nevertheless, the natural flow theory continues to be preserved and applied in particular circumstances that warrant flexibility and integration of both theories to reach a reasonable accommodation between flows necessary to satisfy water users demands and minimum streamflows that server to protect the natural river environment.

#### Doctrine of Prior Appropriation

In January 1848, John A. Sutter and James T. Marshall discovered gold in the millrace of a sawmill they were constructing on the American River in the Sierra Nevada Mountains of California [Irwin v. Phillips, Sup. Ct., 5 Cal. 140 (1855)]. Word spread quickly and the pursuit of instant riches prompted a mass migration toward the west during the California gold rush of 1849. The preferred method to extract gold in the region was placer mining that requires large amounts of flowing water through a sluice to

settle the precious heavy metals from the earthen materials. In smaller streams the competition for the placer mining flows became keen. Demand for adequate water supplies began to extend beyond the miners in the mountains to include the farmers, merchants, and ranchers who settled in the valleys to develop agricultural farms and commercial enterprises intended to serve the mining camps. Soon, the pursuit of adequate and reliable water supplies began to be more contentious and difficult to obtain than golden nuggets. The Doctrine of Prior Appropriation was born in the gold mining camps in an attempt to bring an orderly method of distribution to the chaotic realm of water development in the mid-19<sup>th</sup> century. Patterned after the precept of staking a mining claim to establish ownership, the doctrine is also known as the priority system or first in time, first in right. The fundamental concept of the appropriation doctrine is those people or entities that divert water from a stream and applied the water to a beneficial use have a superior claim for water over all those people that subsequently diverted and used water at a later time -- regardless of their respective location on the stream or the purpose for using the water.

Appropriative water rights are governed by statutory law, opposed to the body of common law that governs riparian water rights (Trelease and Gould, 1986). If sufficient water is available for a contemplated appropriation, the water right contains several key elements. The point of diversion is described in a legal context and in relation to a surveyed location or section, Township, and Range boundaries. The amount of water is also specified, and is limited to only that amount necessary to accomplish the intended beneficial use of the water without waste -- to prevent hoarding all available streamflows. The date the water was first diverted and applied to use establishes the priority of the

water appropriation against all other water users on the same stream system. Water rights granted under the Doctrine of Prior Appropriation are usufructuary water rights – or the right to temporary use water without full dominion of the resource (Black’s Law Dictionary, 1990). Priority, or appropriative water rights are also subject to abandonment proceedings or forfeiture of the water right if they are not used for a defined period of time, which forms the common admonition in western water administration of “use it, or lose it”.

Contrary to riparian water rights, it is not necessary for the owner of an appropriative water right to own land bordering the stream. To develop irrigable land or serve distant mines in the arid west, it was often necessary to convey water through ditches, canals, or a series of flumes for many miles. In a parallel manner, appropriative water rights include transbasin diversions that capture and transport a portion of the headwaters of a river basin for application to beneficial use in a different watershed than the basin of origin.

The first judicial recognition of the Doctrine of Prior Appropriation was the seminal 1855 court case *Irwin v. Phillips* decided by the California Supreme Court. This case settled the question of whether an owner of a canal that diverted water from a stream in the Sierra Nevada Mountains in California for mining had a superior right to those who later developed lands along the banks of the same stream. The court found in favor of the earlier mining diversion and firmly established the Doctrine of Prior Appropriation as the predominant method to allocate limited water supplies in arid regions of the western United States. Nine states apply the priority system in its pure form, referred to as the “Colorado Doctrine” (Trelease and Gould, 1986). These states include Alaska, Arizona,

Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. The remaining western states apply the “California Doctrine”, which recognizes both riparian and appropriation water rights – with emphasis upon the priority system as the dominant law to govern water allocation within their borders.

### Ground Water Law

The increasing reliance upon ground water supplies has prompted a corresponding need to adopt laws that integrate ground water with surface water supplies and regulate its diversion and use. Unfortunately, confusion continues to exist in many states because of different applications of law for surface water versus ground water that is tributary to the same stream system. For example, in some states the Appropriation Doctrine governs surface water diversions from streams but overlying land ownership dictates the amount of ground water withdrawal from alluvial and hydraulically connected aquifers (Hutchins, 1958). Further, ground water law is more complex than surface water law due to an imprecise understanding of its clandestine hydrology. The first set of ground water laws followed English Common law and was related to land ownership: the overlying landowner was permitted to take whatever quantity they were physically and economically able to capture (Trelease and Gould, 1986). The states of Connecticut, Maine, Massachusetts, Mississippi, and Vermont continue to apply the overlying land ownership rule. State courts began to recognize the advancing knowledge of ground water hydrology and extended the Doctrine of Reasonable Use to artesian and other types of percolating ground water in the early 1900’s through imposition of specific

requirements that the owners' use of ground water must indeed be reasonable and directly applied to beneficial use on the overlying lands. Extending the application of reasonable use, Alabama, Arizona, Illinois, Iowa, Kentucky, Michigan, New York, and Wisconsin are examples of states that use this rule in regulating ground water diversions. Western states such as Alaska, Colorado, Kansas, Montana, North Dakota, and Utah have similarly adapted the prevalent Doctrine of Prior Appropriation in the region to include tributary ground water in its allocation system. The states of California, Florida, Nebraska, New Mexico, and Texas also employ a separate ground water code and use ground water districts to exert a measure of control on ground water withdrawals. Providing a complete account of applicable laws and rules that govern the diversion and use of ground water resources in the United States is beyond the scope of this effort. However, the following narrative is intended to provide a synopsis of applicable ground water case law and administrative law that may be of assistance in considering the inclusion of ground water within the allocation system for an interstate river compact.

*Tributary ground water is hydraulically connected to the stream or river.*

Conjunctive use is the integration of tributary ground water with surface water in the allocation and distribution system for a river (Corbridge and Rice, 1999). That is, solutions to conjunctive use water supply problems involve the use of both ground and surface water supplies. To effectuate the use of tributary ground water, a myriad of judicial, legislative, and administrative laws are available and implemented within the United States. Ground water permitting is typically performed by the State Engineer or other representative state official for the allocation of ground water supplies in the western states that adhere to the Doctrine of Prior Appropriations. In the eastern United

States, in which the Riparian Doctrine is applied, many states such as Michigan have no well permitting requirement – if someone wants a ground water well they simply contact a water well driller and no state permit or formal approval is required (William E. Brown, personal communication, February 24, 2003). In the arid western states a permit to divert and use ground water is required and the level of analysis to obtain a ground water well permit is commensurate with the amount of withdrawal and intended beneficial use. For example, large capacity wells that divert 800 to 1000 gallons per minute to serve as a municipal water supply or for irrigation in a center-pivot system are non-exempt wells and must also be administered within the priority system in their respective river basin. These large capacity wells require a finding that water is physically and legally available for appropriation and the diversion of ground water would not harm other water users. In Colorado, these ground water wells undergo the dual process of receiving administrative review by state officials in the permitting process and also judicial review in receipt of a ground water right. The true application of conjunctive use is evident through the ability for Colorado surface water right owners that serve their irrigated lands primarily through gravity canal diversions from a stream to also obtain a ground water well decreed as an alternate point of diversion to irrigate the same lands. The legislative branch of government may also impose conditions that affect ground water administration. In Nebraska, notification of large-capacity wells is mandatory, but it is not necessary to seek any well permit from state officials for domestic use of ground water by individual families (Ann Bleed, personal communication, April 3, 2003). The Colorado General Assembly created a declaration of no injury to senior water rights and exempts wells that

divert fifteen gallons per minute or less for domestic needs from administration or curtailment in the priority system (Colo. Rev. Stat. § 37-92-602).

Promulgation of formal rules and regulations to govern the diversion, use, and measurement of ground water is another mechanism used for administration of ground water resources. Legislative authority is typically vested to the State Engineer or other representative state official to adopt rules that regulate the large capacity wells and their impact upon tributary streamflows within the priority system or other appropriate water administrative scheme. The genesis of rules and regulations is often an intrastate lawsuit or concern by surface water right owners that they are not receiving water they are entitled to in amount and timing because of tributary ground water diversions that are junior in priority. It is important to recognize that adoption and implementation of rules and regulations to govern tributary ground water pumping must be on a river basin scale. Although it may be convenient and appear administratively efficient, targeting individual wells for curtailment that are in close proximity to the river or are located just upstream of a senior water user that is short of water would be considered arbitrary and capricious by the courts. In a threshold case on this subject, surface water right holders in the Arkansas River Basin in Colorado became increasingly concerned with the growing number of irrigation wells and their affects on stream flows. In 1964 they petitioned the Colorado State Engineer to regulate wells and curtail them in amounts necessary to protect their earlier surface water rights. During the summer of 1966 the State Engineer ordered thirty-nine wells to cease pumping. The owner of one of the wells refused and an ensuing enforcement lawsuit was brought to the courts. The Colorado Supreme Court recognized that the legislature had the authority to delegate to State water officials the

power to protect senior water right owners and the stream from material injury by junior well diversions, but noted that prescribed rules and regulations are necessary to provide equal treatment of water users under the protection clause of the Colorado and United States Constitutions [Fellhauer v. People, 167 Colo. 320,447 P.2d (1969)]. The Court further directed that non-exempt wells should be administered in the priority system, but only in accordance with reasonable rules, standards, and a plan adopted by the State Engineer *prior* to issuing curtailment orders. The Colorado State Engineer adhered to the directive of the Supreme Court and performed the requisite technical and administrative analysis for the Arkansas River Basin. On November 16, 1972 the Colorado State Engineer adopted the first set of Rules and Regulations Governing the Use, Control, and Protection of Surface and Ground Water Rights Located in the Arkansas River and Its Tributaries. The Rules have been modified over the course of time until the latest version in 1996 that reflects the increasing knowledge of ground water hydrology, modeling, and water administration to meet the complex demands of senior Colorado water users and to assure Colorado meets her interstate compact delivery obligations to downstream states.

Non-tributary ground water is not hydraulically connected to the stream system and the initial conclusion is that it should have no impact to interstate river compacts. However, a conundrum often exists because of the difference in physical and legal reality. The burden of proof in claiming that ground water is not tributary typically lies with the person making the assertion and that it must be approved by “clear and satisfactory evidence” [Safranek v. Limon, 123 Colo. 330, 228 P.2d 247(1933)]. Further, the term non-tributary itself presents a measure of ambiguity. Certainly there exist aquifers that are not hydraulically connected to any natural surface stream. However, the

term non-tributary is often intended to designate ground water aquifers that have a delayed time response to streams that is measured in a time scale of years or decades, opposed to days or weeks in tributary aquifers. For an illustration of non-tributary ground water management, farmers in the eastern plains of Colorado began developing thousands of large-capacity wells in the early 1960's into the Ogallala aquifer for irrigation of croplands. Recognizing the declining water levels would threaten the sustainability of the limited water source, the Colorado legislature created the Ground Water Commission to evaluate areas within the state where ground water withdrawals appeared to have reached or exceeded the normal annual rate of replenishment. Relying upon enabling statutory law, the Commission was authorized to create "tentatively critical ground water districts" to protect and regulate ground water withdrawals (CGWC, 1957). Intent of the Commission and supporting legislation was to provide a measure of local control to reflect site-specific physical and economic conditions by creating a local advisory board comprised of water users in the relevant ground water area to assist in the information collection and administration of ground water resources. Since inception of the Colorado Ground Water Commission, eight designated ground water basins have been identified and are managed in cooperation with thirteen local ground water management districts. To manage non-tributary ground water, the Commission has promulgated rules to regulate ground water withdrawals such as adopting a three-mile radius circle of influence around a proposed well for quantifying their depletions. To protect the sustainable yield of the aquifer, ground water appropriators are limited to an annual diversion that will not deplete the aquifer under their lands more than 40 percent in 100 years and are required to install flow meters or other devices to accurately measure

the amount of withdrawal. It is through the cooperative data collection and ground water management activities of local ground water management districts and state officials charged with interstate river compact enforcement that the intricate, and sometimes evolving, relationship of tributary and non-tributary ground water resources can be managed in perspective with interstate river compact administration.

## Interstate River Compact Law

### History and Constitutional Authority

The need for a legal venue within the United States to settle disputes over shared boundaries and natural resources dates to pre-colonial times. The earliest formal resolution of a contested territorial issue occurred over a boundary argument between two colonies in 1656 (Connecticut and New Netherlands Boundary Agreement in Frankfurter and Landis, 1925). Historical records reveal there were two peaceful forums to address disputes over shared interests or resources among the original colonies. Negotiations through joint commissions were the preferred initial attempt toward resolution. Absent reaching a mutually acceptable negotiated agreement, the contesting parties then sought the alternative method toward resolution by a formal appeal to the Crown. The initial step in this defined procedure was a hearing before the Royal Commission, which bore the characteristics of formal litigation. If necessary, an appeal contesting the decision of the Royal Commission was brought to an assembly of confidential councilors appointed by the King of England known as the Privy Council. The Privy Council reviewed the

arguments and would subsequently tender a prospective ruling to the King of England for “Royal Approbation and Confirmation” (15 Massachusetts Provincial Acts, 157 in Frankfurter and Landis, 1925). The confirmation, or reversal, of the decision by the Privy Council by the monarchy was considered resolute and final. This form of inter-colonial dispute resolution was the common practice for over 100 years until independence from England was achieved. The latest appeal on record with the Privy Council involves a boundary dispute between New York and New Jersey in 1773 [Acts of Privy Council (Col. Ser.) 45 in Frankfurter and Landis, 1925].

Upon successfully gaining independence, the statesman who authored the Articles of Confederation were keenly aware that a number of boundary disputes were still in contention among the former colonies (Frankfurter and Landis, 1925: 694). They were also mindful of the need to protect the new Union of States from the destructive political combination of two or more States and yet maintain a balance with the federalist principle of dividing authority and functions between the national government and the States. Therefore, the Articles of Confederation provided a specific appeal to Congress “in all disputes and differences now subsisting or that hereafter may arise between two or more states concerning boundary, jurisdiction or any cause whatsoever” (1781). The need to create a forum that recognized the value of solving regional issues that affected two or more States, but not the entire nation remained. It was for this express purpose that the framers of the Constitution astutely created a mechanism of legal control over affairs that project beyond state lines but may not yet call for, nor be capable of, national treatment (Frankfurter and Landis, 1925). To safeguard the national interest and coincidentally facilitate interstate adjustments, the architects of the United States

Constitution provided explicit authorization to construct interstate agreements. This mechanism is codified as the Compact Clause of the Constitution. The Constitution puts this power in a negative context to express the limitation imposed upon its exercise. The applicable provision is contained in Section 10 of Article I:

No State shall enter into any Treaty, Alliance, or Confederation...  
No state shall, without the consent of Congress, ...enter into any agreement or compact with another state...

The Compact Clause of the Constitution has been applied to a myriad of functions as a means to settle contentious issues between States in lieu of litigation. Interstate compacts have been used in context of (1) boundaries and cessions of territory; (2) control and improvement of navigation; (3) penal jurisdiction; (4) uniformity of legislation; (5) interstate accounting; (6) conservation of natural resources; (7) utility regulation; and (8) taxation (Frankfurter and Landis, 1925). It is within the realm of conservation of natural resources that interstate river compacts occur. The first interstate river compacts addressed the regulation of fisheries in rivers shared by adjoining States and navigation. Examples of these compacts include the New York and New Jersey Compact of 1833 which exercised jurisdiction over the Hudson River; New Jersey and Delaware Compact of 1907 used to settle a 27-year litigation over fishing rights in the Delaware River; and the Oregon and Washington Compact of 1918 to regulate and preserve the fishery in the boundary waters of the Columbia River. The first interstate river compact that centered upon water apportionment is the 1922 Colorado River Compact (Pub. L. No. 56, 42 Stat. 171) that provides a water allocation system to distribute the limited water supplies in the Colorado River system among the seven arid southwestern States of Colorado, Wyoming, New Mexico, Utah, Nevada, Arizona and California.

## Foundational Case Law

In addition to entering into interstate compacts or agreements, another constitutional mode of adjustment between states is provided through judicial decisions. Jurisdiction to hear lawsuits over “controversies between two or more States” is vested exclusively to the United States Supreme Court (U. S. Const. Art. III, Sec. 2). Early in the 20<sup>th</sup> Century and before interstate compacts were ratified by the respective states to govern shared water resources, decisions by the Supreme Court provided guiding and interpretive law that proved to be the foundation for subsequent compacts. In the first case that addressed a controversy over sharing water from an interstate river, the State of Kansas filed a petition on May 20, 1901 in the Supreme Court against the State of Colorado (*Kansas v. Colorado*, 1907). In *Kansas v. Colorado*, the State of Kansas appealed to the common law or Riparian Doctrine that claimed the owners of riparian lands adjacent to the river are entitled to the continual and undiminished flow of the Arkansas River. Kansas conceded that the common law had been modified in the arid western states for appropriation to mining purposes and reclamation of arid lands, but not to the extent that Colorado was justified in decreasing the amount of water delivered downstream at the Colorado-Kansas state line. The State of Colorado argued, in part, it had a right to fully appropriate the available water supplies and develop irrigable lands for increasing the value of lands and its inherent prosperity within its boundaries (*Kansas v. Colorado*, 1907). In delivering the opinion of the Supreme Court, Mr. Justice Brewer stated:

“One cardinal rule, underlying all the relations of the states to each other, is that of equality of right. Each state stands on the same level with all the rest. It can impose its own legislation on no one of the others, and is bound to yield its own views to none”(Kansas v. Colorado, 1907: 98).

The court found the diversion of water from the Arkansas River in Colorado, for the purpose of irrigation, had transformed thousands of acres of barren lands into productive and fertile fields for cultivation. Although the irrigation in Colorado had indeed diminished the flow into the State of Kansas, the court recognized its beneficial use was warranted and found the diminution in streamflow provided little, if any, detriment to Kansas’ interests. In its dismissal of the lawsuit with prejudice, the court provided cogent notice that further depletions of the Arkansas River by Colorado which would alter the equitable division of water, would justify Kansas to seek relief in the future. This decision serves as the foundation for the Doctrine of Equitable Apportionment, which portends the assurance to adjacent states that they each receive an equitable allocation of the benefits and responsibilities derived from an interstate river (Knox, 2001). The true weight and application of equitable apportionment is made clear through their finding “no one State can control the power to feed or to starve, possessed by a river flowing through several States” (Kansas v. Colorado, 1907: 98).

The second case, *Wyoming v. Colorado*, is an original action brought by the State of Wyoming against the State of Colorado and two Colorado corporations to prevent a proposed diversion from the headwaters of the Laramie River [259, U.S. 419, 42 Sup. Ct. 552, (1922)]. The Laramie River is an interstate river that arises high in the Rocky Mountains in north-central Colorado and flows north 27 miles before crossing into Wyoming. This lawsuit was brought by Wyoming to seek an injunction to prevent the

two corporate defendants, operating under the permission of the State of Colorado, from constructing a large diversion in Colorado that would transport a significant portion of the Laramie River to the Cache la Poudre River Basin for consumptive use wholly within Colorado. Wyoming sought the injunction on two bases: (1) water from an interstate stream could not rightfully be taken from its watershed and carried into another; and (2) water appropriations in Wyoming which were prior in time and superior in right to the proposed Colorado diversion would be harmed by the transbasin export (Wyoming v. Colorado, 1922). Colorado answered, in part, the transbasin diversion was justified since irrigation of lands in the Poudre valley was in a higher state of development and more agricultural production would be achieved than if the water were applied to lands in the Laramie valley. The Supreme Court did not accept the first argument from Wyoming because diversions from one watershed to another were common practice in both States. The court went on to acknowledge that both States applied the Doctrine of Prior Appropriation within their respective borders for as long as 50 years. In delivery of the opinion of the court, Mr. Justice Van Devanter found this method of water allocation should also apply across state borders:

“The cardinal rule of the doctrine is that priority of appropriation gives superiority of rights. Each of these states applies and enforces this rule in her own territory, and it is the one to which intending appropriators naturally would turn for guidance. The principle on which it proceeds is not less applicable to interstate streams and controversies” (Wyoming v. Colorado, 1922).

In its finding, the court clearly held that when both states apply the same method of allocating water resources within their respective boundaries, they must extend this same

principle across state lines and distribute the limited interstate river water strictly in accord with that method of allocation as if the boundaries did not exist (Knox, 2003).

The application of interstate river compacts to allocate limited water supplies is not vested exclusively to the western United States. In its bill in equity known as *New Jersey v. New York*, the State of New Jersey sought to enjoin the State of New York and City of New York from diverting any water from the headwaters of the Delaware River [283 U.S. 336, 51 Sup. Ct. 478 (1931)]. New York sought to meet the burgeoning municipal water supply demands of New York City by diverting a large amount of water from the Delaware River and its tributaries into the Hudson River watershed. The petition filed by New Jersey asserted a strict application of the Riparian Doctrine was warranted to protect the right enjoyed by owners of riparian lands to the undiminished flow of the river to which they were entitled by the common law adopted by both States. New Jersey also asserted the proposed transbasin diversion would interfere with the navigability of the Delaware River, injuriously affect water power development, the fishery, salinity, and sanitary conditions of the river (*New Jersey v. New York*, 1931). The State of Pennsylvania intervened to protect her interests and future needs (*New Jersey v. New York*, 1931). The case was referred to a Special Master appointed by the Supreme Court to hear evidence and tender a report to the court for consideration. After hearing a substantial amount of evidence, the Master concluded that upper reaches of the Delaware River where the City of New York proposed to erect dams and diversion was not navigable and would not impair the future hydropower development plans of New Jersey. The Master went on to find the proposed diversion of 600 million gallons per day would not adversely affect the sanitary or salinity conditions, but did hold that amount to

be excessive in terms of equity and reduced the draft to 440 million gallons per day. The Special Master also recognized the importance of integrating streamflows and reservoir storage as an effective means of conjunctive water supply management and thereby required New York City to release impounded waters in its upstream storage facilities in sufficient volume to assure the downstream flow of the Delaware River was at least 1,535 cubic feet per second at Port Jervis, New York and 3,400 cubic feet per second at Trenton, New Jersey. In confirmation of the report tendered by the Master, the court reaffirmed the principle of equitable apportionment. As stated in the opinion delivered by Mr. Justice Holmes:

“In a most competent and excellent report the Master adopted the principle of equitable division which clearly results from the decisions of the last quarter of a century. Where that principle is established there is not much left to discuss. The removal of water to a different watershed obviously must be allowed at times unless States are to be deprived of the most beneficial use on formal grounds” (New Jersey v. New York, 1931).

The final case brought for reference is the decree handed down by the Supreme Court in 1945 that ended 11 years of litigation over the interstate North Platte River known as *Nebraska v. Wyoming* [325 U.S. 589, 65 Sup. Ct. 1332 (1945)]. The State of Colorado was also listed as a defendant and the United States was granted leave to intervene. Again, a Special Master was appointed to hear evidence and tender a proposed ruling to the court for final consideration. The North Platte River rises near the Continental Divide in Colorado and flows north into Wyoming before turning southeast and flowing into Nebraska where it meets at the confluence with the South Platte River to form the Platte River. Extensive lands are irrigated in both Wyoming and Nebraska through surface water diversion and storage projects that were constructed in cooperation

with the United States Bureau of Reclamation starting in 1904. Nebraska initiated this action in 1934 as a result of an extended dry cycle in which the river flow was insufficient to meet irrigation and storage demands then in existence. The Special Master recognized all three States applied the appropriation doctrine as the dominant method of water allocation within their respective boundaries (*Nebraska v. Wyoming*, 1945).

Nebraska sought a decree of equitable apportionment to enjoin upstream water diversions by those junior, or later in priority. The complexity of this case is compounded by the distance and transit time of water flowing between the upper and lower reaches of the river. For example, Nebraska conceded that the rule to curtail all junior appropriations should not be strictly applied to Colorado since water bypassing a closed canal headgate in North Park, Colorado would take two to three weeks to reach a Nebraska water user - if in the unlikely event it would not be consumed entirely in transit. The Special Master recommended the court adopt a decree that segmented the North Platte River system into administrative reaches with specific irrigated acreage limitations and a defined percentage to allocate streamflows in the lower reaches between Wyoming and Nebraska. The Special Master also recommended Wyoming be enjoined to respect the priority of discrete storage reservoirs and canal diversions. In a split decision, the Supreme Court found the allocation method recommend by the Special Master to be the most equitable means of apportionment and confirmed the report. The difficulty and complexity of administering an interstate river in an arid region, even when all participatory states adhere to the same method of allocation, is codified in the opinion by Mr. Justice Douglas:

“If an allocation between appropriation States is to be just and equitable, strict adherence to the priority rule may not be possible. For example, the economy of a region may have been established on the basis of junior appropriations. So far as possible those established uses should be protected though strict application of the priority rule might jeopardize them. Apportionment calls for the exercise of an informed judgment on a consideration of many factors. Priority of appropriation is the guiding principle. But physical and climatic conditions, the consumptive use of water in the several sections of the river, the character and rate of return flows, the extent of established uses, the availability of storage water, the practical effect of wasteful uses on downstream areas, the damage to upstream areas as compared to the benefits to downstream areas if limitation is imposed on the former – these are all relevant factors. They indicate the nature of the problem of apportionment and the delicate adjustment of interests which must be made” (Nebraska v. Wyoming, 1945).

### Justification for Adopting Interstate River Compacts

Adoption and ratification of compacts by participatory states to allocate and share the water supply afforded by an interstate river system has several key advantages over litigation. First, the ratification of an interstate river compact is dependant upon a thorough and factual discussion of all relevant issues outside of formal court proceedings. Historic streamflow and climate records, irrigated acreage, municipal water supply demands, streamflow transit time and gain/loss, reservoir storage location and capacity, and other integral factors are quantified and evaluated by the representative compact authorities for each state. It is also important to recognize the professional expertise offered by those individual that are involved in compact negotiations and discussion. Engineers, hydrologists, land use specialists, irrigators, planners, and other technical experts complement the political representatives and legal counsel that negotiate the express terms and language in a proposed interstate river compact. They are also able to

conduct these discussions in a more congenial and flexible work environment than that afforded in the decorum of litigation in a court of law.

The second advantage an interstate compact offers to participatory parties is acceptance of a solution that is mutually beneficial. The litigation process is designed to be adversarial in nature and costly in both time and fiscal resources. Design of an allocation system to equitably share limited water supplies from an interstate river system in time, amount, and location is complex and requires thoughtful consideration to address all of the parties needs. Collaborative decision making by representatives of the shared interstate river is always preferable to the peril of a judicial decision made by one individual that may be made under limited factual understanding or in a constrained timeframe.

Compacts are legally binding instruments that are contractual in context and enforcement. They are defined as a contract between parties, which creates obligations and rights capable of being enforced as contemplated as such between the parties, in their distinct and independent characters (Black's Law Dictionary, 1990). Interstate river compacts typically include a water allocation system or some other form of index to assure the downstream states they are receiving their entitlement in time and amount as specified in the terms and conditions of the compact. Interstate river compacts also offer a measure of confidence to those participatory states that develop their water resource needs as a slower pace than the other signatory states. A typical interstate river compact that centers upon a water apportionment system will include protective language that assures the right to full development of each participatory states' water allocation in perpetuity.

## Implementation of Interstate River Compacts in the United States

As noted previously, interstate compacts used to settle existing and future disputes have been employed in the United States since colonial times. They are also dynamic legal instruments that are subject to amendments to reflect evolving conditions and meet new challenges. For example, Maryland and Virginia ratified the Potomac River Compact in 1785 to provide a measure of mutual protection and benefit over the fishery shared by both states. This compact has been amended and updated throughout history to the present 1958 compact that continues to provide joint conservation and improvement of the fishery resources in the Potomac River tidewater [Potomac River Compact, Mary. Nat. Res. Code Ann 4-306 (1958)]. Currently there are 45 interstate compacts that focus on water resources within the United States. The geographic application of water-related interstate compacts covers the breadth of the continental United States from Maine to California and Minnesota to Texas. Eighteen of the interstate compacts are located east of the Mississippi River. They encompass a wide variety of intended purposes. The principal purposes of these compacts include water supply/allocation, water quality, sanitation, fishing, recreation, flood control, and coordinated planning and development of the shared water resources. Forty states of the Union are represented in interstate compacts that have a water resources related focus. One compact, the Great Lakes Basin Compact includes States of Ohio, Indiana, Illinois, Michigan, New York, Minnesota, Wisconsin, Pennsylvania and the two Canadian Provinces, Ontario and Quebec, to promote the development, use, and conservation of Great Lakes Basin [Pub.

L. No. 90-419, 82 Stat. 414 (1968)]. The Rocky Mountains are the apex of the Continental Divide and the headwaters for many western rivers in the United States. It is therefore logical for Colorado to be party to the most interstate compacts of any state. Colorado is party to one international treaty, nine interstate river compacts, two interstate agreements, and two U.S. Supreme Court Cases that govern the allocation of water [Treaty with the Republic of Mexico on the Rio Grande, Tijuana, and Colorado Rivers (1945); Colorado River Compact (1922); La Plata River Compact (1922); South Platte River Compact (1923); Rio Grande River Compact (1938); Republican River Compact (1942); Amended Costilla Creek Compact (1963); Upper Colorado River Compact (1948); Arkansas River Compact (1948); Animas-La Plata Project Compact (1969); Pot Creek Memorandum of Understanding (1958); Sand Creek Memorandum of Agreement (1997); Nebraska v. Wyoming 325 U.S. 589 (1945); and Wyoming v. Colorado 353 U.S. 953 (1957)]. Neighbors of Colorado to the north and south, Wyoming and New Mexico respectively, follow in the number of compacts with eight. At this juncture it is important to note that interstate compacts are not the exclusive mechanism employed by neighboring states to administer or allocate shared water resources. Many river systems are administered pursuant to explicit direction provided by the United States Supreme Court. An example of water administration conducted pursuant to judicial direction is the North Platte Decree of 1945 that allocates water from the Laramie and North Platte Rivers among Colorado, Wyoming, and Nebraska (Nebraska v. Wyoming, 1945). The Chesapeake Bay Commission Agreement is an example of a formal intergovernmental agency created to provide mutual protection of the Chesapeake Bay and offers

coordinated planning and development opportunities for Maryland, Virginia, and Pennsylvania (Mary. Ann. Code § 8-301).

As previously mentioned, 29 interstate river compacts cite water supply/allocation as the principal purpose of the compact, of which six of the water supply compacts include ground water within the defined sources of supply and within the allocation system. It is also interesting to note the Klamath River Basin Compact specifically omits ground water from the allocation system [Ore. Rev. Stat. 542.610 (1957)]. Allocation of interstate river water supplies was first addressed in the Colorado River Compact of 1922 and has carried forth to the two most recent compacts, the Apalachicola-Chattahoochee-Flint River Basin Compact (Ga. Code Ann. § 12-10-100) and Alabama-Coosa-Tallapoosa River Basin Compact (Ala. Ann. § 33-18-1), which were ratified in 1997 by their respective states legislatures but have not yet been approved by Congress because they are still awaiting construction and acceptance of the water allocation formulas/system.

The historic application of Constitutional authority to create interstate river compacts was formed with the intent to exert proper stewardship and conservation of surface water as a natural resource. Implemented as a legal contract among participatory states, the core purpose of an interstate river compact is to provide a regional solution to regional problems – without intrusive control or oversight by the federal government (Frankfurter and Landis, 1925). Invocation of the Compact Clause to exercise appropriate stewardship of an interstate river system provides a viable and dynamic mechanism to assure an equitable allocation of available streamflows, with no preference given to upstream states. Although the early interstate river compacts satisfied the original intent to equitably allocate a shared river for reclamation of arid territory in the southwest,

administrators of interstate river compacts throughout the nation are faced with the mandate of meeting increasing water supply demands for a myriad of new uses. These additional demands vary in scope from meeting the potable drinking water supply demand in growing towns and cities to serving new types of water use, such as snowmaking and instream flows to protect endangered species, which were not even contemplated by water administration officials only a few decades ago. Interstate compact administrators must also apply this mandate across state lines and actively seek and capture new water supply sources for inclusion within the allocation system for interstate river compacts. Unfortunately, the original authors of the compacts did not typically contemplate the use of ground water since they often were unknown to them in terms of availability, need, or even existence. Regardless of historic knowledge or decisions, tributary ground water supplies are increasingly used to meet demands and often warrant inclusion within the allocation system in interstate river compacts.

## Development of Ground Water Resources

### Ground Water Well Drilling

The Chinese are recognized as being the first innovators to drill wells using percussion methods. Review of various accounts indicate they used a walking beam or a spring pole with an attached iron tipped bamboo rod as a chisel and also cased the well with bamboo (Parker, 1988). The purpose of these early wells was to extract salt from brine, and they often required several decades to complete. Ancient Persians and

Egyptians also applied rudimentary percussion drilling techniques to develop drinking water supplies. About 2100 B.C., one leader of Mentuhotep's Egyptian forces reported sinking fourteen wells with an army of three thousand men (Johnson, 1966). Drilling for ground water was not documented in Europe until the 12<sup>th</sup> century. In 1126, the first known well was successfully drilled at Artois, France. The term "artesian" is derived from the name of this community. Later in 1833, drilling began for an artesian well near Paris at Grenelle, France that was constructed to a depth of 1,798 feet and required eight years of work until its completion in 1841 (Johnson, 1966). In the United States, one of the first uses of the percussion method for drilling wells was in Buffalo Lick, Virginia about 1808 using a manually operated spring pole system. Upon the advent of steam power, boilers and engines replaced the manual up and down motions of the spring pole. On August 27, 1859, Edward L. Drake struck oil near Titusville, Pennsylvania at a depth of 69 feet below the ground surface. The ensuing "oil boom" provided the impetus to develop bigger, better, and more powerful drilling and pumping equipment. The period from 1870 to 1900 was a period of experimentation to develop new methods of water well drilling that were more portable and could be operated at a lower cost. By the advent of the 20<sup>th</sup> century, improved cable-tool and hydraulic-rotary methods were being used to reach the deepest aquifers. Advanced drilling methods are now available to penetrate all the various geologic conditions that range from hard rock such as granite to unconsolidated sand and gravel materials in a river alluvium. The different options for modern well drilling include cable tool, direct rotary, reverse circulation rotary, air systems, inverse drilling, dual-wall reverse circulation rotary, jet drilling, hydraulic-percussion, boring with earth augurs, and directional drilling (Driscoll, 1986).

## Pumps and Power Supplies

Through the Revolutionary War in the United States, hand-dug wells were typically cased with stone or brick and a wooden bucket attached to a hand-winch was the predominant mechanism to retrieve ground water. During this era, percussion-drilled wells were equipped with suction water pumps that were completely wooden except for the wrought iron lifting rods and the handle. In 1798, the English hydraulic engineer Joseph Bramah made the first cast iron pump which was ideal because it did not rot like wood or corrode like wrought iron (Driscoll, 1986). As settlement of the Great Plains in western United States progressed, farmers began to use ground water to irrigate a few acres of farmland or orchards. Since the only source of power available was from the natural environment, western farmers desperate for irrigation water used the windmill, which was patented in 1854 by Daniel Halladay (Green, 1986). Unfortunately, windmill design during the late-1800's limited pumping to shallow water depths less than 80 feet and were capable of providing sufficient flows to irrigate only a few acres – and only when the wind was available. To lift sufficient water to meet commercial irrigation demands, the centrifugal pump with diffusion vanes surrounding the impeller was developed in 1875 (Driscoll, 1986). By 1910, the internal-combustion engine was being used to provide the source of power for pumping plants. Unfortunately, at that time gasoline was an expensive fuel, which led to development of the oil-burning engine. This engine provided the dual advantages of simple design and inexpensive fuel. However, the piston and centrifugal pumps of this era continued to have power transmission

problems. Engineers at the time were convinced that placing the pump and power supply in close proximity could alleviate the problems. In 1916 the Russian Armais Arutunoff developed a completely new and innovative motor and pump system design that is still in use, the first submersible motor (Water Well Journal, 1985). The next major advancement in pumping technology was the turbine pump developed in the 1920's. The pump was developed for application in municipal water supplies and the multistage impellers turn inside "bowls" at a much higher number of revolutions per minute in 8-inch well casings that reduced the minimum size of well bores and corresponding well construction costs (Driscoll, 1986).

Post World War II, ground water irrigation expanded dramatically – particularly in the western United States. To complement the advanced pump and well construction designs, two other aspects proved important to the development of ground water irrigation. First, the center-pivot irrigation system was patented in 1949 by Frank Zybach (Water Well Journal, 1985). These systems offered a significant advancement in farming practices and economics by providing a reliable source of water supply to meet crop demands and increase production yield per acre. They also provided a mechanized application system that allowed a farmer to greatly expand irrigated acreage while minimizing irrigation manual labor. As a measure of increasing center pivot irrigation and the corresponding ground water development, the Highline Electric Association provides power to irrigation wells in rural northeastern Colorado. In 1960, the association provided power for 284 turbine pumps that were located close to the South Platte River to flood irrigate crops. Twenty years later, in 1980 the association was providing power to 2,538 irrigation pumps serving automatic sprinkler systems

(McCaffree, 1985). The second major aspect came in the form of power supplies to run the pumps. Fuel costs were lowered when farmers converted from gasoline and diesel fuel to less-expensive methane, propane, and butane gases that were piped in from large regional gas fields in Texas, Oklahoma, Kansas and other states. Another significant power source that became a viable economic alternative in rural America was electricity. The Rural Electrification Administration (REA) was created by Executive Order 7037 and approved on April 8, 1935 (USDA REA, 1936). The initial focus of expenditures and efforts of this Congressional action was to broaden the telephone and electrical service associated with the Tennessee Valley Authority. However, post-World War II the program was amended to lower the repayment costs that would bring electricity to vast rural areas west of the Mississippi River. Local Rural Electric Associations were incorporated to provide electrical service and management in regional areas. For example, the Highline Electric Association was incorporated on December 19, 1938 to provide service in Phillips County in the extreme northeastern corner of Colorado. Construction of power infrastructure and expansion of service of electricity in the agrarian area expanded from 288,514 KWH sold in 1945 by several orders of magnitude to 263,626,281 KWH in 1984 (McCaffree, 1985). In the rural High Plains of eastern Colorado, the population declined as people emigrated from the farms to seek employment in the cities and the preponderance of the increased KWH sold by the Highline Electric Association is attributed to providing power to ground water pumps for irrigation. Although the power supply to service ground water irrigation wells fluctuates between natural gas and electricity based upon price and proximity to gas fields,

electricity has become the predominant source of power due to its accessibility, reliability, and the cost of building power lines opposed to gas pipelines.

## Quantification of Ground Water Resources

### Hydrograph Separation Techniques

To quantify the contributory flow from ground water aquifers into a tributary stream system or interstate river there are graphical, empirical, and computer-based techniques available. For foundation, three principle components of water travel patterns from precipitation comprise a streamflow hydrograph: surface runoff, interflow, and ground water flow that is also called baseflow (Linsley, *et. al.*, 1982a). Surface runoff is precipitation that travels across the ground and flows directly into the stream system. Interflow or subsurface storm flow is precipitation that infiltrates the soil surface and moves laterally through the upper soil layers until it enters the stream channel (Linsley, *et. al.*, 1982a: 205). Due to the relatively short time it takes for the interflow water to travel through the shallow depths until it reaches the stream channel, interflow is commonly included within the direct surface water runoff component (Linsley, *et. al.*, 1982a: 171). The third and final component is that precipitation that percolates through the upper soil layers until it reaches the water table. The geologic stratum that exhibits sufficient porosity and hydraulic conductivity to store and transmit water in significant quantities is defined as an aquifer (McWhorter and Sunada, 1988: 7). Groundwater movement through aquifers follows the subterranean hydraulic gradient until they reach a

point of intersection with the surface water stream. The rate of ground water contribution from baseflow does not vary significantly and does not mimic the pattern or amplitude of a storm water runoff since the flow velocity through the porous earthen materials is very slow – often taking months or years to reach the river system.

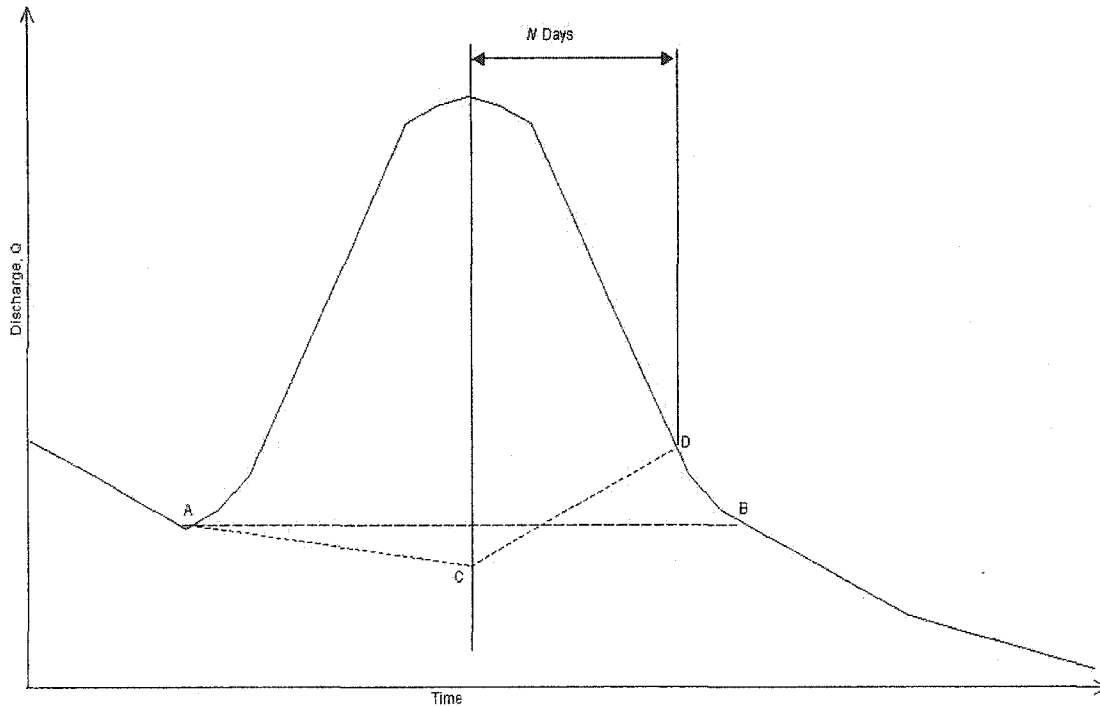
Graphical hydrograph separation is the traditional method used to quantify the contributory effects of baseflow in a streamflow hydrograph. For illustrative purposes, the components of a hydrograph are shown in Figure 2. The simplest graphical baseflow separation technique is to draw a horizontal line from the point at which surface water runoff from a precipitation event begins, Point A in Figure 2, to an intersection with the hydrograph as it recedes depicted by Point B.

An alternative method is to consider the timing of the precipitation event by projecting a continuance of the hydrograph curve downward from Point A to Point C, which lies directly below the peak flow. The projection then intersects the hydrograph recession at Point D, which are  $N$  days after the peak rate of flow occurs. One estimate of  $N$  is based on the formula (Linsley, *et. al.*, 1982b):

$$N = A^{0.2}$$

Where  $N$  = the time in days  
 $A$  = the drainage area in square miles.

Figure 2. Hydrograph Separation



Both of these methods are considered to be approximate because of the short periods of analysis and subjectivity of the analyst, but prove to be a reliable and accurate representation of the separation between surface runoff and baseflow on an annual basis. The main drawback to graphical hydrograph separation technique is the tedious work and substantial time demand required by the analyst.

In an attempt to dampen the subjectivity of base flow analysis performed by individual analysts; the British Institute of Hydrology developed a deterministic procedure that is less tedious and more objective in 1980 (Institute of Hydrology, 1980). The procedure divides the water year into 5-day increments; from which the minimum flow during each 5-day period is identified. Minimums are then compared with the minimums of adjacent 5-day periods to determine turning points on the baseflow

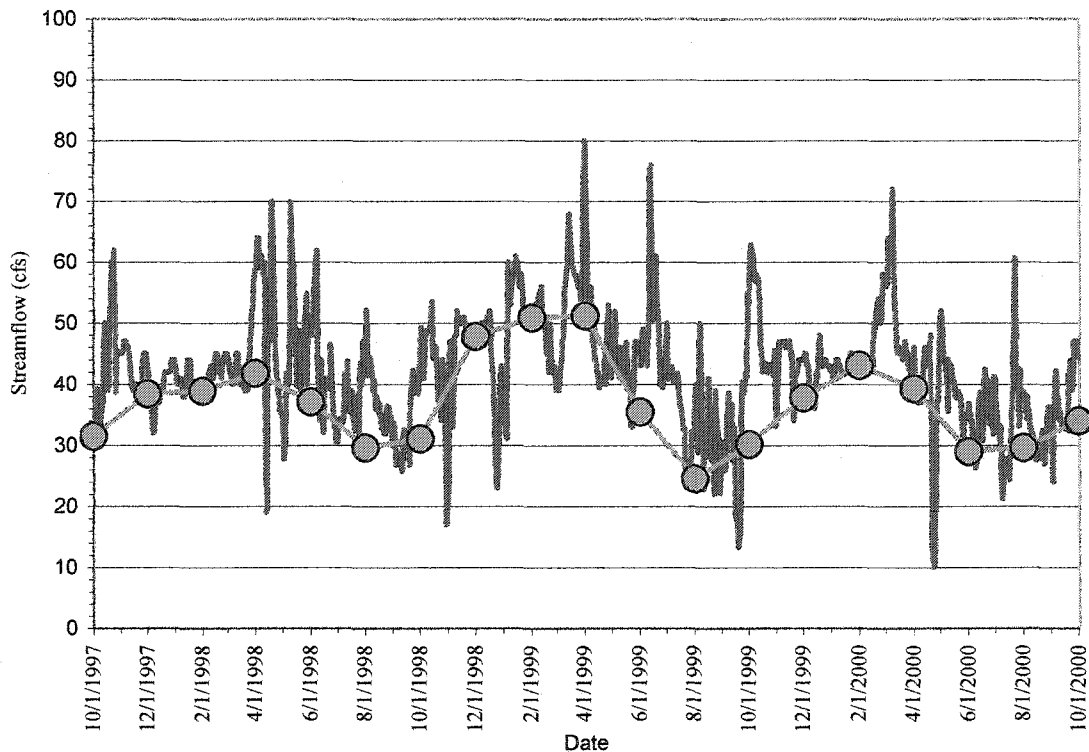
hydrograph. A 5-day minimum is considered a turning point if 90 percent of its value is less than both the preceding and succeeding 5-day period minimums. Straight lines are drawn between the turning points on semi-logarithmic paper and the area beneath the hydrograph is the estimated volume of baseflow for the period of analysis. The ratio of this volume to the total volume of streamflow for the period is defined as the baseflow index (Wahl and Wahl, 1988).

The baseflow index procedure has been automated through computer programming to efficiently and objectively perform a hydrograph separation analysis for many years (Wahl and Wahl, 1988). Applying the baseflow index method to the total streamflow volume at one or multiple sites has the obvious advantages of objectivity and computational efficiency for unregulated streams. Caution is extended for potential application on streams regulated by reservoir storage/releases that affect the total measured streamflow (and subsequently the baseflow) at a river gaging station or for short-term storm events (Wahl and Wahl, 1988). Further, it is important to recognize that the baseflow index method has been found to provide an indicative and consistent estimate of baseflow, but it may not yield the true baseflow as might be determined by a more sophisticated analysis (Wahl and Wahl, 1988: 244).

The most recent advancement in hydrograph separation analysis is referred to as the Pilot Point method. This procedure combines the increased accuracy of graphical baseflow analysis with the computational efficiency afforded by electronic spreadsheets. Daily streamflow information for one, or multiple years, is easily tabulated in an electronic spreadsheet such as Microsoft Excel<sup>®</sup> and daily hydrographs are subsequently plotted using the graphics package. The analyst performing the baseflow separation uses

the tools available in the electronic graphics package to select pilot or turning points that signify the baseflow component in the total amount of streamflow measured at a river gaging station. An example of the Pilot Point method is illustrated in Figure 3.

Figure 3. Estimated Baseflow at North Fork of Republican River at CO-NE State Line.



A significant contribution of the graphics and computational package afforded by Microsoft Excel<sup>®</sup> is the flexibility to easily change the assignment of each pilot or turning point upon comparative review with other nearby streamflow hydrographs or in collaboration with another analyst. The analyst may change one or multiple pilot points using the click-and-drag tool to another location and instantly recalculate the amount of baseflow for a defined period of time. Use of the electronic graphical/computational

Pilot Point method also dampens the objectivity criticism of the traditional hand-graphics technique performed by an individual analyst.

### Consumptive Use Analyses

To complement the calculation of ground water discharge from an aquifer into an interstate river, it is also advantageous to determine the total and net amount of ground water withdrawn from the aquifer. Discrete measurements of ground water pumping are easily obtained through use of flow meters or other empirical methods to quantify the rate and volume of ground water withdrawals. Flow meters offer a simple and widely accepted means to measure ground water pumping because the factory-calibrated instruments are easy to install and read. To retain an acceptable degree of accuracy, flow meters require periodic maintenance and eventual replacement because pumped ground water typically carries a measurable amount of fine sands or sediments that cause damage to the impellers of a flow meter. Ground water pumping may also be accurately measured through application of a power conversion coefficient (PCC) calculation that is an empirical method that establishes a correlation between the amount of electrical power consumed to the amount of water pumped by a particular structure. This numerical calculation offers a mechanical advantage over flow meters because it requires less mechanical maintenance. Although it is obvious that the application and use of flow meters or PCC calculations are commonly used to measure the amount of ground water withdrawal, their application is limited to ground water wells that are so equipped with either form of instrumentation. The computation of the total amount of ground water

withdrawn and used in a region or watershed will often require other methodologies because not all of the wells in the watershed are metered or calibrated to a PCC correlation.

An attractive alternative to requiring the installation and maintenance of flow meters on all ground water wells within an interstate river basin to measure total ground water withdrawals is the application of the crop irrigation requirement (CIR) empirical analysis. This method estimates the total amount of ground water pumped and net amount consumed by the irrigation of crops. The following eight-step procedure may successfully be employed to quantify ground water pumping for irrigation of croplands in a county, region, or river basin within the United States:

1. The total amount of irrigated acreage is estimated for each county, township, or other geopolitical region (county) based upon data recorded in the local County Assessor's office. The information from the County Assessor's office is deemed reliable and accurate because it is highly scrutinized by individual landowners who are required to pay property taxes on the size and type of lands identified. The county-level irrigated acreage information is verified by comparison with irrigated acreage information published by the National Agricultural Statistics Service (NASS).
2. The amount of acreage irrigated by surface water is quantified from the County Assessor's records. The County Assessor's office typically identifies surface water irrigated lands because they assess a higher valuation and tax per irrigated acre than for non-irrigated lands.

3. The acreage irrigated by ground water is calculated as the difference between the total irrigated acres and acreage irrigated by surface water sources.
4. The maximum farm efficiency for center-pivot, gated pipe, flood, or other methods of irrigation is estimated for each year.
5. The percentage of acreage irrigated by center-pivot systems and other irrigation methods are estimated for each county in the basin each year.
6. The potential crop water requirements are estimated in each county using the Hargreaves, Blaney-Criddle, Penaman-Monteith, or other empirical crop consumptive use calculation for the reference crop evapotranspiration. The quantity of irrigated acreage for each crop is estimated from NASS county-level crop statistics. The effective precipitation is estimated from climatological records and prescribed Department of Agriculture procedures (USDA SCS, 1967). The net crop irrigation requirement is calculated as the difference in the potential crop water requirement and the effective precipitation.
7. The calculated net crop irrigation requirement is reduced by the measured average amount of antecedent soil moisture from winter and spring precipitation.
8. Estimated ground water pumping for each county is the product of irrigated ground water acreage multiplied by the net crop irrigation requirement multiplied by the fraction of crop irrigation requirement satisfied (the fraction of crop irrigation requirement satisfied is estimated from measured pumping records that are available within the basin). The total volume of ground water pumped in each county is the estimated ground water pumped divided by the maximum farm efficiency. The maximum farm efficiency is a weighted average based upon the

amount of lands served by center-pivot sprinklers, flood, or other irrigation methods in the county (RRCA Ground Water Model, 2003).

Calculation of the amount of ground water pumped and consumed by small domestic wells in the geopolitical regions is performed by multiplying the total number of adjudicated or permitted domestic wells in the region by the appropriate consumptive use factor. Based upon professional experience, an accepted water resource engineering consumptive use calculation for a domestic well is 35 gallons per household per day plus the net irrigation requirement to irrigate 1.0 acres or less of lawn and gardens (the well is assumed to serve a residential family of 3.5 people who use 100 gallons per person per day and the net consumptive use is 10 percent of the diversion)(Colorado SEO, 1990). Municipal and industrial ground water net consumptive use is typically calculated as the difference between the measured quantity of ground water pumped through a flow meter minus the amount recorded through a wastewater discharge point.

### Modeling

Mathematical models are used to represent and simulate the physical environment to a reasonable degree. The application of ground water mathematical models is particularly attractive to water administration officials seeking to understand the flow of clandestine ground waters and to determine the impacts of ground water pumping upon tributary stream systems. Although the discussion of the mathematics and intricacies of ground water modeling is beyond the scope of this dissertation, their application and use

in conjunctive water resources management and inclusion within interstate river compact administration is growing.

The most common mathematical model used in ground water investigations is a computer program developed in 1984 that is referred to as MODFLOW (Harbaugh, *et. al.*, 2000). This numerical computer program solves the three-dimensional ground water flow equation for a porous medium using the finite-difference method. It is designed to have a modular structure that facilitates two primary objectives: ease of understanding and ease of enhancement. The developers of MODFLOW adhered to the premise that technical water resources managers who are charged with operating and applying the ground water model to a specific ground water system should have a basic understanding of how the model works in order to use it properly. Ease of enhancement is the second objective because practical experience indicates there is a perpetual need to include new model functionality to keep pace with growing demands for additional study parameters. Both attributes are necessary when attempting to quantify and administer ground water resources within any water management system (Harbaugh, *et. al.*, 2000).

To complement the mathematical modeling used to represent ground water movement, analytical models also provide a tangible mechanism to advance engineering research by assisting policy-makers in the decision process. The genesis for the scientific approach of using mathematical models to assist in the decision-making process was the need to allocate scarce resources in the most effective manner possible during World War II, which became known as operations research (Hillier and Lieberman, 1990). The primary objective of operations research is to provide an optimal solution to a complex problem by using a mathematical model to represent the physical and organizational

constraints inherent within a real issue (Hillier and Lieberman, 1990). During the subsequent decades, the use of advanced mathematical problem solving techniques and high speed computing capabilities has progressively been used to develop numerical, analytical, statistical, and optimization models (Labadie, 1999). Mathematical models have increased in use, but they continue to exhibit limited capabilities in formulating decision options for complex regional water problems due to the non-technical components in the decision-making process (Adams, 1998). In an attempt to address the need to consider non-technical parameters, mathematical programming and models such as Goal Programming, ELECTRE, PROMETHEE, and Analytical Hierarchy Process were developed with the intent to assign numeric values to judgment factors for application in an analytical evaluation (Labadie, 1999). According to Labadie, new techniques such as fuzzy logic, expert systems, and other mathematical models continue to be developed in water resources research in the attempt to effectively represent the non-quantifiable or judgment decisions in water resources engineering and management. However, decisions that are based solely on mathematical computer models without human judgment and subjectivity are ineffective (Loucks, 1992; Adams, 1998; Labadie, 1999). Because sound human judgment and objective analysis continue to be necessary for effective decision-making in water resource management and compact administration to address the social, economic, and political factors, it is necessary to understand these intricate and integrated processes through a systems approach with non-numeric and unstructured data (Goodman, 1984; Adams, 1998).

## CHAPTER 3

### RESEARCH METHODOLOGY AND DESIGN

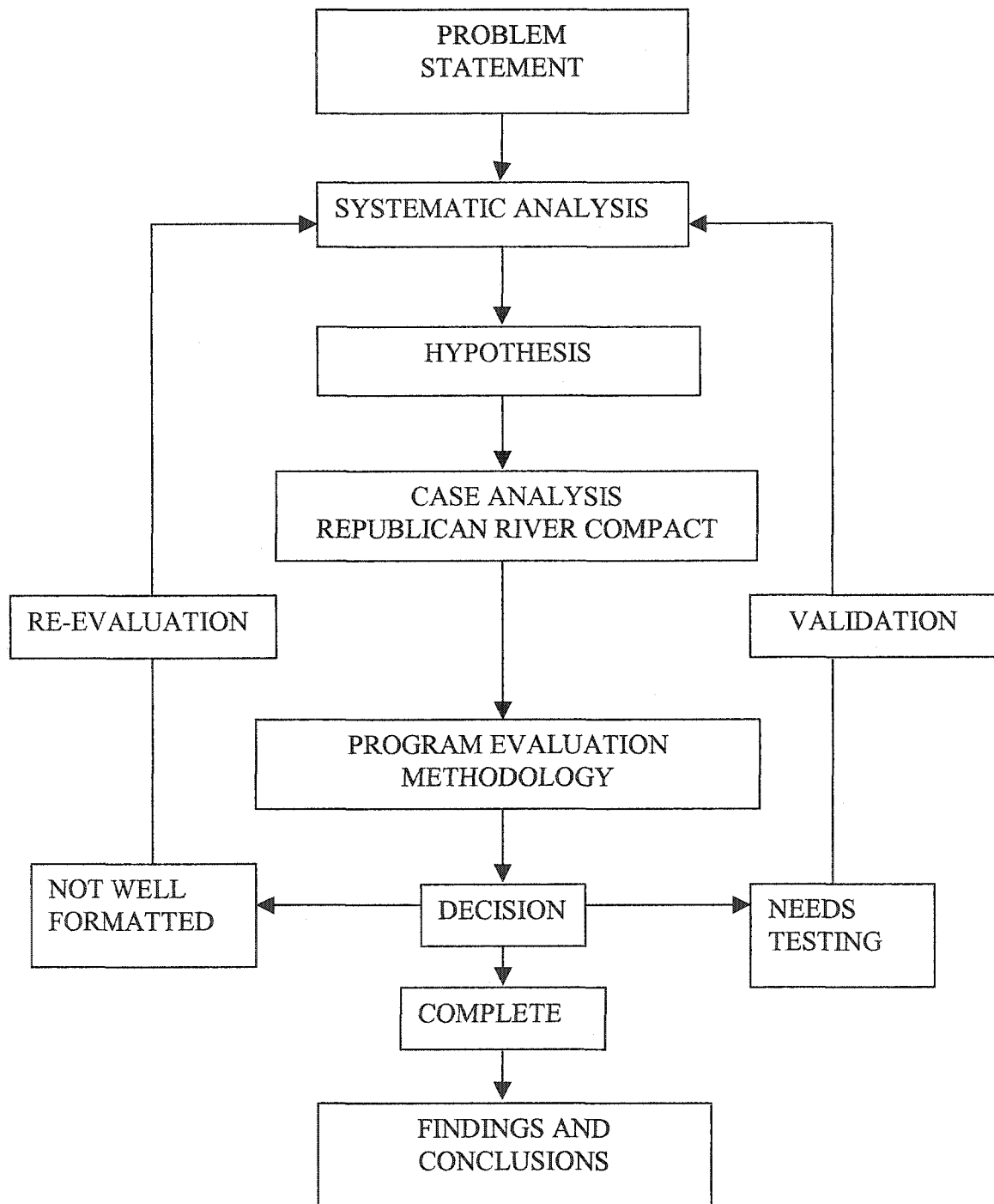
As described in the introduction, the basis for this research is an evaluation of the Republican River Compact administration as a case study and the issues associated with including ground water within the allocations system. The use of case studies, as a research strategy, is an effective method to systematically analyze the integrated processes associated with complex interstate water issues in a comprehensive manner (Yin, 1993, Adams, 1998). The impetus to analyze interstate river compact administration as a comprehensive, holistic, and integrated water management program is through recognition that water management activities are multi-faceted and require a systems approach to improve our understanding of the issues and assist in the decision-making process (Grigg, 1996a). The application of a case study in the evaluation of interstate compact administration, as a public program, is appropriate because the decision-making processes include qualitative data and factors that cannot be readily converted to numeric values. Interstate compact authorities use qualitative information in policy planning, promulgating regulations, and enforcement activities (Barton, 1967). Such qualitative data can be “represented by categorical data, by perceptual and attitudinal dimensions not readily converted to numerical values, and by real-life events”

(Yin, 1993: 57). The case study method is a valuable evaluation method, distinctive in its ability to do the following (Yin, 1993: 75):

- ◆ Attend to program operation and context.
- ◆ Accommodate single programs (cases) or situations with a small number of cases.
- ◆ Capture process and outcomes in a causal logic model and thereby provide useful and intermittent feedback to program officials.
- ◆ Adapt to the availability of different types of evidence.
- ◆ Assess outcomes and test causal theories and rival theories.
- ◆ Develop lessons that may be generalized to the major substantive themes in a field.

Although the use of case studies is a paradigm shift from traditional quantitative research approaches, it is an appropriate method for engineering research because it is a qualitative research design that addresses non-numeric and unstructured data and information that is used in the decision-making process by water resources engineers (Adams, 1998). Figure 4 represents the flow diagram for the theoretical research plan of this dissertation.

Figure 4. Research Plan.



In development of the theoretical framework for the case analysis, it is important to recognize and address the potential for subjectivity by the researcher in performing qualitative research. However, a solid empirical basis will successfully be achieved by using a well-designed method of developing, analyzing, and verifying the results of the case study to minimize the potential bias and subjectivity (Adams, 1998). Yin (1994:20) asserts there are five components that require definition in the proper research design of a case study:

1. A study's question(s).
2. Its propositions, or if exploratory then proposals.
3. Its unit(s) of analysis.
4. The logic linking the data to the propositions.
5. The criteria for interpreting the findings.

The conceptual framework for this research revolves around addressing the first component or the paramount question in this case study – how to successfully integrate ground water within the allocation system of an interstate river compact. The Republican River Compact was selected as the case study for this investigation to assess the integration of ground water as a supplemental source of water supply in an interstate river compact because it offers several distinct advantages. First, as previously mentioned, it represents the majority of 23 out of 29 water supply/allocation interstate river compacts that exclusively consider surface water supplies within the allocation system and not ground water. Second, ground water resources were extensively developed within the Republican River Basin in all three participatory states after the compact was adopted

and ratified. Third, review of historical records and minutes of annual Republican River Compact Administration (RRCA) meetings indicate the representative state officials were cognizant of the increasing ground water withdrawals and potential depletions to natural streamflows, but repeatedly chose to defer action to address the additional depletions or consider including ground water within the allocation system. Succinctly, they repeatedly postponed the decision to the future under the premise of conducting further studies to better understand the ground water resources and their potential impact to streamflows. The fourth and final reason the Republican River Compact was chosen pertains to the water administration, political, and economic ramifications induced by the interstate lawsuit filed before the United States Supreme Court in 1998 by the State of Kansas. The lawsuit alleged the unregulated ground water withdrawals in upstream Nebraska were adversely impacting the natural streamflows to the Republican River, thereby causing material injury to Kansas' water users.

To address the second research design suggested by Yin (1994), two propositions or hypotheses are evaluated that seek to explain the omission of ground water from an interstate river compact allocation system. The two hypotheses are:

1. If the language contained in an interstate river compact is general in nature, without specificity as to the inclusion of ground water as a source of water supply, the inclusion of ground water within the allocation system will be deferred in the pursuit of continued studies to determine the existence, amount, location, and sustainability of this clandestine resource.
2. If the interstate river compact does not include enforcement language or a dispute resolution mechanism, the compact's administrative body will defer inclusion of ground water in the allocation system due to a perceived lack of authority.

The third component in Yin's definition of the proper research design is the unit of analysis. The defined unit(s) of analysis is the case study, which must be bounded by

time constraints and subject context (Yin, 1994). The unit of analysis in this research design is the case study of the Republican River Compact, which offers instruction into the decision-making process that is bounded by the pre-compact negotiations among water administration officials and engineers that pre-dates the 1943 compact and continued in the form of annual compact administrative decisions for over 60 years, litigation, and the eventual collaborative settlement agreement amongst the three states in 2003. The Republican River Compact case study is also bounded in subject context because it focuses upon the administration of ground water and inclusion of this source of water supply within the compact allocation system from its nascent understanding as a clandestine resource until recent quantification in time, amount, and location through a comprehensive mathematical model (RRCA Groundwater Model, 2003). The amount of time available, scope of research, and analytical strategy dictate the number of cases that can be researched (Yin 1993, Adams, 1998). When appropriate, the use of multiple cases in a research study may offer a deeper understanding and explanation for the issue under analysis (Adams, 1998). However, professional experience indicates a single case may indeed prove sufficient to address the study question because there are no set criteria for determining the minimum number of cases required for analysis (Yin, 1993; Adams 1998). The use of a single case study is appropriate to this dissertation to research the influencing variables and effectiveness of including ground water within the allocation system of an interstate river compact due the unique attributes of an interstate river compact (Featherstone, 1999). Each river basin subject to regulation through an interstate river compacts has unique hydrology, physical attributes, legal mandates,

political ramifications, and other intervening variables that diminish the value of comparative analysis with other interstate river compacts (Barton, 1967).

The fourth and fifth research design components suggested by Yin (1994), the logic that links the data to the propositions and defining the criteria for interpreting the findings respectively, require development of an analytical strategy to perform the case analysis (Adams, 1998). The analytical instrument selected to develop the case study is the program evaluation methodology. This research design fulfills the intent to provide interstate river compact policy and decision-makers with an effective procedure to address complex problems and to make intelligent choices (Fitzpatrick, et. al., 2004). The complexity of managing an interstate river is manifest in the realization that distribution of a natural resource among multiple state jurisdictions is inevitably subject to a myriad of social, economic, and ultimately political influences. The political influences often dominate the decision making process, and in this research are considered in relevance of the potential to include ground water in the compact allocation system, or not to include it as a source of water supply (Viessman, 1990). The program evaluation methodology is an effective policy analysis tool that evaluates the decision-making process with the intent to avoid or minimize future conflict and political influences. In its purest state, evaluation research is closely related to policy analysis and generates objective measures of observed experiences, such as the increase in reservoir storage or instigation of lawsuits to resolve controversies, in the interest of improving decision-making and operations (Brewer and deLeon, 1983). The research design for this dissertation does not employ the prevalent experimental design in water resources engineering research because control variables or experimental conditions do not exist for

this application because the Republican River Compact was adopted in 1943 and has been in continuous operation for the succeeding 61 years. The absence of experimental conditions precludes the application of an experimental design (Brewer and deLeon, 1983, Featherstone, 1999).

### Program Evaluation Methodology

This dissertation employs a program evaluation methodology as the analytical tool or instrument to research the Republican River Compact case study. The primary purpose of using the program evaluation method is to assess the performance of the RRCA in meeting the stated objectives in the Republican River Compact through identification of specific indicators or outcome measures (such as the increase in ground water well development in the Republican River Basin), thereby providing the mechanism to improve the quality of the program and communicate information for future decisions (Suvedi, 2003). The application of program evaluation methods, particularly theory-based evaluations, have been extensively applied in the education, legal, and medical fields but are increasingly being utilized in government agencies and service organizations (Weiss, 2003). According to Weiss, three reasons are offered to explain the increase in popularity and use of program theory:

1. It provides a logical framework for planning data collection.
2. It is able to address complex problems where randomized assignment is not possible by proving a mechanism to attribute causality.
3. Theory-based evaluation helps to explain *why* and *how* the program works.

The two general categories of evaluations are informal and formal. Informal evaluations are the most prevalent because of their simplicity and ability to provide general information about ongoing activities (Brewer and deLeon, 1983). In its purest state, a formal evaluation methodology is designed to generate objective measures of observed experiences in pursuit of improved decision-making and was selected for this research because of its increased scientific rigor (Brewer and deLeon, 1983). Although there are many types of formal evaluations, two dominant methods are used in evaluation research theory and are termed formative or summative (Fitzpatrick, *et. al.*, 2004; Brewer and deLeon, 1983). The former refers to tactical observations and recommendations made to decision-makers for intermediate corrections or to improve on-going program performance. The program evaluation method applied in this dissertation is a summative form of evaluation that is more encompassing and is designed to “inform high-level policy makers about the overall consequences of both large-scale programs and significant policies” (Brewer and deLeon, 1983: 346).

Construction of an objective and verifiable summative evaluation requires composition of standards that will satisfy the scientific principle that the findings or statements of fact may be independently reproduced by another researcher (Bostwick and Kyte, 1993). Further, the composition of accuracy standards help to ensure that an evaluation will reveal and convey technically adequate information about the features that determines the effectiveness of the program being evaluated. As suggested by Ramlow (2004), the accuracy standards for a formal and summative evaluation include:

1. The program being evaluated should be described and documented clearly and accurately, so that the program is clearly identified.
2. The context in which the program exists should be examined in enough detail, so that its likely influences on the program can be identified.
3. The purposes and procedures of the evaluation should be monitored and described in enough detail, so that they can be identified and assessed.
4. The sources of information used in a program evaluation should be described in enough detail, so that the adequacy of the information can be assessed.
5. The information gathering procedures should be chosen or developed and then implemented so that they will assure that the interpretation arrived at is valid for the intended use.
6. The information gathering procedures should be chosen or developed and then implemented so that they will assure that the information obtained is sufficiently reliable for the intended use.
7. The information collected, processed, and reported in an evaluation should be systematically reviewed and any errors found should be corrected.
8. Quantitative information in an evaluation should be appropriately and systematically analyzed so that evaluation questions are effectively answered.
9. Qualitative information in an evaluation should be appropriately and systematically analyzed so that evaluation questions are effectively answered.
10. The conclusions reached in an evaluation should be explicitly justified.
11. Reporting procedures should guard against distortion caused by bias of the evaluator to fairly reflect the evaluation findings.

12. The evaluation should be formatively and summatively evaluated against these standards.

The program evaluation methodology in this dissertation analyzes and measures the success of the RRCA in achieving compliance with the objectives of the Republican River Compact. The program evaluation methodology envelops the accuracy standards cited above and is composed of four dominant steps in its research design: (1) identification of the predetermined objectives of the Republican River Compact at its origination; (2) establishing outcome measures for said objectives; (3) identification of actions that influence the outcomes; and (4) development of research designs to prove the two hypothesis for not including ground water within the allocation system and to assess the effectiveness of the RRCA in meeting the objectives of the compact. Data and information for this dissertation was obtained through surveys, review of literature and historical records, interviews with principal compact authorities, and two research designs (pre- and post-test analysis, trend analysis).

The program evaluation methodology flow diagrams are provided in Figures 5-8 at the conclusion of this chapter. One flow diagram is provided to represent each of the four identified objectives of the Republican River Compact. The flow diagrams also list the identified outcome measures and influencing actions pertinent to each objective as well as their interrelationship within the research design.

## Identification of Objectives

The primary goal of the Republican River Compact is the equitable division of Republican River waters among the States of Colorado, Kansas, and Nebraska. This goal is embodied within the Republican River Compact in the form of principal objectives, which are described in the first article of the compact as follows:

“The major purposes of this compact are to provide for the most efficient use of the waters of the Republican River Basin (hereinafter referred to as the “Basin”) for multiple purposes; to provide for an equitable division of such waters; to remove all causes, present and future, which might lead to controversies; to promote interstate comity; to recognize that the most efficient utilization of the waters within the Basin is for beneficial consumptive use; and to promote joint action by the States and the United States in the efficient use of water and the control of destructive floods” (Republican River Compact, Art. I, 1943).

Interpretation of the Compact text indicates there are four principal objectives that may be derived from the Republican River Compact, which are: (1) to maximize the efficient and beneficial consumptive use of waters within the Republican River Basin; (2) to provide an equitable division or allocation of Republican River waters; (3) to promote interstate comity and resolve present and future controversies among the states; and (4) to promote coordination or collaborative action between the states and the federal government. The first objective, maximizing the efficient and beneficial consumptive use of water, is directly applicable to water resources management. The second objective, to provide an equitable division or allocation of Republican River waters, is the cornerstone of this dissertation through research of the applicability of including ground water as a supplemental source of water supply within an interstate river compact. The third and fourth objectives warrant study because they relate to the collaborative

management of water resources among the three states and also the relationship between the Republican River Compact Administration representing the three states and the United States federal government.

### Establishing Outcome Measures

The terms “outcome measures” or “indicators” are interchangeable in this research and their importance to this evaluation study is paramount because they “are used to simplify, quantify, communicate and create order within complex data” (UNESCO, 2004: 32). The driving impetus to develop indicators are: the need to present complex issues in a clear, concise, and objective manner to the decision-makers; and to establish objective benchmarks or standards to analyze changes over time or spatial area (UNESCO, 2004). An outcome measure or indicator may be comprised of a single variable or a set of data variables that are used to systematically describe a process and communicate information on the system or process. Designed properly, outcome measures are important to allay bias or subjectivity in the case analysis by instilling a decorum of objectivity to adhere to the scientific principle that any statement of fact made by one researcher can be independently verified by another (Thyer, 1983). Indicators may be either descriptive or normative; they may also be used to represent quantitative or qualitative information and are applicable to varying time and spatial dimensions (UNESCO, 2004). Measurement facilitates the ability to discover and establish trends and relationships among variables and increases the effective communication of a study’s findings (Thyer, 1983). “The

dominant criterion behind an indicator's specification is scientific knowledge and judgment" (UNESCO, 2004: 33).

In order to gauge the institutional success of the RRCA in meeting its purposes, "outcome" measures are defined for each of the aforementioned four objectives. The outcome measures or indicators for this research design are dependent variables (Thyer, 1993; Featherstone, 1998). Performance measures are typically classified as being either absolute or relative. Absolute performance measures are assessed with respect to a pre-defined standard or feature. Relative measures gauge the success of the program in meeting the defined objectives in comparison with another institution's performance (Child, 1974). For the first objective to maximize the efficient and beneficial consumptive use of water, the two outcome measures are related to water supply in the Republican River Basin and include (1) the development of surface water supplies; and (2) the development of ground water from both the river alluvium and from the bedrock Ogallala aquifers.

For the second objective, an equitable division of Republican River Basin waters, the two outcome measures address the performance of the allocation system and include (1) the complexity of the allocation system; and (2) enforcement of the allocation system.

With respect to the promotion of comity among the states and resolution of existing or potential controversies, three outcomes measures are employed for this objective. For foundation, the rules governing the administrative actions of the RRCA dictate a unanimous decision from all three states is necessary to pass any resolution or institute a formal action (RRCA Rules and Regulations, 1959a: 4). Therefore, the first outcome measure evaluates the number and type of actions or resolutions brought before the

RRCA that were passed, deferred, or failed. The second outcome measure is the uniform and equal regulation of water users in all three states to assess the measure of consistency and equity of water administration within the Republican River Basin. The final outcome measure is the discrete action or decisions by one or more of the parties to the compact to escalate the degree of conflict to the point that informal mediation is initiated or judicial relief is sought through litigation before the United States Supreme Court.

Guidance for the identifying the outcome measures relevant to the joint action between the states as represented by the RRCA and the federal government is provided explicitly by the Republican River Compact. Two measures are identified for this objective, (1) actions that advance the efficient use of water; and (2) those that pertain to flood control.

#### Identification of Actions that Influence the Outcomes

This aspect of the research identifies the qualitative and quantitative actions, or lack thereof, taken by the RRCA that influence the outcome measures previously established. It is important to identify or recognize the actions that influence the outcome measures, but also to consider how and why the actions had an influence (Brewer and deLeon, 1983; Featherstone, 1999). In perspective of the research methodology, the actions that represent change in the outcome measures are the independent or explanatory variable (Thyer, 1993; Fitzpatrick, *et. al.*, 2004). Intervening variables that may influence the outcome measures are also identified and evaluated in this step of the procedure. For illustrative purposes, the United States Department of Agriculture and its

subsidiary federal agencies provide cooperative funding to individual farmers and ranchers if they install land terraces. Designed to reduce soil erosion and also increase the soil moisture content of irrigable land through temporary retention of precipitation on the land, the terraces effectively serve their purpose by reducing detrimental soil erosion and increasing per acre crop yields through increased water supply. The terraces act as an intervening variable to the outcome measures relevant to water supply by reducing the amount of tributary surface water runoff, thereby affecting the quantity of water measured at Republican River Compact streamflow gaging stations and altering the amount of water available for distribution among the three states.

Upon review of historic records, data, legal documents, and technical reports, 13 actions are quantified or qualitatively evaluated in this research to assess the performance of the RRCA in meeting the compact objectives. The actions that influence the previously identified outcome measures are also depicted in Figures 5-8. In regard to the water supply outcomes, five actions were identified: (1) reservoir storage development; (2) surface water delivery systems; (3) ground water withdrawals; (4) surface water irrigation districts; and (5) ground water management districts. Four actions are contemplated for the design of an equitable allocation system: (1) assessment of the amount, type, and location of all water supplies; (2) the formula for distribution or allocation system itself; (3) monitoring and measurement of water supplies; and (4) the adaptability of the allocation system. Two actions seek to influence the outcome measures for the objective seeking interstate comity: (1) technical or water administration investigations; and (2) interagency coordination. There are two actions identified that

relate to the state and federal coordination outcome measures: (1) water supply infrastructure improvements; and (2) flood storage development.

### Development of Research Designs

This dissertation employs two research designs that are utilized to assess the performance of the RRCA in meeting the four principal objectives established by the Republican River Compact: (1) a non-experimental pre- and post-test analysis; and (2) a trend analysis. The application of multiple research designs provides a corroboration of the empirical results through comparative analysis of the independent findings from both methods (Adams, 1998, Featherstone, 1999). The use of multiple research designs also provides an additional measure of validity through independent methodologies in that a potential deficiency in one design may not inadvertently bias or influence the results (Bostwick and Kyte, 1993). The results or findings are considered to be valid and reliable if they are found to be consistent by using multiple independent research designs (Thyer, 1993; Brewer and deLeon, 1983; Adams, 1998).

#### Pre- and Post-Test Analysis

This research design employs a case study and program evaluation methodology to evaluate the Republican River Compact by critiquing program actions with program results in the absence of any control groups. The literature and professional experience previously cited indicate the research design is appropriate for this dissertation because

the dependent variables (outcome measures) applied before ratification of the Republican River Compact continue to remain valid to the present state (Featherstone, 1999; Fitzpatrick, *et. al.*, 2004). The pre- and post-test research methodology is used to evaluate the performance of the RRCA in achieving the stated objectives through measurement of the change in the dependent variables “after the fact” of their implementation and in context of influential actions that function as independent variables (Brewer and deLeon, 1983). It is also used to provide a comparative analysis of the present state of an objective with the desired status of the objective (UNESCO, 2004). The Republican River Compact was ratified by the three states and approved by Congress in 1943; therefore 1943 represents the target year to measure the change in the state of the dependent variables over 61 years to their current status in 2004. For data and information that is not available in 1943, other time periods or years are referenced to represent the pre-conditions to the Republican River Compact.

Because interstate river compacts function as water administration programs in the operational world, and not in a laboratory environment where conditions may be controlled, the case analysis and program evaluation research design may incur methodological problems associated with intervening variables (Brewer and deLeon, 1983). These intervening variables are decisions or actions instituted by the federal government or other groups that may impact the performance of the RRCA in their attempt to satisfy the stated objectives in the Republican River Compact. Since the RRCA does not operate in isolation, necessary information or data that is pertinent to the intervening variables is often missing or incomplete, which adversely impacts the contributive effect of these variables and the subsequent performance measurement of the

program. Therefore, multiple research designs are employed to alleviate this potential concern and corroborate the results found through the pre- and post-test analysis (Featherstone, 1999).

An experimental pre-and post-test analysis that is used in traditional water resources engineering research is based upon the measurement of dependent variables before the influence of independent variables, and again after the introduction of independent variables to develop an empirical relationship between the two (Brewer and deLeon, 1983). This traditional method is not applicable to the Republican River Compact, or other operational interstate river compacts, because the pre-independent variable state no longer exists -- thereby prompting other forms of research design such as the case study to further develop water resources engineering research in application to interstate river compacts (Adams, 1998; Featherstone 1999).

### Trend Analysis

A trend analysis is utilized for the second research design in this dissertation. As the name implies, it is used to assess the changes or progress in the dependent variables over time (UNESCO, 2004). The trend analysis complements the pre- and post-test analysis by assessing the impact of many RRCA decisions and actions that were not implemented until several years or decades after ratification of the Republican River Compact. This form of analysis is particularly well suited for this research topic because it addresses the increase of ground water development in the Republican River Basin from compact ratification in 1943 to the present.

Changes in the dependent variables that may be attributed to decisions or actions taken by the RRCA substantiate the existence of an empirical association (Thyer, 1993; Brewer and deLeon, 1983). In a parallel conclusion, where there is data or information that indicates there is not a discernable change in the dependent variable(s), it is presumed that actions taken by the RRCA did not have any effect upon the outcome measures (Bostwick and Kyte, 1983; Brewer and deLeon, 1983).

Potential problems associated with trend analysis as a research design are typically attributed to missing or poor data quality, opposed to the methodology (Featherstone, 1999; Bostwick and Kyte, 1983). When adequate and reliable data does not exist, short-term data or other indicator data was used as supplemental information in the evaluation process.

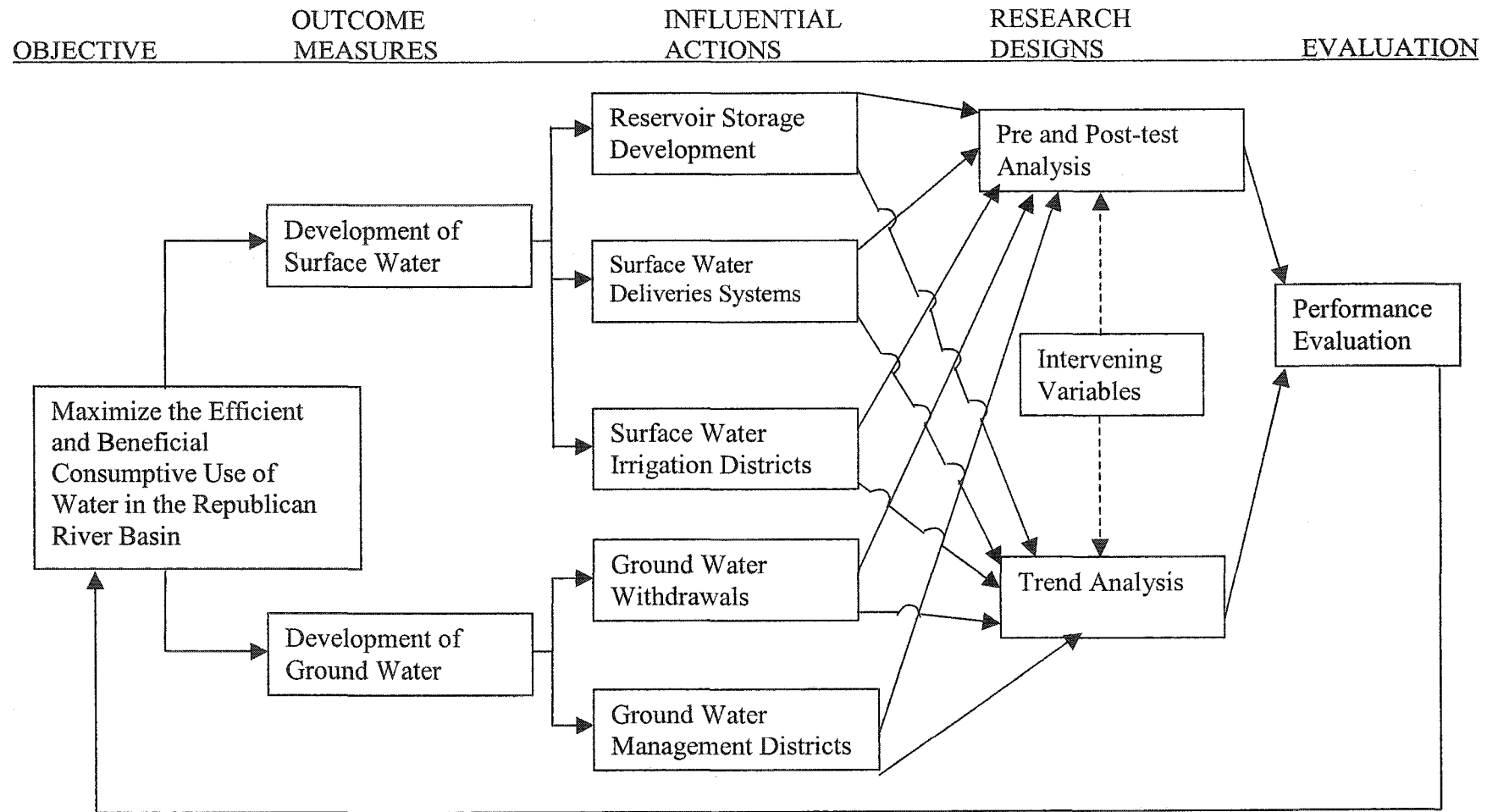


Figure 5. Flow Diagram for the Efficient and Beneficial Consumptive Use of Water in Republican River Basin.

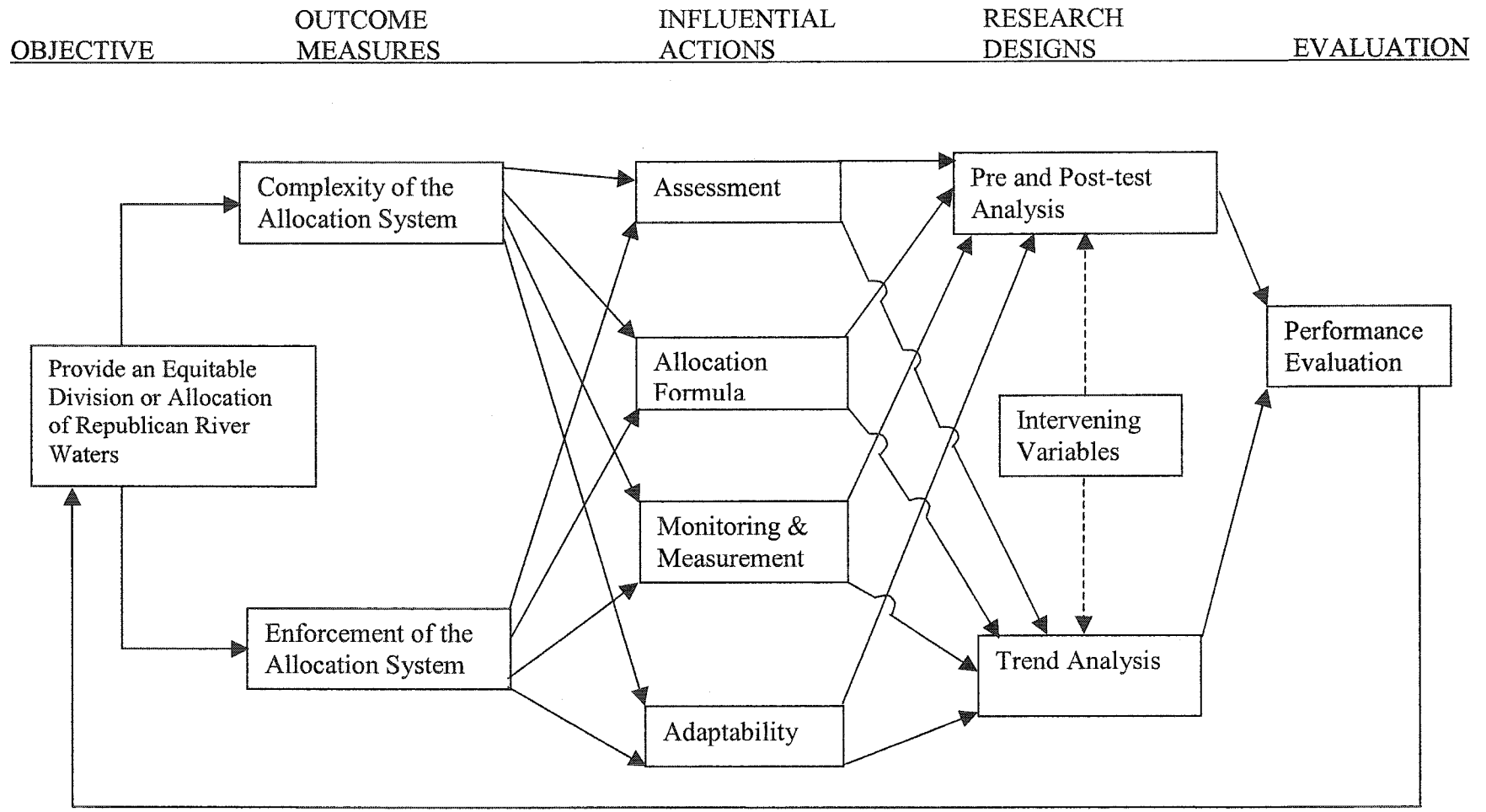


Figure 6. Flow Diagram for the Equitable Division of Republican River Waters.

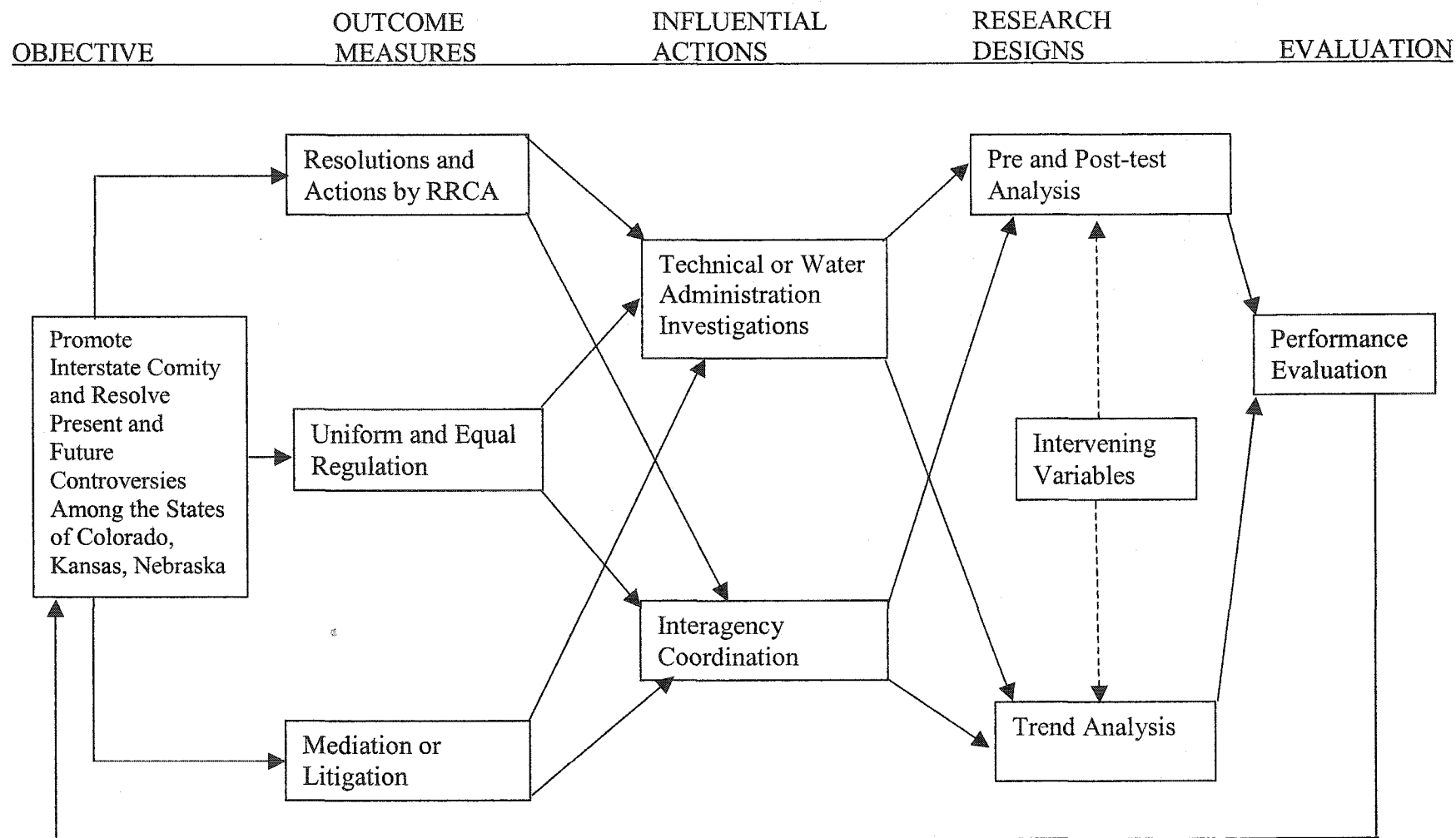


Figure 7. Flow Diagram for the Promotion of Comity among the States of Colorado, Kansas, and Nebraska.

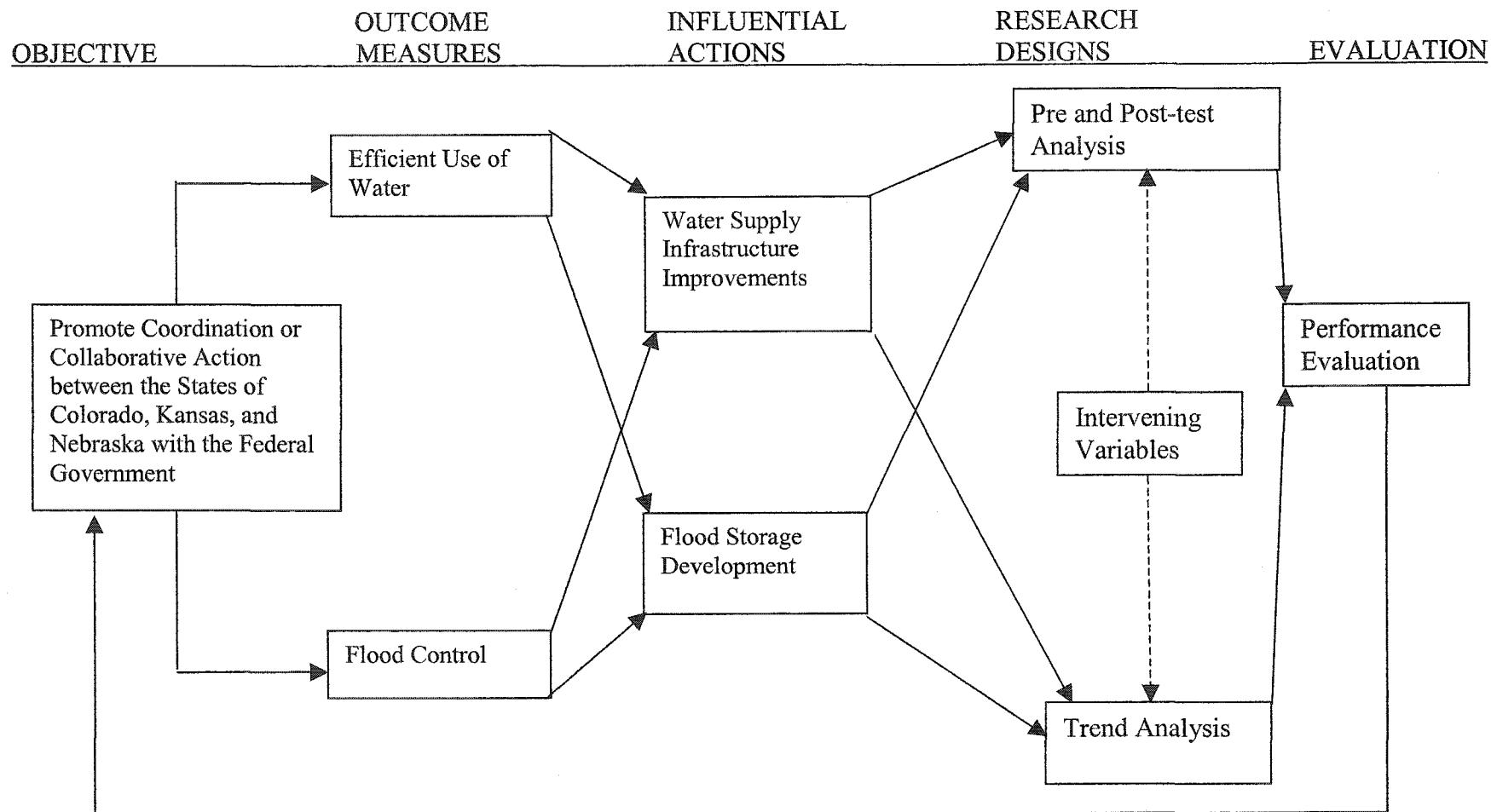


Figure 8. Flow Diagram for Coordinated and Collaborative Action between the States and Federal Government.

## CHAPTER 4

### PRE-COMPACT CONDITIONS OF THE REPUBLICAN RIVER BASIN

The purpose of this chapter is to provide an overview of the demographic and natural resource conditions that existed within the Republican River Basin and the institutional framework that is pertinent to the development of water resources in the years preceding adoption of the compact. These pre-compact conditions are also applied in a comparative analysis with the performance of the RRCA in meeting the Republican River Compact objectives in Chapter 6.

#### Demography

In order to properly understand each discrete factor in the 1943 Republican River Compact and in conceptual entirety, it is important to consider the context of the era and the challenges that were prevalent in the minds of the compact negotiators. For foundation, encroachment upon the lands occupied by several different Native American tribes in the Republican River valley began in the eastern region with fur trading before 1800 and extended to lands in present-day Colorado by 1820. Although miners and speculators passed through the basin on their way toward the promise of riches in the

California gold fields in 1849 and subsequent years, few stayed and settled the land. In 1867, a railroad shipping terminal was established in Abilene, Kansas and it served as a catalyst for the cattle drives that originated in Texas that were trailed north through the Republican River Basin in pursuit of luxuriant prairie grasses (USDA BOAE, 1940). Subsequent to the cattle drives, permanent cattle ranches were established in the Republican River valley through the 1870's. The Chicago, Burlington, and Quincy Railroad was built through the Republican River valley between 1870 and 1887 which brought a large number of settlers under its colonization activities who supplanted the open range with farms established under the Homestead, Timber Claim, and Preemption Acts (USDI BOR, 1940). By 1930, the population in the Republican River Basin expanded to a total of 247,299 residents that lived primarily in the rural areas. As depicted in Table 1 the average occupancy was 9.9 persons per square mile (USDA BOAE, 1940: 17).

Table 1. Population in the Republican River Basin in 1930

State	Urban	Rural Non-Farm	Rural Farm	Total Population	Square Miles	Residents per Square Mile
Colorado	-	12,210	28,175	40,385	7,722	5.2
Kansas	16,571	26,793	58,979	102,343	7,519	13.6
Nebraska	12,995	32,843	58,733	104,571	9,714	10.8
Total	29,566	71,846	145,887	247,299	24,955	9.9

Commensurate with the prevailing rural population, the economy of the region was dominated by farming and ranching activities. Manufacturing was limited to grain mills, creameries, and other agriculture-related goods. In 1929, the estimated gross revenue

from farm crops and agricultural products was \$94.9 million and the value of manufactured products was \$22.0 million (U.S. Dept. of War, 1937).

The culture of the Republican River Basin, and the United States, in the decade preceding enactment of the Republican River Compact was dominated by the severe drought that was known as the “Dust Bowl” during the mid-1930’s and the economic depression that followed the stock market crash in October 1929. Private farms composed 91 percent of land ownership in the Republican River Basin in 1934, with cities, towns, highways, and other public-owned lands serving the remaining 9 percent (USDA BOAE, 1940: 18). As a measure of the adversity of the drought and economic depression upon the agrarian society and in context of location, the tax delinquency rate in Washington County, Kansas at the eastern edge of the basin rose from 7.2 percent in 1928 to 72.2 percent in 1932 and decreased to 36.8 percent in 1936. Situated in the western region, the tax delinquency rate in Kit Carson County, Colorado rose from 38.8 percent in 1928 to 62.9 percent in 1932 before settling to 50.9 percent in 1936 (USDA BOAE, 1940: 25). In proportion with the loss of farms, the population in all 28 counties in the Republican River watershed decreased from 1930 to 1940, with an average 14.1 percent decrease in the basin (USDA BOAE, 1941: 103).

### Natural Resources

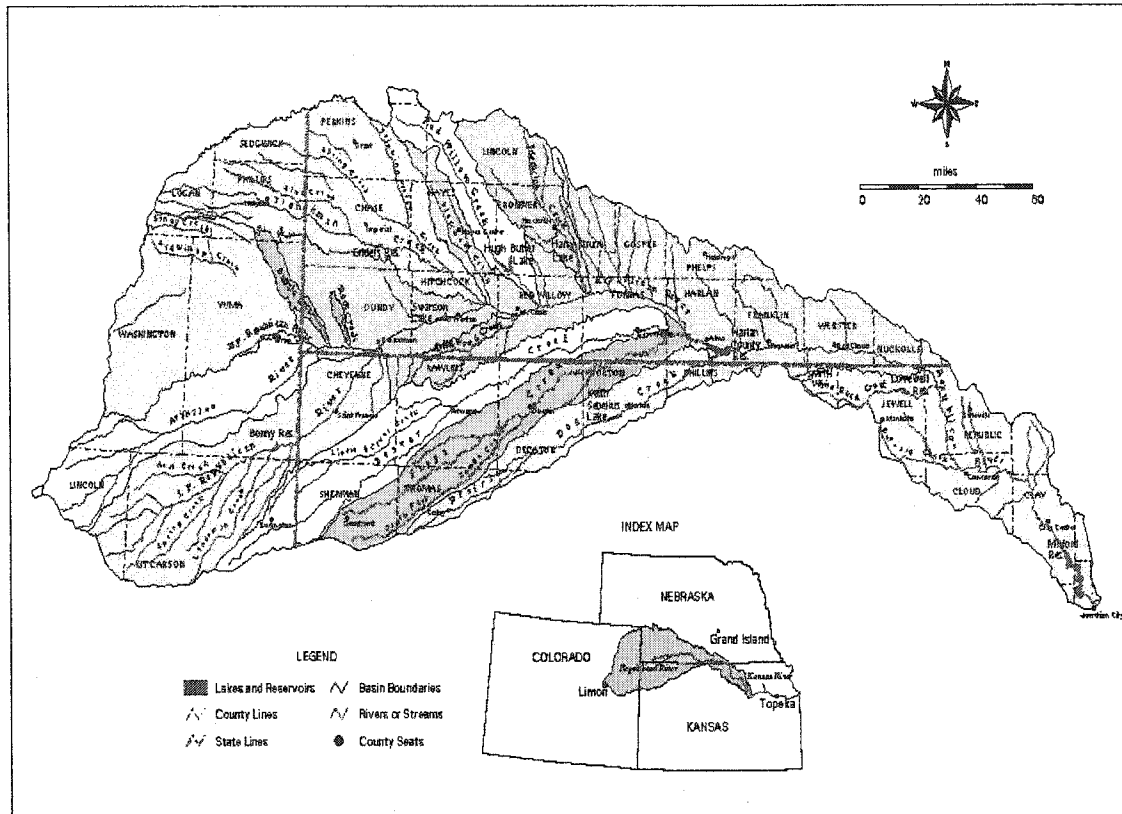
Tasked with the responsibility of quantifying the amount of Republican River waters available for an equitable distribution among the three states, the representative engineers and hydrologists conducted a thorough technical analysis of the climatic, hydrology, land

use, and other information that was available to them in the decade prior to enactment of the compact (RRCC, 1940; RRCC, 1942a; RRCC, 1942b; Republican River Compact, 1943; Kansas v. Nebraska and Colorado, 2000). The geographic setting of the Republican River Basin and the major topics of consideration in their engineering and technical analyses are provided in the succeeding sections.

### Geographic Setting

The headwater tributaries of the Republican River rise on the high plains of northeastern Colorado and western Kansas and Nebraska. The watershed encompasses an area of approximately 24,955 square miles, of which 7,722 are in Colorado, 9,714 in Nebraska, and 7,519 are in Kansas (USDA BOAE, 1940: 2). The topography in the watershed is generally characterized by near-level lands in the Great Plains that are traversed by broad and shallow river valleys in the upper and westward regions and are transformed toward the eastern portion by rolling hills and more steeply incised stream banks. The mainstem of the Republican River is formed by the junction of the North Fork of the Republican River and the Arikaree River near Haigler, Nebraska. From its headwaters, the river flows in a generally eastern direction for approximately 445 miles and decreases in elevation from 5,500 feet above mean sea level to 1,000 feet before it joins the Smoky Hill River at its confluence to form the Kansas River at Junction City, Kansas. The Republican River Basin is illustrated in the map provided below (RRCA Ground Water Model, 2003):

## Map of the Republican River Basin



### Hydrogeology Framework

The predominant source of ground water supply within the Republican River Basin is the shallow alluvium and deeper bedrock formations that collectively form the High Plains aquifer. The High Plains aquifer underlies portions of eight western States, including Colorado, Kansas, and Nebraska, and the topography is characterized by flat to gently rolling terrain that is bisected by mostly eastward-flowing rivers and streams, such as the Republican River. The predominant geologic unit of the High Plains aquifer is the

Miocene-aged Ogallala formation of the Tertiary period (CGS, 2003). The Ogallala formation principally consists of unconsolidated to semi-consolidated sands, gravels, clays, and silts. The High Plains aquifer is also composed of the shallower river alluvium and eolian deposits of the later Quaternary period (CGS, 2003). Water-table or unconfined conditions are predominant throughout the aquifer. However, in some areas the hydraulic interconnection between the stream systems and aquifers have been broken and in other localized areas cemented “mortar” (caliche) beds are common and create artesian or confined aquifer conditions (CGS, 2003).

The depositional history of the High Plains Aquifer is complex because it contains both fluvial (stream-deposited) and eolian (wind-deposited) sediments. Braided stream systems that flowed eastward across the alluvial fans adjacent to the Rocky Mountains served as the primary source of deposition of coarse-grained and fine-grained sediments to the Ogallala formation during the Tertiary time period (CGS, 2003). However, in the Quaternary period, as the climate in the area turned drier and colder due to mountain uplift, the major form of sediment deposition changed to eolian. The winds transported the fine materials caused by stream erosion in dust storms that carried very fine to medium sands to the east before settling into dune deposits, the largest and most prominent being located in west-central Nebraska. The Quaternary age alluvial, valley-fill, dune sand, and loess deposits are also considered to be part of the High Plains aquifer where they are hydraulically connected to the underlying Ogallala formation (CGS, 2003).

The saturated thickness of the High Plains aquifer ranges from zero in the western edge of the aquifer in Colorado where the aquifer outcrops, to approximately 1,000 feet

in west-central Nebraska (CGS, 2003). Ground water flow in the High Plains aquifer is generally from west to east in response to the predominant slope of the water table.

### Hydrology

The Republican River Basin is characterized by highly erratic climate conditions. Precipitation records from 45 U.S. Weather Bureau stations scattered throughout the Basin were compiled in 1941 to quantify the annual average precipitation. The annual average amount of precipitation declines from 25.4 inches in the eastern portions of the Basin at Superior, Nebraska to 15.0 inches near the western boundary at Arriba, Colorado (USDA BOAE, 1940: 19). Coincident with the variance across the watershed, the most significant factor to agricultural development in the Republican River Basin was the wide fluctuation in annual precipitation. The precipitation varied in the 1930's from extreme drought to catastrophic flooding. Although written in 1896, the acute observations by F. H. Newell characterize the climatic conditions during the Dust Bowl years that preceded creation of the Republican River Compact and continue in relevance to date:

“Year after year the water supply may be ample ... the herds multiply, the settlers extend their fields, when, almost imperceptibly, the climate becomes less humid, the rain clouds forming day after day disappear on the horizon, and weeks lengthen into months without ... moisture. The grasses wither, the herds wander wearily over the plains in search of water holes, the crops wilt and languish, yielding not even seed for another year... another and perhaps another season of drought occurs... and this beautiful land and so fruitful, is now dry and brown. Then comes a season of ample rains. The prairie grasses, dormant through several seasons, spring into life, and with these the hopes of new pioneers. Then recurs the flood of immigration to be continued until the next long drought” (USDA, 1896: 168).

The preponderance of annual precipitation is in the form of rainfall with approximately 70 percent of the annual volume occurring April through September. The basin is also subject to high intensity storms that yield four to six inches of water in a 24-hour period. For the period of record, storms that produced major floods in the watershed occurred in 1903, 1915, and 1935. The 1935 storm was a catastrophic event in the Republican River Basin. The soils in the watershed were well saturated by two periods of rainfall that yielded up to five inches of rain during the first period of May 12-22 and another inch from May 26-29. During the nights of May 30 and 31, 1935 a general storm formed over eastern Colorado, northwestern Kansas, and western Nebraska with a cloudburst of an estimated 15 inches of rain that was centered over the headwaters of the Arikaree River and South Fork of the Republican Rivers (USDA BOAE, 1940: 33). The torrential rains induced a major flood along the entire mainstem of the Republican River that caused \$9,054,000 in damages and claimed 105 lives (U.S. Dept. of War, 1940).

Tributary streams systems in the Republican River watershed vary in yield and duration. The headwater streams in the western region are often limited in drainage areas and many are ephemeral. Consistent with the prevalent precipitation patterns, the surface water runoff increases progressively as the Republican River migrates downstream to the east with incremental tributary inflows. In consideration of the amount of surface water available, three contributory sources of water supply to the Republican River were identified in 1941:

- (1) The tributary stream systems that carry surface water runoff within the Republican River Basin.
- (2) Ground water that originates within the Republican River Basin and discharges to the stream systems.
- (3) Ground water that originates in the Platte River Basin that discharges to the surface streams in the northeastern portion of the Republican River Basin (USDA BOAE, 1941: 29).

Quantification of the amount of surface water available for distribution in the Republican River Compact was based upon stream discharge records located on several tributaries and at various locations along the mainstem. Since the purpose of the hydrologic analysis was to determine the average annual amount of surface water available, the water year 1935 was excluded from all compilations due to the extraordinary flood flows. A summary of the streamflow records within the Republican River Basin is provided in Table 2 (USDA BOAE, 1941: 32).

Table 2. Summary of Republican River Stream Flows Prior to the Republican River Compact

Gaging Station	Period of Record	Peak Flow (cfs)	Annual Discharge (acre-feet)		
			Maximum	Minimum	Mean
N. Fork of Republican R. at CO-Nebraska Stateline	1924-39	--	42,110	26,460	34,940
Arikaree R. at Haigler, NE	1925-39	50,000	91,700	7,530	21,000
Republican at Benkelman, NE	1895, 1903-07, 1924-30	--	77,400	48,100	60,360
S. Fork of Republican R. at Benkelman, Nebraska	1895, 1903-06, 1924-33	--	52,660	24,950	39,250
Republican River at Max, NE	1929-39	190,000	484,200	90,720	143,000
Republican R. at Cuthbertson, NE	1922-28 1931-39	--	561,800	83,410	147,550
Frenchman Cr. nr Champion, NE	1933-39	849	21,700	17,080	19,060
Frenchman Cr. bl Champion, NE	1935-39	--	30,430	23,650	26,700
Frenchman Cr. near Hamlet, NE	1929-39	2,200	80,190	61,150	70,380
Frenchman Cr. at Cuthbertson, Nebraska	1922-39	15,000	135,350	67,650	92,770
Red Willow Cr. nr. McCook, NE	1923-38	--	32,939	16,152	22,046
Medicine Cr. nr. Cambridge, NE	1923-31 1937-38	--	67,450	26,700	45,800
Beaver Cr. At Ludell, Kansas	1929-32	--	5,620	3,970	4,360
Beaver Cr. nr. Beaver City, NE	1937-39	2,270	16,320	12,510	14,415
Sappa Cr. near Oberlin, Kansas	1929-32	1,380	16,500	--	11,260
Sappa Cr. near Beaver City, NE	1937-39	2,040	--	15,190	21,120
Prairie Dog Cr. nr. Woodruff, KS	1929-32	2,830	34,100	31,700	33,510
Republican at Bloomington, NE	1929-39	260,000	1,002,300	302,000	460,200
Republican R. at Bostwick, NE	1904-15	--	1,169,000	310,000	569,000
Republican R. at Superior, NE	1896-1903	--	1,040,000	197,000	464,300
Republican R. at Hardy, Nebraska	1932-39	225,000	1,119,000	313,500	505,540
Republican R. at Scandia, Kansas	1920-39	215,000	1,214,000	316,000	548,200

Engineers and geologists recognized the existence of potable ground water resources throughout most of the Republican River Basin well before consideration of the compact. Their uncertainty was determining the amount and location of ground water available for use (USDA BOAE, 1941). Two principal sources were identified, ground water in the stream alluviums and ground water stored in deep bedrock aquifers. At the time of the compact negotiations, alluvial ground water was being used for domestic purposes, stock watering and crop irrigation in the riparian bottomlands. The source and quantity of alluvial water was considered to be in a form of equilibrium through recharge from transient storage in the Ogallala formation or in hydraulic connection to the overlying stream systems (USDA BOAE, 1941). As previously noted, the contribution of subterranean water following the hydraulic gradient from the Platte River into the Republican River Basin was recognized – but the contribution of these flows in time, amount, and location before they discharged to the stream systems in the northeastern portion of the basin remained a quandary.

Ground water storage in the Tertiary sediments or bedrock aquifers of the High Plains were used in limited amounts to serve municipalities and railroads in the watershed (USDA BOAE, 1940). However, pumping from the greater depths for irrigation of crops proved economically unattractive. The quantification of ground water available in the deeper aquifer systems remained a mystery and was deferred until the value of ground water pumping from this source became economically viable. Further, protection of the resource was evident in the early 1940's through the admonition that the amount of ground water reserves in the Ogallala formation "that could be withdrawn without

permanent depletion will be determined finally only through experience” (USDA BOAE, 1941: 118).

### Water Supply Infrastructure

Surface water diversions for irrigation in the Republican River Basin occurred on many streams prior to the 1890’s. Protection of the early water appropriations against others seeking to use water from the same source of supply and diminishing the amount available to the original water use(s) is achieved through formal recognition of the use of said water from either a court of competent jurisdiction or an administrative governmental agency. Water rights or permits are granted by the courts or administrative agency respectively, and they provide a legal and defensible right to divert and apply water to beneficial use. Water rights or permits are property rights, and as such are entitled to full judicial protection, as are all other property rights. The earliest recorded water right that is still in use in the Republican River Basin is the O’Donnell Ditch, which retains a priority of June 1, 1887 and was granted 4.0 cubic feet per second to irrigate lands in the North Fork of the Republican River valley near Wray, Colorado. By 1941 in the Republican River Basin, 59 surface water diversion structures were supplying water to irrigate 25,891 acres of land and 82 river pumping stations were irrigating an additional 4,623 acres (USDA BOAE, 1941: 68). The three largest canal systems were: (1) the Pioneer Irrigation Company that diverts 15.0 cfs for irrigation of 656 acres in Colorado and another 29.0 cfs for 2,029 acres in Nebraska from a common point of diversion on the North Fork of the Republican River approximately five miles from the

Colorado-Nebraska state line; (2) the Frenchman Valley Irrigation District that diverts from Frenchman Creek at point just below the confluence with Stinking Water Creek and serves approximately 9,300 acres with a permit for 215 cfs; and (3) the McCook Irrigation and Water Power Company that diverts 145 cfs from the Republican River just below the confluence with Frenchman Creek to irrigate 2,870 acres of land. A tabulation of water use and adjudicated or permitted water rights by 1940 is provided in Appendix C and a summary by tributary basin is provided below:

Table 3. Summary of Decreed or Permitted Water Rights

Stream	Number of Water Rights	Earliest Priority Date	Total Amount Decreed or Permitted (cfs)	Total Amount Decreed or Permitted (af)
Main stem Republican River	121	9-1-1877	975.62	958
North Fork Republican River	25	6-1-1887	191.09	
South Fork Republican River	60	10-24-1890	429.05	3,886
Arikaree River	3	7-12-1912	7.00	
Beaver Creek	15	12-12-1910	121.64	557
Sappa Creek	20	9-9-1926	22.79	54
Prairie Dog Creek	20	5-19-1928	22.75	
Medicine Creek	17	4-4-1907	252.39	80
Red Willow Creek	11	12-5-1910	13.39	
Frenchman Creek	63	7-31-1886	774.23	11,900

Ground water pumping through 156 irrigation wells irrigated approximately 9,670 acres in the Republican River Basin by the end of 1941(the acreage cited is not considered to be reliable because well registration was not legally required in the Republican River Basin in 1941) (USDA BOAE, 1941: 70). The lands irrigated were located within the river valley bottomlands or on nearby terraces with minimal pumping lifts. Several experimental irrigation wells were operable at this time on the High Plains,

but their use was limited due to the higher costs associated with power operations to pump water from a depth between 84 and 215 feet. Ground water pumping provided the predominant source of domestic, industrial, and fire protection water supplies to the 58 municipalities in the Republican River Basin (USDA BOAE, 1941: 55). Since most of the cities or towns were located near the streams, pumping municipal water from the river alluvium was convenient and adequate to meet demands. Ground water adjudications or permits were not required in Colorado, Kansas, or Nebraska prior to the compact negotiations, or for many years thereafter. Therefore, no priorities were assigned to ground water diversions or use. A summary of the average annual ground water use in the Republican River Basin in 1941 is provided below:

Table 4. Summary of Annual Use of Ground Water

Stream	Number of Structures	Average Annual Use (af)
Main stem Republican River	81	5,467
North Fork Republican River	1	30
South Fork Republican River	14	55
Arikaree River	4	33
Beaver Creek	21	999
Sappa Creek	22	943
Prairie Dog Creek	5	452
Medicine Creek	2	113
Frenchman Creek	19	1,151

#### Flood Protection

Prior to the Republican River Compact negotiations, water storage was limited to very small stock water ponds that were scattered throughout the basin. However, the devastating effects of the 1935 flood provided the impetus for the United States Congress

to pass the Flood Control Act of 1936 to provide a comprehensive plan for flood control in the Republican River Basin. Almost simultaneously, the Army Engineers, Bureau of Reclamation, and Department of Agriculture initiated reconnaissance level surveys and comprehensive water supply analyses for flood control and multi-purpose reservoirs that would increase the firm yield of water supply that was considered crucial for additional irrigated acreage, municipal and industrial development, hydropower generation, and flood protection. The Army Engineers completed a thorough flood control and multi-purpose reservoir storage analysis in 1940 that investigated 17 potential reservoir sites in the Republican River Basin. The District Engineer recommended construction of Harlan County Reservoir as the pre-eminent flood control project and multi-purpose reservoir for irrigation, power, recreation, and other beneficial purposes. Other reservoirs, particularly those on the tributaries, were dismissed because they were considered to be economically unjustifiable. A summary of the reservoir survey and total projected cost per structure is provided in Table 5 (U.S. Dept. of War, 1940).

Table 5. Reservoir Survey in the Republican River Basin in 1940

Reservoir	County/ State	Stream	Drainage Area (mi <sup>2</sup> )	Reservoir Capacity (af)	Total Cost \$
Scandia	Republic, KS	Republican R.	22,930	1,095,000	20,611,987
Harlan County	Harlan, NE	Republican R.	20,753	1,008,000	20,078,098
Woodruff	Phillips, KS	Prairie Dog Cr.	937	43,400	3,161,730
Beaver City	Furnas, NE	Beaver Creek	1,966	49,700	4,469,458
Sappa Creek	Furnas, NE	Sappa Creek	1,516	40,200	4,479,083
Medicine Cr.	Frontier, NE	Medicine Creek	838	40,400	1,894,500
Red Willow	Red Willow, NE	Red Willow Cr.	632	31,300	1,639,007
Culbertson	Hitchcock, NE	Frenchman Cr.	3,753	53,000	5,505,184
Enders	Chase, NE	Frenchman Cr.	2,240	49,200	3,800,627
Harvey	Chase, NE	Frenchman Cr.	2,144	47,300	2,470,920
Stinking Water	Hayes, NE	Stinking Water Cr.	1,113	30,100	1,774,621
Benkelman	Dundy, NE	S. Fork Republican	2,721	105,100	5,716,527
St. Francis	Cheyenne, KS	S. Fork Republican	2,094	81,800	5,641,488
Hale	Yuma, CO	S. Fork Republican	2,003	78,900	5,139,336
Pioneer	Cheyenne, KS	Arikaree River	1,909	59,700	3,912,366
Beecher Island	Yuma, CO	Arikaree River	1,740	54,000	3,988,387
Idalia	Yuma, CO	Arikaree River	1,569	47,200	3,697,581

## Management and Institutional Characteristics

Development of water resources within the Republican River Basin in the years preceding adoption of the Republican River Compact predominantly occurred in an uncoordinated manner by independent farmers or municipalities, with a limited amount of collaborative management activity by incorporated ditch and canal systems. The purpose of this section is to address the institutional characteristics of the governmental agencies charged with water administration authority in the Republican River Basin and the circumstances and activities of the era that prompted representative state officials to initiate interstate river compact negotiations.

### States of Colorado, Kansas, and Nebraska

Applicable statutory law and judicial case law governs water administration by state officials. The method of distributing surface water resources in Colorado at the time of compact ratification was a strict application of the Doctrine of Prior Appropriation [Coffin v. Left Hand Ditch Co., 6 Colo. 443 (1882)]. In contrast, the States of Kansas and Nebraska employed a blend of both the Riparian Doctrine and Doctrine of Prior Appropriation. The Riparian Doctrine was the paramount rule of water law in Kansas until 1886 when that state enacted legislation that required all new water appropriations were to be governed by the priority system [Clark v. Allaman, 71 Kans. 206, 80 Pac.571 (1905)]. The riparian water rights that existed prior to 1886 dominated water usage in

Kansas at the time of compact negotiations because they continued to serve the majority of river valley lands that were the first settled. These riparian water rights were not disturbed by the shift in water doctrines and continued to be exercised for their original purposes, including irrigation. The number of riparian water rights in Kansas at the time of compact negotiations, or amount of water required to serve them, was not included in Table 3 or the Appendix because these water rights were acquired by virtue of land ownership with no requirement for independent documentation or recording. In Nebraska, the riparian and appropriation doctrines existed concurrently. The Nebraska courts held a riparian water right is “coordinate” or equal to other riparian water rights in the same stream system, but they are subordinate to appropriative water rights previously acquired on public land; and they are superior to appropriative rights on private land if the riparian owner made actual use of the water prior to acquisition of the appropriative water right [Crawford Co. v. Hathaway, 67 Nebr. 325, 93 N.W. 781 (1903)].

The legal parameters that governed ground water in the Republican River Basin were slightly more complex. Ground water was generally categorized into two primary segments that were based upon the hydraulic connection with tributary streams. Ground water that flowed in subterranean stream channels or in the river alluvium was classified as “underflow”. Underflow ground water in Colorado was considered to be part of the hydrologic stream system and the courts applied the Doctrine of Prior Appropriation to those ground water applications in a conjunctive manner with surface water diversions [Buckers Irrigation, Milling, and Improvement Co. v. Farmers’ Independent Ditch Co., 31 Colo. 62, 72 Pac. 49 (1903)]. In the Republican River Basin in northwest Kansas, statutory law allowed the diversion of subterranean waters for application to beneficial

use as long as other vested water rights were not interfered with. However, the subterranean waters in the southwest portion of the state were declared by statute to be appurtenant to overlying lands [Kans. Gen. Stat., Ann. § 42-301, 42-305(1935)]. Review of Nebraska case and statutory law indicates there were no formal decisions to govern ground water by 1943.

Ground water that was not confined to the subterranean channel, typically the water stored in the Ogallala formation or bedrock aquifer systems was commonly referred to as “percolating” ground water. In Colorado, percolating ground water that was found to constitute a tributary source of water supply to the surface streams was included within the appropriation doctrine for that stream system [Faden v. Hubbell, 93 Colo. 358, 28 Pac. 2d, 247 (1933)]. There is an absence of judicial decisions on non-tributary ground water in Colorado prior to ratification of the compact. The State of Kansas adopted the English rule of absolute ownership of percolating waters. In contrast, Nebraska adopted the American rule of reasonable use whereas the landowner could extract ground water for reasonable and beneficial use, but could not do so in a manner that would cause injury to the rights of others [Olson v. Wahoo, 124 Nebr. 802, 246 N.W. 304 (1933)].

The officials charged for the comprehensive regulation or administration of both surface and ground water resources in all three states were the State Engineers in Colorado and Nebraska and the Chief Engineer for the State of Kansas.

## Federal Government Agencies

Activities by the federal government within the Republican River Basin prior to 1943 were limited primarily to agricultural consultation, streamflow measurement, and reconnaissance surveys, not active water resources management. The Department of Agriculture provided farm and land use planning services through the Bureau of Agricultural Economics. Soil conservation and erosion prevention techniques and contributory funding were offered through the aptly named Soil Conservation Service. The United States Geological Survey conducted streamflow measurements, maintained river gaging stations, and compiled annual flow records to quantify the peak discharge and yield of tributary streams in the Republican River Basin. In anticipation of potential reservoir and large-scale irrigation development, the Reclamation Service and the Army Engineers conducted a series of independent reservoir site identification and flood protection surveys within the basin.

Although there was not a significant amount of water management activity by federal agencies in the Republican River Basin prior to World War II, the petitions for federal funding and relief increased in volume and frequency in the late 1930's. The calls for federal assistance were borne in context of the era. The prolonged drought and the catastrophic 1935 flood prompted local citizens to seek relief through the construction of reservoirs. In recognition of her powerful and unique position as First Lady and confidant to the President of the United States, the residents of the Republican River Basin appealed to the conscience of Eleanor Roosevelt for aid. Through a series of correspondence in 1940 between Mrs. Roosevelt and Secretary of the Department of

Interior Harold L. Ickes, the foundation was laid to begin construction of a series of reservoir projects by the Reclamation Service to “stabilize the Great Plains” by stemming the tide of emigration of bankrupt farming families and increasing the value of land and agricultural economy by supplying precious irrigation water (letter from Harold L. Ickes to Eleanor Roosevelt, April 27, 1940).

### Republican River Committee

The impetus for creation of the Republican River Compact is typical of other water administrative mechanisms, either through formal administrative actions or casual agreement, since it was borne in need. The mid-1930's was a time of drought and hardship for the predominantly agrarian residents of the Republican River Basin. Construction of large-capacity reservoirs was considered to be a crucial component in the quest to supplement deficient surface water supplies by providing storage vessels to capture excess precipitation that would naturally flow unused to the Atlantic Ocean, particularly in perspective of providing water late in the irrigation season and to serve expanded irrigated acreage. However, the problem of debt repayment remained since large-capacity reservoir construction costs exceeded the budgets of consolidated farmer groups and also state governments during the Depression of the 1930's. To secure the requisite funding, the water users and their representative state officials turned to the United States government for fiscal relief. Although funding was limited, the federal government was receptive to building new multi-purpose reservoirs and streamflow diversion structures if two general caveats were overcome; the proposed projects must be

economically feasible and interstate compacts were to be adopted to protect federal interests and assure an equitable apportionment of interstate river waters. In 1934, the Governors of Colorado and Nebraska appointed M.C. Hinderlider and R.H. Willis respectively as compact commissioners to negotiate a Colorado-Nebraska interstate river compact for the North Fork of the Republican River and Arikaree River. Soon thereafter, President Franklin D. Roosevelt appointed E. B. Debler as the federal representative to the Republican River Compact negotiations (letter from Franklin D. Roosevelt to Nebraska Governor R.L. Cochran January 17, 1935). In January 1935, Colorado State Engineer Hinderlider expanded the scope of the compact to include the South Fork of the Republican River. The State of Kansas was keenly aware of the compact negotiations and indicated it would not become a formal party to the compact unless a reservoir would be proposed on the South Fork (letter from M.C. Hinderlider to Nebraska Attorney General William Wright January 10, 1935). Both Colorado and Nebraska commissioners conducted several hearings with water users in their respective states to acquaint them with the potential benefits of an interstate river compact and its proposed operations. Concurrent with compact investigations and negotiations, water users in Nebraska followed the initiative taken by the two states and the Benkelman-Haigler-Arikaree Public Irrigation District in Dundee County, Nebraska filed an application with the Federal Administration of Public Works for a grant and loan in excess of \$1.7 million to construct three reservoirs and an extensive irrigation system to serve 55,000 acres of land along the Republican River (letter from M.C. Hinderlider to Governor Ralph L. Carr October 26, 1939).

After an extensive study of the hydrology in the area and irrigated lands, the commissioners participated in intermittent compact negotiations sessions and prepared a final draft compact on May 8, 1935. Although it appeared the two states were in substantial agreement and were attempting to resolve outstanding issues such as the reservation of water for proposed storage projects, the catastrophic flood of 1935 caused an immediate impact to compact negotiations. The raging flood flows destroyed numerous diversion structures and scoured thousands of acres of formerly rich valley bottomlands to exposed gravels, which prompted Nebraska water users to cease pursuit of the Benkelman-Haigler-Arikaree project. Compact negotiations became strained and effectively ceased in January 1937 when the Nebraska Attorney General advised the Nebraska commissioner there was little use in continuing because the Nebraska people had lost interest and further recommended that Kansas be brought into any Republican River Compact negotiations (letter from William Wright to R.H. Willis January, 15 1937). Soon thereafter, formal negotiations between Colorado and Nebraska ceased and with them the first attempt at an interstate compact for the Republican River.

By the summer of 1937, interest had resumed in crafting an interstate river compact. The interest came forth from both a water supply and legal perspective. Water users in Colorado, Kansas, and Nebraska once again began to express their desire for expanded irrigated acreage and their wishes became manifest with a series of reconnaissance surveys by the Reclamation Service, Bureau of Agricultural Economics, and Army Engineers to build reservoirs for flood protection and to expand the rudimentary water supply infrastructure in the Republican River Basin. Coincident with the technical investigations, the United States Supreme Court issued a decision in 1938

that concerned the La Plata River Compact, which reaffirmed the rights of states to equitably distribute waters in an interstate river compact and to administer water rights within each respective state in a manner that complies with said compact [Hinderlider v. La Plata River & Cherry Creek Ditch Col., 304 U.S. 92, 99 (1938)]. This ruling was particularly relevant to Colorado State Engineer M. C. Hinderlider because it upheld his administrative decision that ordered curtailment of out-of-priority diversions by the Colorado owned La Plata River & Cherry Creek Ditch to meet water delivery obligations pursuant to the La Plata River Compact (1922) at the interstate boundary with New Mexico.

Commensurate with the investigative studies being conducted by the Bureau of Reclamation and Army Engineers in all three states in the Republican River valley, the Governors of Colorado, Kansas, and Nebraska recognized the need to draft an interstate river compact as a precursor to federal reservoir project construction (letter from M.C. Hinderlider to Ralph L. Carr October 26, 1939). The first meeting of the Republican River Compact Commission was held on May 28, 1940 in Denver, Colorado for the express purpose of drafting an interstate river compact that would provide “an equitable allocation of the waters of the Republican River system for beneficial uses and for the control of floods” (RRCC, 1940: 2). State Engineer M.C. Hinderlider, State Engineer A.C. Tilley, and Chief Engineer George S. Knapp represented Colorado, Nebraska, and Kansas respectively. Although Mr. E.B. Debler of the U.S. Bureau of Reclamation was in attendance to present the preliminary federal investigative reports in the Republican River Basin, no federal representative to the Republican River Compact Commission was requested or appointed to participate in the negotiations. The Republican River Compact

Commission continued to review the hydrology and other technical investigations in collaboration with federal agency representatives, assign tentative water allocations among the three states, quantify past and present uses of water in the basin, and deliberate upon draft compact language over the course of the succeeding ten months. After 22 days of negotiations conducted during eight meetings, the First Republican River Compact was consummated and signed by the three representative commissioners on March 19, 1941. The compact was ratified by the State of Colorado on April 10, 1941; ratified by the State of Kansas on April 4, 1941; and ratified by the State of Nebraska on April 18, 1941. The states worked with their representative Congressional representatives to seek the Consent of Congress. Upon review of the pending federal legislation, the Chairman of the Federal Power Commission objected strenuously to the Republican River Compact based solely upon language contained in Article I of the compact that stated, "The Republican River and tributaries thereof within the Basin... are not navigable..." (letter from Leland Olds to Representative Compton I. White, Chairman of Committee on Reclamation and Irrigation, October 18, 1941). Chairman Olds alleged that only a federal agency or Congressional legislation could designate the navigability of Republican River or its tributaries. The contested issue did not focus upon the concern there was insufficient draft in the Republican River for boats or ships, rather it was the assertion the federal government could claim control of the water in a stream for federal purposes whether it was indeed navigable or not (letter from Clifford H. Stone to Senator Alva B. Adams, November 5, 1941). Nevertheless, three Bills were introduced in the 77<sup>th</sup> Congress, 1<sup>st</sup> Session to seek the Consent of Congress to approve the proposed Republican River Compact (H.R. 4647; H.R. 5945; S. 1361). Although the

compact successfully passed the House of Representatives and Senate, President Roosevelt vetoed the Bill on April 2, 1942. President Roosevelt expressed his support for the need for the Republican River Compact to provide an equitable apportionment of water in the Republican River Basin. However, the President returned the Bill without approval because it did not “reserve to the United States all of the rights and responsibilities which it now has in the use and control of the waters of the basin” [House Doc. No. 690, 77<sup>th</sup> Cong., 2<sup>nd</sup> sess. (April 2, 1942)].

### Chapter Summary

In summary, prior to adoption of the Republican River Compact, the limited demands for water use within the basin were satisfied in most years by streamflow diversions and minimal ground water pumping from the alluvial aquifers. The primary focus of the state water administration officials was upon the equitable division of surface water supplies in the Republican River Basin. Although the compact commissioners and their respective technical advisers were aware of the existence of deep ground water in the table-lands, they did not have the need or inclination to conduct additional research into the availability of ground water resources from the bedrock aquifers because other alternatives appeared more attractive. To secure additional water supplies, the preferred option in the mid-20<sup>th</sup> century was the construction of dams and reservoirs. The capture of excess streamflows in storage vessels offered the dual benefits of increased water supply and a measure of flood protection against loss of life and property. The States of Colorado, Kansas, and Nebraska initiated compact negotiations in the Republican River

Basin in the early 1940's to pursue an equitable apportionment of interstate river waters and to secure federal cooperation in the construction of several anticipated reservoir projects.

## CHAPTER 5

### DESCRIPTION OF THE REPUBLICAN RIVER COMPACT

#### ADMINISTRATION

##### Background

Subsequent to the veto by President Roosevelt, the Republican River Compact Committee members continued to confer with their Congressional representatives and the federal agencies to address two main objectives that were necessary for ratification of the compact: the first was to request a federal representative be appointed to participate in compact negotiations; and the second to collaborate with the Federal Power Commission to compose mutually acceptable language that addressed the navigable rivers issue. Their efforts proved successful. The President appointed Mr. Glenn L. Parker of the United States Geological Survey as federal representative for compact negotiations and mutually acceptable language was reached between the states and Commissioner Olds of the Federal Power Commission to alleviate the issue of sovereign authority over navigable waters (Scott and Willis, 1942). Congress endorsed their actions and granted the States of Colorado, Kansas, and Nebraska authority to negotiate a Republican River Compact [An Act Granting the consent of Congress to the States of Colorado, Kansas, and

Nebraska to Negotiate and Enter into a Compact for the Division of the Waters of the Republican River, Public Law 696, 77<sup>th</sup> Cong., 2<sup>nd</sup> sess. at 545 (1942)].

The Republican River Compact Commission reassembled for their ninth meeting on December 2, 1942 and Mr. Parker was unanimously elected the presiding officer during the negotiations (RRCC, 1942a: 1). The assembled commissioners and their legal advisors reviewed a draft of the compact line-by-line that included new language that resolved the navigable waters issue with the Federal Power Commission. The meeting was recessed until December 29<sup>th</sup> with the intent to reach final consummation of the Republican River Compact at that time. In the interim period, Leland Olds of the Federal Power Commission asserted new objections to pre-existing language in the draft compact that described the equitable distribution of waters in the Republican River Basin and offered a new draft with numerous and substantial changes to federal representative Parker for consideration on December 26, 1942 (letter from Leland Olds to Glenn L. Parker, December 26, 1942).

Negotiations for the Republican River Compact resumed as scheduled on December 29<sup>th</sup> and discussion of the Federal Power Commission's proposed draft quickly ensued. Upon careful and extended review of the language proposed by Mr. Olds, the Power Commission draft was rejected because it eliminated all reference to the term "beneficial consumptive use", which was the basis for allocation of water supplies in the Republican River Compact and its proposed elimination was forecasted to imperil ratification of the compact by all of the states (RRCC, 1942b: 4). The compact negotiators and legal counsel continued to review and refine the entire text of the

compact over the course of three days until mutual acceptance and adoption of the Republican River Compact final draft on December 31, 1942.

### Enabling Legislation

The draft Republican River Compact was submitted by each of the compact commissioners to their respective governors in early January 1943 with a recommendation for introduction and approval by their state legislative bodies. Nebraska Senator Hugh Butler initiated federal action to seek Congressional approval of the compact through introduction of Senate Bill 649. Although the Republican River Compact commissioners and their legal representative were confident of ratification of the compact in their respective states, federal approval was considered more tenuous because of the rejection of the December 26<sup>th</sup> compact draft tendered by the Federal Power Commission. The states garnered support for the compact through other influential federal agencies and personal contacts such as Secretary of Interior Harold L. Ickes who offered unqualified support for Senate Bill 649 (letter from Harold L. Ickes to Senator J.H. Bankhead, Chairman of the Committee on Irrigation and Reclamation, February 24, 1943). On February 27, 1943, the Department of Agriculture and the War Department joined Interior and testified in support of the legislation before the House Committee on Irrigation and Reclamation, while no person appeared on behalf of the Federal Power Commission (letter from Glenn L. Parker to George S. Knapp, April 3, 1943). The States of Colorado, Kansas, and Nebraska ratified the compact and federal representative Parker recommended a favorable action in his report to Congress and to

the President of the United States (letter from Glenn L. Parker to the President of the United States, March 29, 1943). The Republican River Compact became effective upon signature of President Roosevelt on May 26, 1943 [Pub. L. 60, 78<sup>th</sup> Cong., 1st sess., Chap. 104 (1943)].

### Authority and Membership

The authority to administer the Republican River Compact is vested exclusively to the States of Colorado, Kansas and Nebraska. The responsibility for administration of the Republican River Compact is set forth in Article IX of the compact:

“It shall be the duty of the three states to administer this compact through the official in each state who is now or may hereafter be charged with the duty of administering the public water supplies, and to collect and correlate through such officials the data necessary for the proper administration of the provisions of this compact. Such officials may, by unanimous action, adopt rules and regulations consistent with the provisions of this compact.”

The United States federal government is not a party to the compact, nor does it retain any form of administrative authority to the Republican River Compact. However, the United States Geological Survey, or its successive federal agency, is tasked with collaborating with the states for proper administration of the compact by collecting streamflow data and other necessary water facts. The Bureau of Reclamation and other federal agencies perform similar actions and also offer collaborative assistance to the states.

The primary intent of the Republican River Compact is contained in the first paragraph of Article I of the Republican River Compact:

“The major purposes of this compact are to provide for the most efficient use of the waters of the Republican River Basin (hereinafter referred to as the "Basin") for multiple purposes; to provide for an equitable division of such waters; to remove all causes, present and future, which might lead to controversies; to promote interstate comity; to recognize that the most efficient utilization of the waters within the Basin is for beneficial consumptive use; and to promote joint action by the states and the United States in the efficient use of water and the control of destructive floods.”

The second Article describes the geographic extent of the Republican River Basin and definition of terms. Article III tabulates the computed annual virgin water supplies in the fourteen designated drainage basins within the Republican River watershed. The allocation of water for beneficial consumptive use for each state by designated drainage basin is documented in Article IV and is tabulated below:

Table 6. Annual Compact Allocation for Beneficial Consumptive Use (Acre-Feet)

Compact Designated Drainage Basin	Average Annual Virgin Water Supply	Colorado Allocation	Kansas Allocation	Nebraska Allocation
Prairie Dog Creek	27,600		12,600	2,100
Sappa Creek	21,400		8,800	8,800
Beaver Creek	16,500	3,300	6,400	6,700
Medicine Creek	50,800			4,600
Red Willow Creek	21,900			4,200
Driftwood Creek	7,300		500	1,200
Frenchman River	98,500			52,800
South Fork of Republican River	57,200	25,400	23,000	800
Rock Creek	11,000			4,400
Buffalo Creek	7,890			2,600
Arikaree River	19,610	15,400	1,000	3,300
North Fork of Republican River	44,700	10,000		11,000
Main Stem of Republican River	87,700			
Blackwood Creek	6,800			
Distribution of Unallocated, Main Stem, & Blackwood Creek			138,000	132,000
Total Basin	478,900	54,100	190,300	234,500

Article V of the Republican River Compact provides specific recognition and protection of the adjudicated water rights and court decision relevant to the Pioneer Canal that serves irrigated lands in both Colorado and Nebraska. Articles VI, VII, and VIII contain protective language for any person or entity to construct a storage reservoir or diversion structure for water regulation if the land or water right acquisitions are properly compensated for in financial terms and exercised in conformance with the applicable laws in that state. As previously described, Article IX documents the authority of the three states to administer the Republican River Compact. Although the federal government does not retain any administrative authority in the Republican River Compact, Article X (a) provides a parallel constraint upon the states to not impinge upon the rights, powers, or jurisdiction of the United States through operation of the compact or subject the United States to state taxation. In the concluding section, Article XI provided recognition that any beneficial consumptive use of water by the United States will be assessed against the state allocation in which the federal use of water is made. Further, the United States recognized the beneficial consumptive use of water within the Republican River Basin “is of paramount importance to the development of the Basin; and no exercise of such power or right thereby that would interfere with the full beneficial consumptive use of the waters within the Basin shall be made”[Article XI (b)].

### Organizational Structure and Funding

Upon enactment of the Republican River Compact, the representative state officials from Colorado, Kansas, and Nebraska met periodically to review water

administrative activities in each state and to collaborate with federal agencies in the development of reservoir storage projects. The compact commissioners began to recognize the need to establish a defined organizational structure and operating principles to facilitate compact administration. In July 1959, the state officials from Colorado, Kansas, and Nebraska that were charged with administering public water supplies in their respective states adopted Rules and Regulations (Rules) for the purpose of implementing the water administrative authority conferred upon them by the Republican River Compact. As prescribed in the Rules, these representative state officials constitute an administrative body that is responsible for implementing the Republican River Compact and was aptly designated "The Republican River Compact Administration" (RRCA, 1959a). The Rules specify the term of office for the RRCA official members, designation and rotation of the Chairman of the RRCA, the authority to create committees to perform tasks deemed necessary by the RRCA, the annual meeting schedule and notification requirements, an order of business to be conducted during the annual meetings, and other reporting and procedural requirements.

The costs associated with administration of the Republican River Compact by the representative RRCA members, or their technical and legal support staff, are borne by that particular state incurring said costs. The RRCA does not have an operational budget and the three states do not, nor does any other entity, provide dues or other monetary contributions to fund RRCA annual operations.

## Decision Making

The decision-making authority to administer the Republican River Compact is vested exclusively to the RRCA. The federal government provides collaborative assistance to the RRCA in the exercise of its administrative authority by providing streamflow records and other water-related information (Article IX). In consideration of all matters that come before the RRCA, any action or decision must be determined by vote. Each state, or member of the RRCA, has one vote and every decision, authorization, or action by the RRCA requires a unanimous vote of the official members or their duly appointed and acting personal representatives that are present at a meeting (RRCA, 1959a).

## Enforcement

The duty to comply with the Republican River Compact rests with the States of Colorado, Kansas, and Nebraska through the state official charged with water administration authority within each states' boundaries (Article IX). It is therefore incumbent upon the responsible state official to enforce the Republican River Compact requirements within their discrete territory. As a collective and administrative body, the RRCA may adopt or modify rules and regulations that are intended to assist in the administration of the compact and may act as a forum to address and attempt to alleviate contentious issues. However, the RRCA does not have authority to issue orders or other mandatory actions to any discrete water user or to an individual state to comply with the

compact. Typical of other interstate river compacts, the Republican River Compact does not contain a provision or clause for intermediate dispute resolution through arbitration or mediation.

In the event that one or more aggrieved parties to the Republican River Compact believes they have been injured by the water administrative actions, or lack thereof, by another party to the compact and the affected states have not reached a mutually acceptable resolution through the RRCA – they may seek a judicial remedy by filing a claim for relief to the United States Supreme Court. Although interstate river compact litigation is an extraordinarily expensive activity in terms of time, energy, and monetary resources, it is an action of finality that will provide a definitive answer or decision to resolve a contentious issue.

### Chapter Summary

The organizational structure and decision-making process of the Republican River Compact is representative of the 29 water supply/allocation compacts in the United States that are designed to maximize the beneficial use of water and distribute available surface waters in an equitable manner. The compact is particularly insightful as a case study because its articles and provisions are indicative of the 23 interstate river compacts that do not include ground water within the allocation system, even though ground water is the predominant source of water supply within the basin. The Republican River Compact is constructed to administer interstate river waters in a collegial atmosphere among the three principal water officials representing the participatory states and with the federal

government by requiring a unanimous decision for passage of any resolution or action. However, the dissent of one party may severely hamper the effectiveness of the compact administration through the omission of an enforcement provision that clearly grants the administrative body the authority to move beyond a stalemate by issuing orders or to take other necessary measures to meet the compact objectives. Complementing the enforcement provision, the Republican River Compact also does not include a dispute resolution process or other interim mechanism to address controversies among the three states. The omission of an enforcement provision and a dispute resolution process to address the inevitable issues of contention that arise in water resources management ultimately provides compact administrators only one unattractive venue to resolve contested issues - interstate litigation to reach a final decision.

## CHAPTER 6

### EVALUATION OF THE EFFECTIVENESS OF THE REPUBLICAN RIVER COMAPACT ADMINISTRATION IN MEETING THE COMPACT OBJECTIVES

This chapter tests the premise that ground water may be successfully included within the allocation system of an interstate river compact, and performs said test through a comprehensive evaluation of the overall effectiveness of the RRCA in achieving the four principal objectives of the Republican River Compact. The research design employed in this dissertation is the case analysis structure described in Chapter 3 for the Republican River Compact and it applies the program evaluation methodology as the analytical instrument to perform the evaluation (Yin, 1994; Brewer and deLeon, 1983). Enveloped within the program evaluation methodology are the accuracy standards necessary for a formal and summative evaluation (Ramlow, 2004).

This evaluation is conducted through a two-part analysis. For each objective, the first component is a comprehensive description of the developments or actions taken within the Republican River Basin that have either a quantitative or qualitative influence in meeting the stated objective. The second component is a formal and summative evaluation of the actions taken within the Republican River Basin through a pre- and

post-test analysis or trend analysis that measures the performance indicators or outcomes of the Republican River Compact in perspective of each of the four identified compact objectives over the tenure of the succeeding 61 years since its enactment in 1943.

OBJECTIVE: MAXIMIZE THE EFFICIENT AND BENEFICIAL CONSUMPTIVE  
USE OF WATERS WITHIN THE REPUBLICAN RIVER BASIN

For this objective, five actions were researched to determine their influence upon the indicator variables or outcome measures that are necessary to evaluate the performance of the Republican River Compact in meeting the objective to maximize the efficient and beneficial consumptive use of water in the Republican River Basin. The research is also instructive in describing *how* and *why* the influencing actions impacted the outcome measures. The identified actions are: (1) reservoir storage development; (2) surface water delivery systems; (3) ground water withdrawals; (4) surface water irrigation districts; and (5) ground water management district development.

Reservoir Storage Development

Prior to ratification of the Republican River Compact in 1943, the federal government was reluctant to aid in the construction of large reservoirs or water supply projects in the interstate Republican River system because there was not a formal compact in place to ensure the water supplies would be equitably apportioned among neighboring states and to protect federal interests. With federal approval secured through

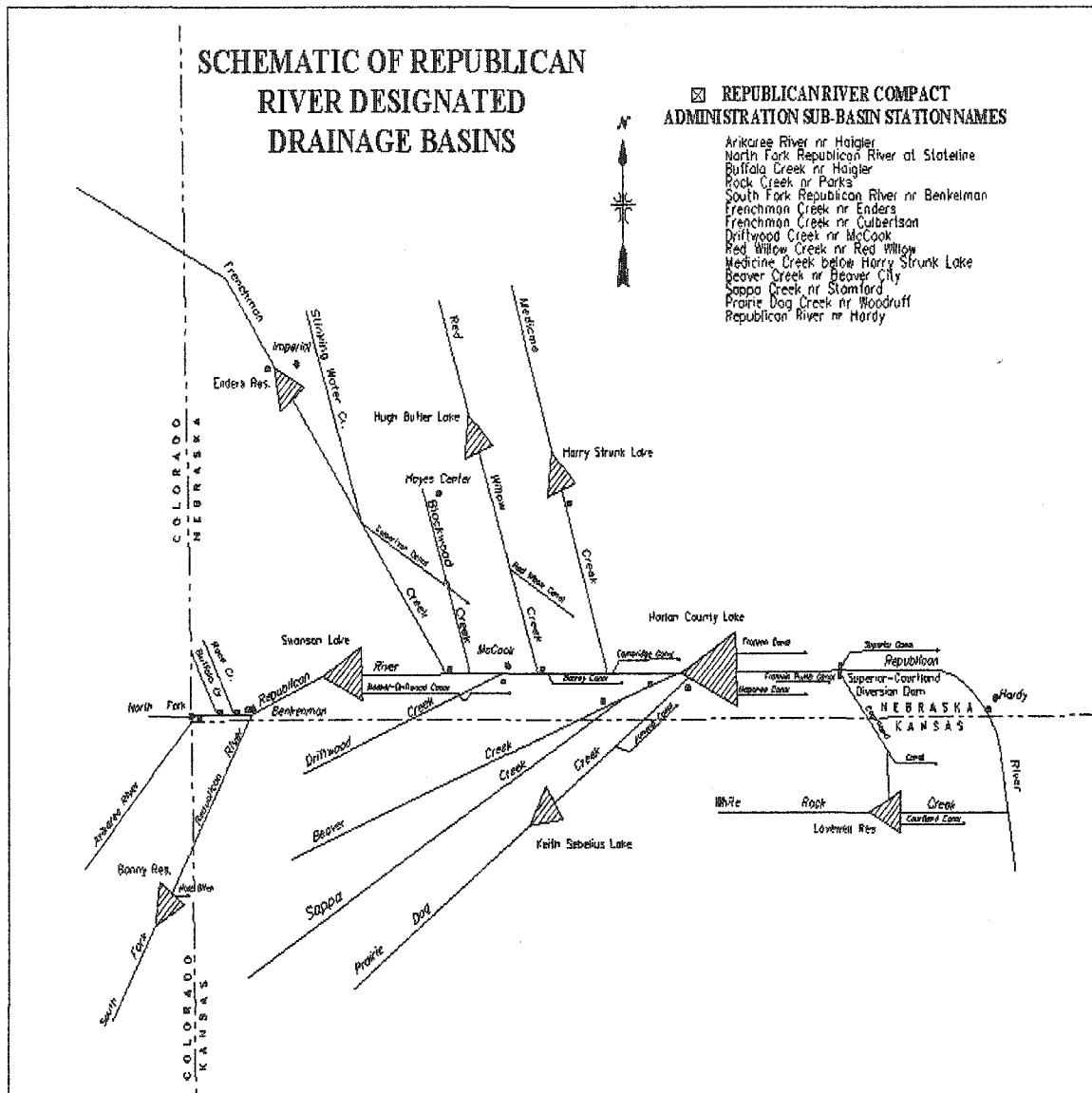
signature of President Roosevelt, the federal government was anxious to invigorate the economy in the Republican River Basin during the post - World War II era through expanded farm production and to stabilize emigration from the basin. The anticipated construction of large reservoirs would serve these needs by providing supplemental storage water for expanded irrigated acreage as well as increasing the fishing and recreational opportunities in the multi-purpose reservoirs. Construction of Bonny Reservoir on the North Fork of the Republican River began in 1948 and signified the first federal reservoir project in the Republican River Basin (RRCA, 1982). Soon thereafter, in 1949 the Bureau of Reclamation presented a comprehensive 12-reservoir plan to the RRCA that would provide the storage capability to increase the projected consumptive use within the Republican River Basin to “only about one-half of the virgin water supply of the Basin” (Republican River Compact Meeting, 1949: 2). Although the actual number of reservoirs constructed was pared from twelve to eight, the Republican River Basin retains a total reservoir storage capacity of approximately 1.7 million acre-feet in a multi-purpose reservoir system that is described in Table 7.

Table 7. Dams and Reservoirs in Republican River Basin

Name	River or Creek	Construction	Date of Closure	Capacity (af)
Bonny Dam and Reservoir	South Fork Republican	1948-1951	July 6, 1950	170,600
Trenton Dam and Swanson Lake	Republican River	1949-1953	May 4, 1953	246,291
Enders Dam and Reservoir	Frenchman Creek	1947-1951	Oct. 23, 1950	72,958
Red Willow Dam and Hugh Butler Lake	Red Willow Creek	1960-1962	Sep. 5, 1961	85,070
Medicine Creek Dam & Harry Strunk Lake	Medicine Creek	1948-1949	Aug. 8, 1949	88,420
Norton Dam and Keith Sebelius Lake	Prairie Dog Creek	1971-1964	June, 1964	134,738
Harlan County Dam and Lake	Republican River	1950-1952	Dec. 2, 1952	814,111
Lovewell Dam and Reservoir	White Rock Creek	1955-1957	June, 1957	86,131

For illustrative purposes below, Figure 9 is a schematic diagram of the Republican River Basin that includes the streams, reservoirs, and river gaging stations in the Republican River Basin (RRCA Ground Water Model, 2003).

Figure 9. Schematic Diagram of Republican River Basin.



## Surface Water Delivery Systems

Individual farmers began irrigating small tract of lands in the tributary valleys and along the Republican River mainstem late in the 19<sup>th</sup> century through private ditches. As settlement in the Republican River Basin increased, the farmers began to consolidate their interests and formed mutual ditch companies with the primary intent to combine their financial resources and share the costs of constructing and maintaining larger canals that could serve multiple parties. In 1902, the United States Congress passed the Reclamation Act that provided a mechanism for the federal government to offer technical and financial assistance to agricultural communities by building canals, reservoirs, and other structures that could provide supplemental water to the existing croplands and new water supplies to served expanded irrigated acreage. A summary of the large irrigation canals that were constructed through cooperative local/state/federal interests in the Republican River Basin is provided in Table 8 (USDI BOR, 2002).

Table 8. Major Surface Water Canals in the Republican River Basin

Name	River or Creek	Irrigated Acres
Culbertson Canal & Extension	Frenchman Creek	20,990
Meeker-Driftwood Canal	Republican River	16,562
Red Willow Canal	Red Willow Creek	4,877
Bartley Canal	Republican River	6,435
Cambridge Canal	Republican River	17,297
Almena Canal	Prairie Dog Creek	5,764
Naponee Canal	Republican River	1,628
Franklin Pump Canal	Republican River	2,106
Franklin Canal	Republican River	11,262
Superior Canal	Republican River	5,972
Courtland Canal – Nebraska	Republican River	1,967
Courtland Canal – Kansas	Republican River	42,500
Total		137,360

## Ground Water Withdrawals

Contrary to the development of surface water supplies that occurred through a blend of private and incorporated ditch/canal systems, ground water supplies developed on a well-by-well basis. The earliest wells in the Republican River Basin were small domestic and stock watering wells that served the new settlers and small towns. The volume of water pumped from these small wells is minimal, which prompted the state legislatures to exempt them from state registration or permitting requirements until the mid-20<sup>th</sup> century. Although the compact negotiators fully recognized the existence of the domestic and stock water wells, the number and impact to the ground water aquifers was unknown and deemed minimal, so they were also exempted from inclusion within the Republican River Compact. Beginning in the late 1950's, the technical advancements in well construction pump technology and power supplies prompted rapid development of large-capacity irrigation wells to serve fertile "table-lands" beyond the river valleys. The number and expansion of registered wells and ground water irrigated acreage within the Republican River Basin is reflected in Table 9 (RRCA Ground Water Model, 2003).

Table 9. Number of Registered Wells and Acres Irrigated by Groundwater

Year	Colorado		Kansas		Nebraska	
	Wells	Acres	Wells	Acres	Wells	Acres
1940	33	767	18	1,479	8	25,045
1950	125	9,562	64	3,819	98	113,514
1960	411	49,808	501	48,152	3,710	332,100
1970	2,681	358,895	1,829	186,811	6,578	525,372
1980	4,082	571,987	4,166	349,266	13,790	1,355,950
1990	4,102	541,307	4,326	394,227	15,421	1,436,374
2000	4,110	567,720	4,439	428,304	17,726	1,605,714

### Surface Water Irrigation Districts

Representatives from the U.S. Bureau of Reclamation and Corps of Engineers met with the RRCA in 1949 to review a comprehensive plan developed by the federal agencies that was intended to utilize the waters available in the Republican River Basin to the maximum extent possible. The Bureau of Reclamation proposed an aggressive construction schedule that included water conveyance and storage structures on most of the principal tributaries that would provide sufficient water to irrigate approximately 188,000 acres of land (Republican River Compact Meeting, 1949: 2). To repay the outstanding debt to the federal government for constructing the reservoirs and irrigation canals, the individuals and small towns that benefited from the increased water supplies created governing institutions referred to as irrigation districts. The irrigation districts are typically governed by local representatives that are charged with managing the system to maximize the beneficial use of water within the district boundaries. The consolidated management system offered by surface water irrigation districts increases the efficient delivery of surface water supplies. Opposed to relatively small ditches with inefficient

diversion and conveyance structures that serve individual farms, the irrigation districts are able to divert water through larger and more efficient structures into fewer canals that decrease the total amount of conveyance seepage loss in delivering water to irrigated fields within a district service region. During water-short periods, irrigation districts are able to implement management directives that either apply an incremental curtailment in water supply to all water users within their region or rotate limited water supplies among the shareholders in a mutually incorporated ditch/canal system when supplies are inadequate. The irrigation districts also employ personnel that are able to deliver reservoir storage releases or make timely diversion adjustments to constantly changing streamflows in a river or creek to meet varying crop irrigation demands. The irrigation districts retain authority to assess and collect an annual tax or fee to raise sufficient revenue to finance operations and maintenance of the water facilities and repay the outstanding debt. Presented in Table 10 is a tabulation of the incorporated irrigation districts in the Republican River Basin (USDI BOR, 2002).

Table 10. Irrigation Districts in the Republican River Basin

Irrigation District	State	Irrigated Acres
Frenchman Valley	Nebraska	9,295
H & RW	Nebraska	11,695
Frenchman-Cambridge	Nebraska	45,171
Almena	Kansas	5,764
Nebraska-Bostwick	Nebraska	22,935
Kansas-Bostwick	Kansas	42,500

## Ground Water Management Districts

The Colorado General Assembly created Colorado Ground Water Commission (GWC) in 1957 with intent to grant this quasi-judicial body the authority to regulate non-tributary ground water and to identify geographic areas with developed ground water pumping that appeared to be approaching or exceeding the normal annual rate of recharge to the ground water aquifer. The authority and duties ascribed to the 12-member GWC were refined in 1965, including the authority to designate ground water basins, in which the ground water in its natural course would not contribute to a surface stream or impact surface water rights [Colo. Rev. Stat. § 37-90-137(6)]. The 1965 Ground Water Act also authorized the GWC to approve local ground water management districts under their authority with the ability to assess and collect taxes and adopt rules on a local basis to manage ground water resources within that district's boundaries. Within the Republican River Basin in Colorado, seven ground water management districts were formed to regulate the use, control, and conservation of ground water as tabulated below (CGWC, 1957).

Table 11. Colorado Ground Water Management Districts

Ground Water Management District	Formation Date
Sand Hills District	December 9, 1966
Plains District	January 27, 1967
Central Yuma District	May 22, 1967
Frenchman District	May 22, 1967
W-Y District	May 22, 1967
Arikaree District	December 13, 1967
Marks Butte District	August 5, 1977

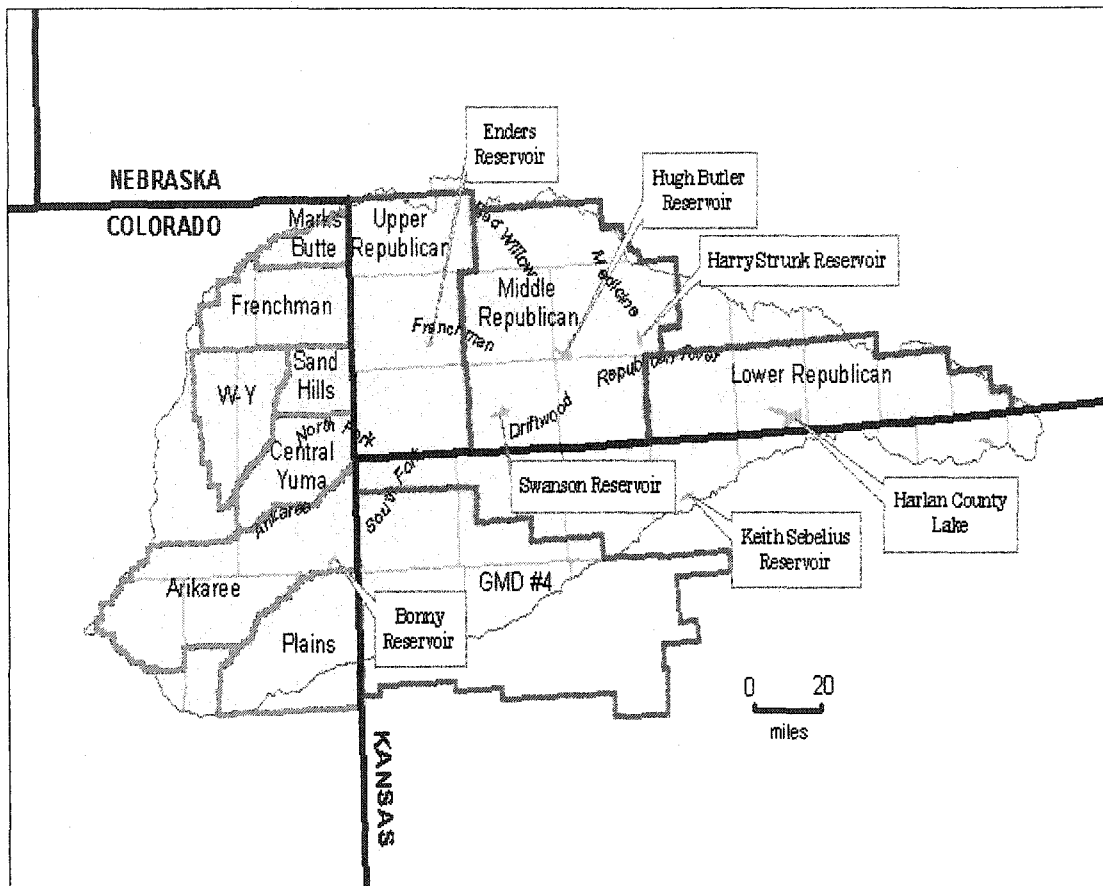
On May 15, 1970 the GWC issued a ban on the issuance of all ground water well permit applications within three miles of the live streamflow of Chief Creek and the North Fork of the Republican River within Colorado. The intent of this moratorium was to protect the surface water rights on these streams within Colorado. In 1975 the 3-mile ban was extended to all tributaries of live streamflow to the North Fork of the Republican River in Colorado.

The Northwest Kansas Groundwater Management District No. 4 (GMD #4) is the only incorporated district that regulates ground water use within the Republican River Basin in Kansas. The GMD #4 covers approximately 3.11 million acres in all or part of ten counties in the northwest corner of Kansas and was formed on March 1, 1976 (Kans. Stat. Ann. § 82a-1020). The purpose of the district is to conserve and manage ground water resources through a locally elected board of eleven members that oversee five essential programs: (1) to locally organize, develop and administer proper management and conservation practices of the ground water resource for the benefit of the entire district; (2) to establish a framework by which local landowners and water users can help determine their own policies and programs with respect to the management and use of the ground water resource within the district; (3) to support and participate in research and education relevant to the proper use and management of the limited ground water resource; (4) to derive optimum social and economic benefits accruing from the wise development, use, and management of the ground water reserves; and (5) to cooperate with all levels of government and all district members in order to accomplish the

objectives of the district and the Groundwater Management District Act and amendments thereto (Overview GWMD 4, 2004).

The Nebraska legislature enacted LB-1357 in 1969 that created natural resource districts (NRD) that focus upon management of ground water resources and also a variety of other natural resource programs targeted toward land and water conservation practices. NRD's provide financial assistance to landowners that seek to improve their irrigation systems and they also promote best-management practices to protect water resources. Local NRD's adopt rules and regulations that promote the efficient use of ground water, protect ground water quality from any further degradation, and extend the aquifer life as long as possible within their district boundaries (Nebraska Association of Natural Resource Districts, 2004). The Nebraska legislature delegated the authority to manage and regulate ground water withdrawals to the Natural Resource Districts, including applications to change the amount or location of ground water withdrawals in the local district's boundaries. Within Nebraska, ground water management in the Republican River Basin is segmented into three NRD's - the Upper, Middle, and Lower Natural Resource Districts. A map of the Ground Water Management and Natural Resource Districts within the Republican River Basin is provided below (RRCA Ground Water Model, 2003):

## Ground Water Management and Natural Resource Districts in Republican River Basin



### Evaluation of the Outcome Measures for the Republican River Compact Objective – Maximize the Efficient and Beneficial Consumptive Use of Water

The actions or performance taken by the RRCA toward meeting the objective to maximize the efficient and beneficial consumptive use of water within the Republican River Basin are evaluated in perspective of two outcome measures. The measures are: (1) development of surface water supplies; and (2) the development of ground water supplies.

### Evaluation Measure: Development of Surface Water Supplies

Surface water irrigated lands within the Republican River Basin increased from approximately 76,283 acres during compact negotiations in 1940 to 129,830 acres in 2000. The increase in acreage is directly correlated to the collaborative efforts between the federal government and local surface water irrigation districts to build large diversion and canal systems that are currently able to serve up to 137,360 irrigable acres in the basin under full water supply conditions. Although the RRCA did not instigate the creation of irrigation districts or take other actions that may be construed as directly relevant to the expansion of surface water irrigated lands, they did act as a forum to coordinate with the Bureau of Reclamation and they consistently endorsed the new surface water diversion projects that were intended to maximize the beneficial use of Republican River waters. The trend in expanded surface water irrigated lands is correlated to the intervening actions of the federal government and is proportional to the construction of the eight federal reservoirs constructed within the Republican River Basin from 1950 to 1964 that provided supplemental water from storage. The trend or increase in surface water irrigated lands by decade is provided in Table 12 (RRCA Ground Water Model, 2004).

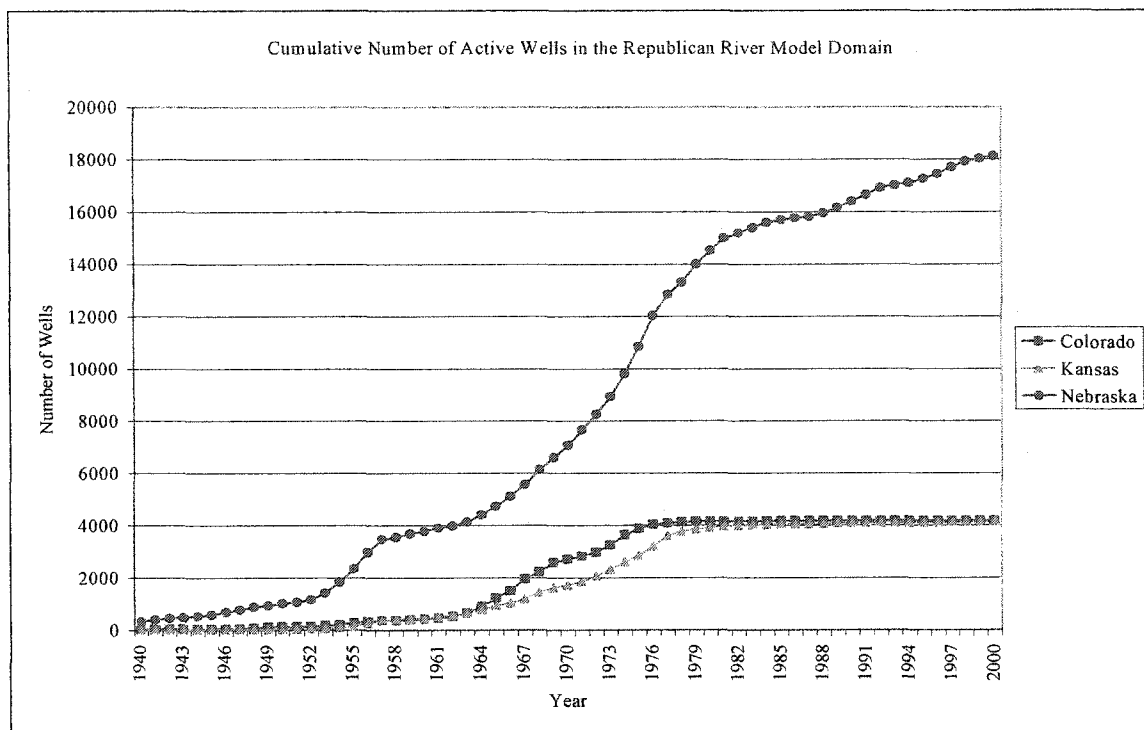
Table 12. Surface Water Irrigated Lands in the Republican River Basin

Year	Colorado	Kansas	Nebraska
1940	4,763	1,620	69,900
1950	4,763	2,297	86,599
1960	4,763	2,297	146,489
1970	4,763	13,040	144,884
1980	4,763	13,038	130,479
1990	4,763	12,067	119,414
2000	4,763	11,216	113,851

Evaluation Measure: Development of Ground Water Supplies

The development of ground water supplies increased dramatically after ratification of the Republican River Compact in 1943. During the compact negotiations in 1940, an estimated 59 ground water wells irrigated 27,291 acres of land. The number of large-capacity irrigation wells swelled to 26,275 wells that irrigate over 2.6 million acres in 2000 (RRCA Ground Water Model, 2003). As indicated by Figure 10, ground water development in the Republican River Basin was relatively minimal until the 1960's and 1970's when ground water well construction increased significantly. From 1980 to the present, ground water development in Colorado and Kansas stabilized with negligible additional wells because of intrastate well permitting regulations that restricted the availability of new well permits. In Nebraska, ground water development continued until declining ground water table elevations prompted curtailment of new wells in 1997 in the western portion of the Republican River Basin and settlement of the interstate lawsuit *Kansas v. Nebraska and Colorado*, No. 126 (May 19, 2003) that required a moratorium on new wells in the remaining two Natural Resource Districts by the end of 2003.

Figure 10. Cumulative Number of Wells in the Republican River Model Domain.



In the pursuit of maximizing the beneficial use of water within the Republican River Basin, the individual water users obviously recognized the value and efficiency of irrigating crops with ground water. Approximately 26,200 large-capacity irrigation wells were constructed to serve an additional 2.6 million acres in crop production since ratification of the compact. Although the trend for construction of new wells slowed after 1980, and is now essentially curtailed through institutional moratoriums, the RRCA consistently failed to recognize or account for the depletions caused by ground water pumping to Republican River streamflows since assembling as an administrative body in 1959.

OBJECTIVE: PROVIDE AN EQUITABLE ALLOCATION OF REPUBLICAN RIVER  
WATERS

The equitable distribution of Republican River waters among the States of Colorado, Kansas, and Nebraska is the primary goal of the Republican River Compact and this objective seeks to assure the method, or allocation system, of said distribution is performed in accord with the principle to treat all three states equally in a just and unbiased manner. To evaluate the effectiveness of the RRCA in the equitable allocation of water resources within the Republican River Basin, four actions were researched that influence the outcome measures. The actions include: (1) assessment of the amount, type and location of all water supplies; (2) the formula for distribution or the allocation system; (3) monitoring and measurement of water supplies; and (4) the adaptability of the allocation system to meet new demands.

Assessment of the Amount, Type, and Location of Water Supplies

The term “virgin water supply” is defined in the 1943 Republican River Compact as the amount “undepleted by the activities of man” and is applied in the assessment of annual average water supplies that originated in the 14 designated drainage basins in the compact (Article II). Although the compact provided a definition for the term used to assess the annual water supplies, it did not provide a mechanism or formula to calculate the numerical amount of water available for distribution on an annual basis that could be

used in compact administration. The impetus to calculate the annual virgin water supply did not occur until formal organization of the RRCA on July 15, 1959 when the representative state officials recognized the need to collect the necessary hydrologic data to develop a procedure to compute the virgin water supply for each of the designated drainage basins. Later that year on November 19, 1959 the RRCA established a "Committee on Procedure for Computation of Annual Virgin Water Supply" (Committee on Procedure), consisting of one representative of each state and inviting the U.S. Geological Survey, Bureau of Reclamation, U.S. Department of Agriculture, and Corps of Engineers to cooperate with the Committee on Procedure (RRCA, 1959b).

Although the primary water supply considered for analysis was the natural streamflow in the Republican River and its tributaries, the RRCA did not restrict the source of supply to surface waters only. The impact of ground water diversions upon the assessment of virgin water supplies in the Republican River Compact was considered by the nascent RRCA. At its first annual meeting in March 1960, the RRCA accepted a recommendation from the Committee on Procedure to include "only the wells in the valley floor of the main Republican River and of its tributaries be considered as depleting the water supply of the Republican River, for present use in the Virgin Flow Formula" (RRCA, 1960). The Committee on Procedure recognized the potential impact to flows in the Republican River from "Table-Land" wells located north of the river on tributaries between Harlan County Dam and Superior, Nebraska, but deferred inclusion of these wells in the virgin water supply computation because they were unable to determine the affect, if any, of ground water pumping from the Ogallala aquifer to the Republican River streamflows. The RRCA approved their interim recommendation to initiate an

observation well program in that specific area in the eastern portion of the Republican River Basin on tributaries located north of the river to determine the effect of these wells upon the ground water table and flows in the Republican River (RRCA, 1960).

In addition to quantifying the amount of surface and alluvial ground water available, the Committee on Procedure was also required to consider the natural state of water supplies that were “undepleted by the activities of man” in computation of the annual virgin water supply. After enduring the devastating affects of soil erosion during the Dust Bowl era, the federal government cooperated with individual farmers to build stock water ponds, land terraces, and institute crop rotation and other farm practices in the basin that were designed to conserve water and prevent soil erosion. For the Committee on Procedure, the question arose of whether or not to include the depletive impacts of these successful “activities of man”. The RRCA answered definitively and determined the depletions to tributary streamflow from soil and water conservation practices installed in the Republican River Basin in cooperation with the U.S. Department of Agriculture were not to be included in the computation of virgin water supplies (RRCA, 1960: 2).

#### Formula for Distribution or the Allocation System

At the Second Annual Meeting of the RRCA on April 4, 1961, the Committee on Procedure partially completed their assignment and tendered a report entitled “Formulas for the Computation of Annual Virgin Water Supply, Republican River Basin” (RRCA, 1961). The basic data used in the formulas included:

1. Stream discharges from surface water records compiled by the U.S. Geological Survey;
2. Total reservoir evaporation records computed by the U.S Corps of Engineers;
3. Precipitation records as compiled by the U.S. Weather Bureau;
4. Reservoir elevations, surface areas and storage contents from records compiled by the operating agency;
5. Irrigation diversions or irrigated acreages from records compiled by each State.

The stream gaging stations used to calculate the virgin water supply are located at or near the confluence of the streams for the drainage basins designated in Article III of the Republican River Compact. The gaging stations are identified below:

Table 13. U.S. Geological Survey Gaging Stations for the Republican River Compact

Station Number	Station Name
6B-8215.00	Arikaree River at Haigler, Nebraska
6B-8230.00	North Fork Republican River at CO-NE State line
6B-8235.00	Buffalo Creek near Haigler, Nebraska
6B-8240.00	Rock Creek at Parks, Nebraska
6B-8275.00	South Fork Republican River near Benkelman, Nebraska
6B-8355.00	Frenchman Creek at Culbertson, Nebraska
6B-8365.00	Driftwood Creek near McCook, Nebraska
6B-8380.00	Red Willow Creek near Red Willow, Nebraska
6B-8425.00	Medicine Creek below Harry Strunk Lake, Nebraska
6B-8470.00	Beaver Creek near Beaver City, Nebraska
6B-8475.00	Sappa Creek near Stamford, Nebraska
6B-8485.00	Prairie Dog Creek near Woodruff, Kansas
6B-8525.00	Courtland Canal at Nebraska-Kansas State line
6B-8215.00	Republican River near Hardy, Nebraska

The general procedure for calculating the virgin water supply for each designated drainage basin was provided in narrative form, without numerical assignments. For each

of the 14 designated drainage basins, the annual virgin water supply equals the recorded streamflow discharge measured at the U.S. Geological Survey gaging station, plus the surface water irrigation diversions, plus the ground water irrigation diversions, minus the return flows from the lands irrigated by surface water, minus the return flows from lands irrigated by ground water, plus the reservoir evaporation (if applicable), plus or minus the change in reservoir storage (RRCA, 1961).

As previously instructed, the Committee on Procedure limited the irrigation diversions from ground water to those wells pumping only from the alluvial stream channels and did not include "table-land" wells. The RRCA endorsed their recommendation because the "determination of the effect of pumping by table-land wells on the streams in the Republican River Basin must await considerably more research and data regarding the character of the ground water aquifers and the behavior of the monthly or annual effects on stream flows" (RRCA, 1961: 3).

To complement the determination of the virgin water supply, it is necessary to calculate the "beneficial consumptive use" of water, which is defined in the Republican River Compact as "that use by which the water supply of the Basin is consumed through the activities of man, and shall include water consumed by evaporation from any reservoir, canal, ditch, or irrigated area. Beneficial consumptive use is the basis and principle upon which the allocations of water are predicated" (Article II). The RRCA recognized the omission of this calculation and assigned the task to develop formulas to determine the consumptive use of water to the renamed Engineering Committee (RRCA, 1963). The Engineering Committee completed the assignment and presented the formulas to compute the annual beneficial consumptive use to the RRCA at the next

scheduled Annual Meeting on April 27, 1964. The annual consumptive use of water in each designated drainage basin for each state is equal to the sum of irrigation diversions in that particular state, minus the return flows from those diversions, plus the net federal reservoir evaporation if there is a storage vessel in the drainage basin (RRCA, 1964).

Coincident with the construction of federal reservoirs, the Engineering Committee calculated the evaporation from the reservoir surface areas and charged the net evaporation as a consumptive use to the state in which the reservoir is located. However, the assignment of evaporation losses from Lovewell Reservoir and Harlan County Reservoir required additional analysis (RRCA, 1963: 3). Specifically, the Engineering Committee was tasked with prorating evaporation losses from Lovewell Reservoir based upon the two sources of surface water supply. Lovewell Reservoir is an on-channel reservoir in White Rock Creek that originates and flows exclusively in Kansas and it also fills with Republican River waters diverted through the Courtland Canal in Nebraska. The Engineering Committee assigned the inflows to Lovewell Reservoir through a water balance computation based upon monthly records of outflow, change in storage to Lovewell Reservoir, inflow and outflow of the Courtland Canal; precipitation at the dam, and evaporation computed by the Corps of Engineers to compute the inflow to Lovewell Reservoir from White Rock Creek. Since the compact allocates all water originating from White Rock Creek to Kansas, the Engineering Committee deemed it necessary to keep separate running accounts of water in Lovewell derived from White Rock Creek and the Republican River and prorated evaporative losses according to the volume in storage from the two sources.

The Engineering Committee was also tasked with establishing a method of prorating evaporation losses from Harlan County Reservoir between Nebraska and Kansas. The Engineering Committee recommended prorating evaporation losses in Harlan County Reservoir between Kansas and Nebraska in the ratio of annual diversion of reservoir storage released to the Republican River in each state below Harlan County Reservoir. The RRCA accepted both recommendations to calculate reservoir evaporation offered by the Engineering Committee (RRCA, 1964: 3).

At their 1981 annual meeting, the RRCA required modification of the virgin water supply and consumptive use formulas to include diversions for municipal and industrial beneficial uses. The Engineering Committee complied with the directive and revised the formulas for calculating the virgin water supply and annual consumptive use to include municipal and industrial consumptive uses in excess of 50 acre-feet per year (RRCA, 1982: 12).

Pursuant to the direction of the RRCA, the Engineering Committee was charged to investigate and refine the computation of consumptive use within the Republican River Basin for ground water pumping from alluvial wells and the consumptive use calculations in the Medicine Creek and Red Willow Creek basins (RRCA, 1989). The Engineering Committee reported the original formulas categorized two types of well use – wells pumping from the alluvium and upland wells, however the latter continued to be omitted from the Engineering Committee's computations (RRCA, 1990). The impetus for the alluvial ground water pumping investigation was the different criteria used by the three states for defining alluvial wells. Colorado and Nebraska considered wells within one mile of either side of a flowing stream to be alluvial, whereas Kansas included all wells

in the entire alluvium in the ground water computation. The Engineering Committee performed the requisite investigations and produced a revised set of formulas for the computation of virgin water supply and consumptive use in June 1990 that adopted the Kansas standard to include ground water pumping from all wells in the alluvium as defined by geologic mapping (RRCA, 1990: 11).

### Monitoring and Measurement

The monitoring and measurement of surface water supplies is relatively easy to accomplish. For streamflows in the Republican River and its tributaries, the instantaneous flow at any given river or creek may be accurately measured by using a current flow meter to determine the velocity of the stream flow at several incremental sections across the river. The velocity in each incremental section is then multiplied by the width and average depth of the section and the total streamflow is the sum of all the incremental measurements. River gaging stations are constructed at strategic locations along a river corridor to obtain the total annual volume of flow, maximum, and minimum discharge of flow at that particular location. The gaging stations are equipped with data recorders that measure the stage or elevation of the river water surface. Through a sequence of streamflow measurements made at various flow amounts, a correlation between the stage and flow discharge may be developed and subsequently used to determine the flow of the river without conducting an actual measurement. In a similar manner, streamflow diversions in ditches or canals may also be measured by a flow meter. However, the more common method of recording streamflow diversion amounts

is through installation of a calibrated measuring flume or weir that has a staff gage installed inside the structure that may be used to measure the height of surface water flowing through the flume. Again, the corresponding discharge amount may be determined by referencing a tabulation of gage-height versus discharge for the particular type and size of measuring structure. Although the quality of the measuring and recording equipment has been upgraded, including the use of satellite telemetry to remotely access streamflow information, the fundamental methods of surface water measurement in the Republican River Basin have remained essentially the same since ratification of the compact in 1943.

Subsequent to the diversion and application of water to the croplands, irrigation return flows constitute a significant contribution to streamflows in the Republican River Basin and an integral component in the annual calculation of virgin water supply. In a cooperative attempt with the RRCA to gain a better understanding of the amount and timing of return flows, the U.S. Geological Survey conducted a series of six gain-loss studies during the period November 1967 to April 1970 in the reach of the Republican River between Trenton to Palisade, Nebraska. Upon evaluation of the gain-loss studies, the Engineering Committee concluded the "seepage runs" were not a satisfactory method in the determination of return flows and the cooperative federal-state procedure was discontinued (RRCA, 1972: 20). Therefore, the Engineering Committee reverted to the empirical method to estimate return flows as a percentage of diversions (25%) for lands irrigated by small canals, stream pumps and alluvial wells. The return flows from lands irrigated by the major irrigation canals were computed as a percent of annual diversions as determined by the U.S. Bureau of Reclamation.

The RRCA recognized the need to quantify the annual volume of ground water pumping, but the real need was to calculate the amount of ground water pumping depletions that were impacting the Republican River and its tributaries because the measure of compliance in the compact is the difference between a state's allocation and its consumptive use. In 1986, the RRCA instructed the Engineering Committee to evaluate the various mathematical or empirical methods to estimate the depletions accruing from ground water pumping and make a recommendation. Upon consideration of the various options available, the Engineering Committee indicated the McDonald-Harbaugh ground water model developed by the U.S. Geological Survey that uses a finite difference solution technique was the best method available to determine the amount, location, and timing of ground water depletions to the river system (RRCA, 1987: 17). However, the Engineering Committee did not recommend application of the model in 1986 because the collection of the requisite data, construction of the model, and calibration was considered to be beyond the means and capabilities of the Committee. As an alternative, the Engineering Committee reviewed the method each state was using to estimate ground water pumping in 1986. Colorado, applied an average value of 159 acre-feet per well based upon a survey performed by the U.S. Geological Survey. Kansas utilized water user reports to estimate total ground water use. The reported volume pumped was divided by the permitted pumping volume for the reported wells and this fraction is multiplied by the total permitted pumping. Nebraska estimated ground water pumping by multiplying the acres irrigated by the irrigation water requirement. The Engineering Committee concluded that the method used by each state is reasonable and each state should continue to review its procedures to determine if the data can be refined

to improve the accuracy of ground water pumping estimates (RRCA, 1987: 28). The RRCA accepted the recommendation of the Engineering Committee and continued the practice to calculate ground water consumptive use in alluvial wells as 75 percent of the annual volume pumped.

### Adaptability of the Allocation System

In 1992, the RRCA created a legal committee for the sole task to compile and analyze all historical compact documents to address the conundrum of including ground water within the allocation system and resolve the difference in opinion among the three states. After two years of research and multiple meetings between the legal counsel representing the three states, the effort to reach a consistent interpretation of the Republican River Compact was abandoned due to deadlock. The States of Colorado and Kansas asserted the compact did indeed include ground water based upon analysis of the historical documentation between the compact negotiators and their respective Governors as well as the language contained in the compact itself, the State of Nebraska disagreed (RRCA, 1994).

#### Evaluation of the Outcome Measures for the Republican River Compact Objective –

##### Provide an Equitable Allocation of Republican River Waters

The actions or performance taken by the RRCA toward meeting the objective to provide an equitable allocation of water resources within the Republican River Basin are

evaluated in perspective of two outcome measures. The measures are: (1) complexity of the allocation system; and (2) enforcement of the allocation system.

#### Evaluation Measure: Complexity of the Allocation System

The impact of ground water was included within the first set of formulas to compute the annual virgin water supply. Although the RRCA deferred inclusion of “table-land” wells within the virgin water supply for many years, they held the wells located in the river alluvium did have an impact upon streamflow and should be included within the computation of the annual virgin water supply. Hence, ground water from alluvial wells was included within the allocation of water supplies in the Republican River Basin since 1959 for the States of Kansas and Nebraska. Ground water pumping in Colorado was considered to be from “table-land” wells and was not included within the virgin water supply computation because of a determination that the impacts would not affect streamflows. The RRCA routinely tasked the Engineering Committee to re-evaluate the contribution of alluvial ground water supplies and as a result Colorado alluvial wells were also included in the virgin water supply calculations for the first time in 1972 (RRCA, 1973: 9). Comparison of the allocation system in place at the time of compact negotiations to the present indicates major advancements in the complexity of the allocation system have indeed occurred. The inclusion of alluvial ground water wells and surface water evaporation from the federal reservoirs are warranted enhancements that were incorporated within the compact allocation system on an as-built basis in the succeeding 61 years since compact ratification. However, the omission of the ground

water wells pumping from the Ogallala aquifer within the allocation system continued to plague the RRCA. In response to the inquiry “does the present procedure of determining virgin water supply comply with the compact definition?” all three RRCA members answered “no” because the method of accounting for ground water pumpage and storage changes and depletions due to conservation practices was inadequate (RRCA, 1986a: 8). The consistent trend of the RRCA to defer inclusion of ground water wells pumping from the Ogallala aquifer in the allocation system eventually proved insurmountable and provided cause to initiate an interstate lawsuit to resolve the issue.

#### Evaluation Measure: Enforcement of the Allocation System

In response to the increasing allegations by the commissioner from Kansas that Nebraska was using more water than entitled to because of unrestricted ground water development in that state, the RRCA convened a special meeting to review the method of computing virgin water supply and consumptive use on February 7, 1986. The general discussion focused upon interpretation of the original intent of the Republican River Compact with respect to ground water and the means to enforce compliance with the compact. After a lengthy discussion, the Nebraska commissioner suggested it “may be easier to just drop ground water from the computations”, to which the Colorado and Kansas commissioners disagreed (RRCA, 1986b: 2). The commissioners continued their discussions at the special meeting on the necessity of including pumping from the Ogallala formation in the computation of virgin water supply and all three agreed it should be deferred.

Five months later at the scheduled July 1986 Republican River Compact Administration meeting the debate on enforcement quickly returned to the threshold question of whether or not ground water pumping from the Ogallala aquifer is to be included in the allocation system, thereby raising the need for enforcement activities. The following list of questions and responses by the respective RRCA members codify the growing dissent among the member over the issue of including Ogallala ground water in the compact computations and their perspective of enforcement authority:

“Is the compact administrable under current procedures of determining virgin water supply?” Colorado – answered yes, Kansas and Nebraska – no. The commissioner for Colorado explained the answer to the question was dependent upon the definition of “administration”. Administration could mean in accordance with the compact as it is now or it could mean administration of water rights including curtailment of use to assure annual deliveries to the lower basin (RRCA, 1986a: 8).

“Is the compact administrable under current procedures of determining consumptive use?” Colorado – answered yes, Kansas & Nebraska – no. The Nebraska commissioner stated a memo written in 1941 provided evidence that the allocations were based on surface water only, therefore it is inappropriate to include ground water in consumptive use calculations. Colorado and Kansas believed ground water should be included (RRCA, 1986a: 8).

“Does the present procedure of determining consumptive use comply with the compact definition?” All three RRCA commissioners answered no (RRCA, 1986a: 8).

“Should the original allocations be revised on the basis of future computed virgin water supply?” All three RRCA commissioners answered yes (RRCA, 1986a: 8).

“Should each state consider and be bound by the compact prior to allowing additional water right permits?” All three RRCA commissioners answered yes, but the Nebraska commissioner stated he did not have authority to limit ground water use. All three commissioners went on to agree that the states had the obligation to comply with the compact (RRCA, 1986a: 9).

The RRCA consolidated the questions into three issues that were assigned to the Engineering Committee for consideration (RRCA, 1986a: 9).

1. Estimate the consumptive uses caused by watershed treatment and by ground water pumping in the entire basin, not just the alluvium.
2. Evaluate how to include ground water in the virgin water supply computation.
3. Calculate new allocations based on the past record and not just the annual record and to compare with the original allocations

After two more years without resolution, in 1988 Kansas expressed their position on enforcement authority as “the basic philosophy of the Republican River Compact

provides for a sharing of shortages and surpluses under Article III” (RRCA, 1988: 13).

Kansas expressed their hope an enforceable administrative procedure under Article IX could be developed that would insure each state receive an equitable portion of water to which it is entitled.

Kansas and Nebraska continued in their disagreement of whether or not to include ground water in the virgin water supply and consumptive use computations. In 1992, the commissioner for Kansas made the assertion that Nebraska was in violation of the compact due to Nebraska’s combined surface and ground water consumptive uses exceeding their adjusted allocations and wished to know what Nebraska was going to do about past shortages and how they were going to come into compliance. The Nebraska commissioner took exception to the inclusion of ground water in the allocations and “felt no liability for alleged depletions” even though their total consumptive use in 1992 of 263, 220 acre-feet exceeded its adjusted allocation of 210,960 acre-feet (RRCA, 1992: 10).

Since inception as an administrative compact authority in 1959, the RRCA has not issued administrative orders or exercised any form of enforcement of the provisions contained within the Republican River Compact. The lack of enforcement is due, in part, to the omission of explicit enforcement authority language within the compact. Another reason for not exercising enforcement actions over the multi-decade debate over the inclusion of ground water within the allocation system was the uncertainty of the resource itself and the impact of ground water pumping depletions upon the Republican River and its tributaries. As an alternative to enforcement actions, the RRCA exhibited a consistent trend to defer action in the pursuit of additional studies.

OBJECTIVE: PROMOTE INTERSTATE COMITY AND RESOLVE PRESENT AND  
FUTURE CONTROVERSIES AMONG THE STATES OF COLORADO, KANSAS,  
AND NEBRASKA

For this objective, the performance of the RRCA in promoting interstate comity and resolution of controversy among the three signatory states to the Republican River Compact is influenced by two actions that were researched: (1) technical or water administration investigations; and (2) interagency coordination.

Technical or Water Administration Investigations

The Engineering Committee is a composite of water resource engineers from the States of Colorado, Kansas, and Nebraska that are required to perform technical, accounting, and other administrative tasks assigned by the RRCA. Each of the three RRCA commissioners appoints one or two engineers to serve on this committee and to work in a professional and collaborative manner with the other members. Representatives from the U.S. Bureau of Reclamation and other federal agencies often participate in an advisory capacity to share information and expertise. Each year the Engineering Committee is responsible for computing the annual virgin water supply and consumptive use estimates. They are also required to perform additional investigations deemed appropriate by the RRCA in the exercise of their responsibility to properly

administer the Republican River Compact. Examples of the technical investigations conducted by the Engineering Committee include:

Engineering Committee assignment in 1965 to investigate the depletions by wells in the alluvium and their potential inclusion in virgin water supply calculations and the effect of distance for a particular well from the stream system (RRCA, 1965: 4).

Engineering Committee assignment in 1966 to explore the need for modifying the annual virgin water supply and consumptive use formulas to include municipal and industrial diversions from surface water and ground water (RRCA, 1966: 4).

New Special Engineering Committee formed in 1974 to address the question of how the RRCA would administer water in the event of a water shortage. The Special Committee was tasked to consider and evaluate different scenarios to divide waters in the most equitable manner possible during water-short years and make recommendations to the RRCA based upon their findings (RRCA, 1974: 9). The Special Committee met twice in 1975 to review the Articles of the compact that pertain to the allocation of water; to prepare illustrative maps of the designated drainage basins, streams, river gaging stations, reservoirs, and approximate locations of the major irrigation canals; and tabulations of historical virgin water supply and consumptive use calculations in the Republican River Basin. The Special Committee reached consensus that, should a shortage of water occur, division of available water would be made to each state in relative proportions based

upon the specific allocations in Article III of the Republican River Compact and provided eight recommendations to the RRCA for adoption as follows:

1. The purpose of the Special Engineering Committee is to develop an acceptable method for equitably dividing, during water-short periods, the flow of streams, which constitute the Republican River Compact between the States of Colorado, Kansas, and Nebraska;
2. The proportional distribution of streamflow will be in accordance with Article III of the Republican River Compact;
3. It will be the intent of any rules and regulations developed by the Committee that administration of a stream will be undertaken only under the extent to fulfill the requirements of the compact;
4. Active administration procedures must be continuous if established;
5. Each state will bear the cost of administration of the compact within its own boundary. Work may be carried out as cooperative programs with the U.S. Geological Survey;
6. The Special Committee will evaluate and develop criteria for administrative procedures of all compact streams;
7. The Special Committee will select a stream, which will serve as a pilot project in administration. Procedures will be developed for the administration of that stream during water-short periods;
8. That the U.S. Bureau of Reclamation be invited to send a representative familiar with the Kansas River Project to each subsequent Republican River meeting (RRCA, 1975: 1-4).

The report prepared by the Special Committee was presented to the RRCA for review and comments at the Sixteenth Annual Meeting on July 30, 1975. Upon consideration of the report and the ensuing discussion, the RRCA tabled any action on the report because the RRCA members could not reach consensus the compact provided authority to adjust the allocations or how to equitably apportion any shortages. The RRCA instructed the Special Committee to discontinue any further studies of administrative procedures (RRCA, 1975: 9).

The RRCA also appointed legal committees to perform historical document review and interpretative legal analyses of the Republican River Compact and other applicable legal instruments. In 1992 the RRCA appointed a legal committee composed of legal counsel representing each of the three signatory states to the compact to research the authority of the RRCA to include ground water within the allocation system and the ability for the RRCA to enforce provisions contained within the Republican River Compact. After two years, the legal committee reported to the RRCA that they were unable to reach consensus on the authority to include ground water within the compact allocation system. The committee did conclude the RRCA could adopt and enforce rules and regulations to administer the provisions of the compact as long as they are not inconsistent with the substance of the compact (RRCA, 1994b). After vigorous and lively debate, inertia reasserted its force and the RRCA made no changes to the formulas or procedures to calculate the virgin water supply or beneficial consumptive use.

### Interagency Coordination

The focus of this performance measurement action is not upon construction of multi-party projects or the coordinated activities between the RRCA and federal agencies. Rather, it is centered on the working relationship between the states. Charged with administrative responsibility for the Republican River Compact, the members of the RRCA and their support staff work collaboratively throughout the year in sharing river flow data, reservoir storage content and releases, streamflow diversions and other water-related information that is necessary to meet both interstate and intrastate demands. Review of the minutes and actions taken by the RRCA since inception from 1959 indicate a consistent pattern of collegial work in a coordinated manner until division over the inclusion of ground water prompted the need for mediation in 1995. As an example, the Engineering Committee faithfully performed the annual computations of virgin water supply and consumptive use that were unilaterally accepted by the RRCA from 1959 through 1994. Further, the original formulas to compute the annual virgin water supply and consumptive use were revised in 1982 and again in 1990 in a coordinated manner to aid in the accurate accounting and administration of Republican River waters.

Evaluation of the Outcome Measures for the Republican River Compact Objective -  
Promote Interstate Comity and Resolve Present and Future Controversy Among the  
States of Colorado, Kansas and Nebraska

The actions or performance taken by the RRCA toward meeting the objective to promote good will among the three participatory states in the Republican River Compact and resolve controversy are evaluated in perspective of three outcome measures. The measures are (1) resolutions or administrative decisions; (2) equal and uniform regulation; and (3) mediation or litigation activities.

Evaluation Measure: Resolutions or Administrative Decisions

As a measure of the comity among the three parties to the RRCA, the resolutions and administrative decisions adopted by the RRCA during their annual meetings from 1959 through 2001 were reviewed. The resolutions analyzed and counted as an indicator or evaluation parameter were those that affected annual accounting, assignments to the Engineering Committee to initiate technical investigations, acceptance of revised formulas to compute the virgin water supply and consumptive use, and other substantive actions. Motions to accept the minutes of the previous meeting or other procedural actions were not included in the analysis.

A total of 103 resolutions were offered, with 87 passing with the requisite unanimous support of the RRCA and 16 failing. It is interesting to note the RRCA members in the early years of the RRCA were typically junior engineers that worked with

the original Republican River Compact negotiators and their camaraderie carried forth for many years. The first dissent did not occur until 1981. The occurrence of failed resolutions corresponds directly with the increasing debate over the inclusion of ground water within the allocation system, 12 resolutions on this particular issue failed during the period 1987 through 1995 and no resolutions were considered in 1996 through 1998 because the states were preparing for the anticipated interstate litigation.

The predominant issue considered by the RRCA since inception in 1959 to the present is the inclusion of ground water within the allocation system. The RRCA consistently deferred taking a formal position for many years. Their preferred course of action was to instigate additional technical investigations to better understand the availability of ground water resources and the potential impact from ground water well pumping to the Republican River and its tributaries. As an example, the Engineering Committee met in Denver on October 29, 1968 with representatives from the U.S. Bureau of Reclamation to continue studying the potential inclusion of ground water in the computation of virgin water supply and consumptive use. "It was the consensus of the group that any improvement of present computation procedures would require the collection of more accurate data on pumping rates, annual quantities and return flows and it was questioned whether the cost to obtain this information could be justified. It was also agreed that results of a research project on a relatively small area probably could not be applied to the entire basin due to differences in geology, concentration of wells and aquifer characteristics" (RRCA, 1969: 4).

The pattern of deferring the consideration of including ground water within the compact allocation system did eventually end. Frustrated with the lack of administrative

action within the State of Nebraska to regulate ground water resources, Kansas became increasingly concerned with the expansion of pumping in Nebraska and repeatedly voiced their opinion that Nebraska was in violation of the compact in several sub-basins and was taking no action to stem the perceived accumulation of ground water depletions to the Republican River streamflows. In 1995, the issue reached a form of administrative climax when Kansas and Nebraska offered countering resolutions to clearly establish their positions and to lay a documented foundation for the impending litigation. Kansas offered Resolution A, which reiterated the duty of each commissioner to comply with the terms of the compact and its operational rules and regulations; to measure within a drainage basin all diversions of surface water and ground water by flow meter or other measuring device within three years of the determination that the consumptive use is in excess of the allocation; and to place an immediate moratorium on any increase in beneficial consumptive use of surface water or hydraulically connected ground water in drainage basins where the annual beneficial consumptive use exceeds the original compact allocation for that drainage basin in or after the 1994 water year. The tone of Resolution A is reflected in the concluding paragraph that states "Adoption by the RRCA does not in any way relieve any state from liability for damages caused by any violations (past, present, or future) of the provisions of the Republican River Compact" (RRCA, 1995: Ex. 6b). Nebraska countered with their own Resolution B that recognized the complexity of water administration to address the impacts of water shortages, increased phreatophyte growth, depletions to streamflows caused by land use or conservation practices, and other "activities of man". Nebraska's resolution sought to defer the issue through continued study of the relationship of ground water to virgin water supply and to

seek authority to engage in negotiations to develop compact amendments that may reallocate or eliminate the sub-basin allocations specified in the Republican River Compact; renegotiate the “renewable” supply; establish target delivery flows; and exclude some particular activities of man from the determination of virgin water supply and beneficial consumptive use (RRCA, 1995: Ex. 9). Neither resolution met the standard of unanimous support by all three members of the RRCA and they failed, thereby setting the course toward ultimate resolution of the quandary of including ground water within the Republican River Compact allocation system through other external means.

#### Evaluation Measure: Equal and Uniform Regulation

As previously noted, a full and complete analysis of the law governing water administration in each of the three states is beyond the scope of this dissertation. However, it is necessary to consider the fundamental doctrines that apply to water administration and the ground water well permitting requirements in all three states to evaluate the regulatory consistency of ground water resources within the Republican River Basin.

The State of Colorado relies upon the Doctrine of Prior Appropriation, or priority system, to administer tributary surface water and ground water rights (Colo. Const. Art. XVI, § 6). Tributary ground water is defined as any underground water that is hydraulically connected to a stream system that influences the rate and/or direction of flow on that stream system [Colo. Rev. Stat. § 37-92-103(11)]. Ground water pumping

from the Ogallala aquifer within the Republican River Basin in Colorado is classified as non-tributary ground water and the amount available for appropriation is based upon overlying land ownership. Non-tributary ground water is defined by state statute and quantified as “the withdrawal of which will not, within 100 years, deplete the flow of a natural stream, ...at a rate greater than one-tenth of one percent of the annual rate of withdrawal” [Colo. Rev. Stat. § 37-90-103(10.5)]. In 1957, the Colorado legislature passed the Ground Water Management Act, which required all users of existing ground water wells to register their existing wells with the State Engineer’s Office. The 1957 Act also required all new ground water appropriators to file a well permit application to the State Engineer. The installation of a flow meter, application of a power conversion coefficient, or other acceptable measuring device have been required for all new large-capacity ground water well permit applications or replacement well applications since 1992 (CGWC, 1992).

Early in its history, the State of Kansas applied the “natural flow” form of the riparian doctrine to govern water use. Kansas modified its administrative practice in 1886 to the “reasonable use” doctrine for the laudable purpose of encouraging irrigation. In 1945, the State of Kansas enacted the Kansas Water Appropriation Act, which converted the discipline of water administration from the riparian doctrine to the prior appropriation system (Kans. Stat. Anno. § 82a-701). All of the riparian water rights vested before June 28, 1945 were honored and given senior priority within the system. The 1945 Act also fully integrated surface water and ground water within the priority system. To protect ground water resources, the Kansas legislature passed the 1972 Ground Water Management District Act to create a mechanism for locally appointed

members of a district to manage the rate and volume of ground water withdrawal from the aquifers (Kans. Stat. Anno. § 82a-1020). Of particular concern to Kansas legislators were the regions with rapidly declining water table elevations that were designated “Intensive Ground Water Use Control Areas”. Since 1978, the Kansas Chief Engineer must approve all new ground water well permit applications, except those serving domestic purposes. The registration of wells and measurement of ground water withdrawals through flow meters has been required by the Kansas Division of Water Resources for all new wells in Kansas since 1978. The administrative requirement was extended in 1997 and requires all wells in the river alluvial areas to measure water through a flow meter. As of 2002, approximately 45 percent of all ground water wells within the Republican River Basin in Kansas have a meter installed (David Barfield, personal communication, August 7, 2003).

Irrigation began in Nebraska during the 1850’s and relied upon the riparian system. However, the drought years of 1889-1895 prompted the Nebraska legislature to adopt the prior appropriation doctrine for surface water rights in 1895 (Nebr. Const. Art. XV, § 6). The first legislation that required registration of irrigation wells was for informational purposes only and it was enacted in 1957. Nebraska followed the example by Colorado and Kansas and passed legislation in 1975 known as the Ground Water Management and Protection Act to provide local control over ground water management. The Act was expanded in 1997 and it delegated the management and regulatory authority over hydraulically connected ground water to the local Natural Resource Districts. Although the 1957 Act recognized the value in registering ground water wells, it was not a requirement to do so until 2001 when all existing ground water wells, excluding test

holes and dewatering wells used for less than ninety days, were required to be registered with the Nebraska Department of Natural Resources (Nebr. Stat. § 46-602). Authority to require flow meters and to report the amount of ground water withdrawals rests with the Natural Resource Districts. Within the Republican River Basin, the Upper Republican NRD required the installation of flow meters on all ground water wells by September 1, 2002; the Middle Republican required flow meters for new ground water wells by July 1, 1999, for existing alluvial wells by December 31, 2000, and for all other existing wells by December 31, 2004; and the Lower Republican NRD will require the installation of flow meters on all ground water wells by April 1, 2005 (Nebraska Association of Natural Resource Districts, 2004).

All three participatory states to the Republican River Compact have been administering surface water supplies since the late 19<sup>th</sup> century. Upon the conversion by Kansas, all three states conjunctively administer surface waters and hydraulically connected ground water within the priority system since 1945. Within Colorado, the State Engineer is responsible for the administration of all surface waters and tributary ground water. The quasi-judicial Ground Water Commission retains administrative authority over pumping from the Ogallala aquifer. The Kansas Chief Engineer is responsible for administration of all surface water and ground water in Kansas. In contrast, the Nebraska State Engineer is responsible for surface water administration and the registration of all ground water wells within Nebraska's borders, but the administrative authority for ground water is delegated to the local Natural Resource Districts.

Since the registration of ground water wells and measurement requirements were not in existence at the time of compact ratification, a pre/post test analysis is not applicable. The trend to require registration of all existing wells and permits for those seeking new ground water wells is not uniform within the Republican River Basin. Among the participatory states to the Republican River Compact, Colorado first required the registration of wells in 1957, followed by Kansas in 1978 and eventually Nebraska in 2001. As to the measurement of ground water withdrawals, all three states exempt small-capacity or limited use wells for domestic, municipal, or stock watering wells from the installation of flow meter requirements. For large-capacity irrigation or municipal wells, the requirement to install adequate measuring devices is even more fragmented. All three states require the installation of flow meters or other measuring device on new well permit applications or requested changes to existing ground water well permits. However, there is no discernable trend to require the installation of measuring devices on existing wells within the Republican River Basin. The States of Colorado and Kansas rely upon well diversion limitations to meet crop irrigation demands and water user reporting to determine well pumping from wells that pre-date the regulatory requirements to install measuring devices. The State of Nebraska is moving towards the installation of flow meters on all existing wells by 2005, but the present status varies upon the individual requirements by the three Natural Resource Districts. The Upper Republican Natural Resource District required the installation of flow meters on all ground water wells by 2002. In contrast, the Middle and Lower Republican Natural Resources Districts implemented an incremental schedule that is based upon the source of supply

(river alluvium or Ogallala aquifer) but they are also striving toward the installation of flow meters on all ground water wells within their districts by the end of 2005.

#### Evaluation Measure: Mediation or Litigation

Beginning in 1988, the State of Kansas formally expressed concern about the perceived long-term depletions occurring in the Republican River Basin, alternatives for effective administration under the compact in the event of water shortages; the methodology in computing consumptive use, virgin water supply and adjusted allocations; and how to deal with the present situation of consumptive uses exceeding adjusted allocation in a number of compact sub-basins (RRCA, 1988: 12). The expressions of concern were established as formal statements in the record of the RRCA annual meeting as a mechanism to lay foundation for the pending litigation.

Coincident with the growing dissention over the inclusion of ground water within the Republican River Compact allocation system, the state officials who were members of the RRCA were fully aware of other interstate river litigation. They were mindful of the legal arguments and judicial decisions in the other interstate river lawsuits that offered instruction and interpretive assistance to all state water officials in the course of compact administration and negotiations. Two such interstate river lawsuits were actively being litigated in the western region of the United States. They were litigated during the period 1985 through the early 1990's when the State of Kansas increased its allegations that Nebraska was in violation of the Republican River Compact and they serve as intervening variables for analysis in this research. The first case is referred to as

*Nebraska v. Wyoming*, No. 108 Original and involved the North Platte River; the second case is *Kansas v. Colorado*, No. 105 Original.

As the contention over the inclusion of ground water within the allocation system, and the allegation over non-compliance intensified, the three states looked to the other interstate lawsuits with acute interest. In 1986, the State of Nebraska filed suit against the State of Wyoming to enforce the 1945 United States Supreme Court Decision *Nebraska v. Wyoming* and to seek injunctive relief. Nebraska alleged Wyoming was unlawfully depleting the flows of the North Platte River that had been determined by the court to consist of tributary inflow and ground water accretions in a hydrologically connected system (*Nebraska v. Wyoming*, 1986). The RRCA commissioners and their representative legal counsel carefully scrutinized the briefs filed by both Wyoming and Nebraska in this interstate river lawsuit, with particular attention to issues regarding the allocation of ground water resources. For this reason, the States of Colorado and Kansas were confused by the dichotomy of interpretation by Nebraska who claimed ground water was not included within the allocation of Republican River waters but simultaneously refuted Wyoming's argument that ground water was not included within the North Platte decree as "absurd" (RRCA, 1994a: 27).

The States of Colorado and Kansas based their interpretation that ground water was included within the Republican River Compact allocation system, in part, upon their experience in the Arkansas River Basin. In 1995, the U.S. Supreme Court endorsed a Special Master's report in the *Kansas v. Colorado* litigation that held wells constructed in the alluvium after ratification of the Arkansas River Compact (1948) were impacting the surface flows and therefore would have to replace their depletions at the Colorado-

Kansas state line or cease pumping. The effect of this ruling upon interstate river compact administration was not lost upon Colorado State Engineer Hal Simpson who encouraged “the State of Nebraska to listen and observe what does happen in interstate litigation...because it is time consuming and it is expensive and the end result may be much less favorable than just trying to sit down and negotiate a reasonable way to move forward” (RRCA, 1995: 7).

Subsequent to the failure of the competing Resolutions A and B, the States of Kansas and Nebraska began to meet in late 1995 and retained the services of professional mediators in the attempt to resolve the issues of dispute between the two states (RRCA, 1996: 2). Despite the acknowledged good faith efforts of those involved in the mediation, it became apparent that resolution of the issues was beyond the scope of the parties involved and on March 16, 1997 Kansas formally notified the State of Nebraska that they would no longer participate in the mediation process and would explore other means for addressing their concerns, thus ending the first attempt by members of the RRCA to seek a mutually acceptable resolution to contentious issues through mediation (letter from David L. Pope, Kansas RRCA Commissioner to Michael Jess, Nebraska RRCA Commissioner, March 6, 1997).

On May 26, 1998 the State of Kansas escalated the issue by filing a complaint to the United States Supreme Court that claimed the State of Nebraska had violated the Republican River Compact by allowing the unimpeded development of thousands of wells in hydraulic connection with the Republican River and its tributaries. Kansas further alleged that Nebraska was using more water than its allocation under the compact and was depriving Kansas of its full entitlement. The States of Kansas and Nebraska

were joined by the United States as amicus curiae in briefing the Supreme Court on January 19, 1999, which formally accepted the lawsuit to be known as *Kansas v. Nebraska and Colorado* (1999a). The State of Colorado was initially joined in the lawsuit because the headwaters of the Republican River rise within that state and it is a party to the Republican River Compact.

The State of Nebraska denied Kansas' allegations and filed a Motion to Dismiss the case upon their premise that the Republican River Compact did not specifically mention ground water, therefore ground water cannot be restricted or included in the allocation or consumptive use computations (*Kansas v. Nebraska and Colorado*, 1999b). The State of Kansas argued the opposite and asserted all forms of ground water should be included within the computation of virgin water supply and consumptive use. The State of Colorado offered an intermediate position and claimed the compact and historic practice of the RRCA justifies the inclusion of alluvial ground water, but did not include wells located on the table-lands that pump from the Ogallala aquifer. The Supreme Court appointed Vincent L. McKusick to serve as Special Master to hear the lawsuit on November 15, 1999. Special Master McKusick held a hearing on January 4, 2000 to receive oral arguments from the three states and the United States as amicus curiae. After careful review of the briefs, Republican River Compact language, extrinsic evidence, and case law, Special Master McKusick issued a decisive ruling 24 days later that denied Nebraska's Motion to Dismiss and concluded ground water is to be included within the allocation and consumptive use computations in the Republican River Compact. As to the alleged ambiguity of inclusion of ground water within the Republican River Compact

allocation system because the compact is silent on the term “ground water”, Judge

McKusick found:

“Nebraska’s assertion that the Compact does not restrict ground water pumping because it never mentions ground water misses a critical fact: Although the Compact never uses the word “ground water”, streamflow, which the Compact fully allocates, comes from both surface runoff and ground water discharge. Interception of either of those streamflow sources can cause a State to receive more than its Compact allocation and violate the Compact. Thus, the comprehensive definition of virgin water supply, even without use of the express term “ground water”, requires a conclusion that, as a matter of law, a State can violate the Compact through excessive pumping of ground water hydraulically connected to the Republican River and its tributaries” [Kansas v. Nebraska and Colorado, 119 U.S. First Report of the Special Master, 21-22 (2000)].

The pivotal decision that all sources of ground water was to be included in the allocation system in the Republican River Compact prompted the three states to request a stay in trial schedule to divert their efforts from trial preparation to mediation. Special Master McKusick granted the petition and representatives from the three states began multiple-day settlement discussions on an approximate two-week schedule from December 2001 through March 2002. The parties retained the service of professional mediators to facilitate the discussions and the United States also participated in an advisory capacity. Each state composed a representative team for the settlement discussions that included the respective State Engineer/RRCA member, Engineer Adviser/Engineering Committee member to the RRCA, and legal counsel. On April 3, 2002 the States reached tentative agreement of the major issues and signed an Agreement in Principle. Special Master McKusick recognized the good faith efforts of the parties and granted another extension to the trial schedule to allow the three states time to reach a final mutually acceptable resolution. Resuming the aggressive mediation schedule, the

States of Colorado, Kansas, and Nebraska successfully reached accord and presented a comprehensive Final Settlement Stipulation to Special Master McKusick at a hearing in Denver, Colorado on December 15, 2002. The Final Settlement Stipulation contains the following principal features:

- ◆ Waiver of claims. All three States agreed to forever waive all claims against each other that relate to use of water in the Republican River Basin prior to December 15, 2002.
- ◆ Ground water modeling. The States agreed to form a committee composed of representatives from each state to construct a comprehensive ground water model to determine the amount, timing, and location of depletions from ground water pumping that accrue to the Republican River and its tributaries by July 1, 2003.
- ◆ Moratorium on the construction of new wells. The Final Settlement Stipulation imposed a moratorium on the construction of new ground water wells in Nebraska upstream of Guide Rock, Nebraska to match the *de facto* moratorium in Colorado and Kansas.
- ◆ Mechanisms for future Compact administration. The Final Settlement Stipulation contained numerous clarifications and accounting improvements that will assist the RRCA in administration of the Compact. The clarifications and improvements include: revised water accounting procedures and formulas; use of a five-year running average for computing virgin water supply and consumptive use; extensive information and data sharing requirements; and commitments by each state to take specific water administrative actions during water-short years.

- ◆ Dispute resolution system. The Republican River Compact is silent on enforcement matters and the Final Settlement Stipulation contains specific procedures to encourage the resolution of disputes, including binding arbitration.
- ◆ Commitments to future joint efforts. The Final Settlement Stipulation endorses the intent of the Republican River Compact to maximize the beneficial consumptive use of water. The three states agree to cooperate with the federal government in conducting studies to assess the impacts of non-federal reservoirs and land terracing upon the virgin water supply in the basin, to calculate and account for the evaporation from small non-federal reservoirs, and to study the feasibility of improving the water delivery and storage infrastructure in the Bostwick Irrigation Districts to improve the efficient use of water resources.

The Supreme Court approved the Final Settlement Stipulation on May 19, 2003 and recommitted the action to Special Master McKusick for the sole purpose of deciding procedural questions that may arise during the completion of the RRCA Ground Water Model by the states (*Kansas v. Nebraska and Colorado*, May 19, 2003). The water resource engineering and ground water modeling experts from the States of Colorado, Kansas, and Nebraska completed the RRCA Ground Water Model and submitted it to the court on July 1, 2003. The RRCA Ground Water Model is fully operational and calibrated to represent the physical and hydrogeological characteristics of the Republican River Basin to a reasonable degree. The RRCA Model matches the trend and magnitude of ground water level changes and stream baseflow targets distributed throughout the Republican River Basin, without significant bias in any region or hydrologic

characteristic (RRCA Ground Water Model, 2003). Special Master McKusick filed a final report to the Supreme Court that certified adoption of the RRCA Ground Water Model by the States of Colorado, Kansas, and Nebraska and recommended dismissal of the case. The Supreme Court accepted the recommendation and Final Report of the Special Master, including final dismissal of the case with prejudice on October 20, 2003 (Kansas v. Nebraska and Colorado, 2003).

In summative evaluation of the success of the RRCA in achieving the objective of interstate comity, the determination is time dependent and circuitous. Certainly from a pre-compact and post-compact perspective the RRCA was not successful in achieving perpetual harmony since the historical documentation indicates the states acted collaboratively prior to ratification of the 1943 Republican River Compact, but were unable to avoid mediation and litigation activities sixty years later. As to the trend, the working relationship among RRCA members and their respective staff was congenial until the 1970's when tensions first arose over the inclusion of ground water in the virgin water supply and consumptive use calculations. Unable to reach consensus over the perceived impact of ground water pumping, the relationship between the States of Kansas and Nebraska continued to degrade until mediation and formal litigation was required. Seeking to avoid the extraordinary cost of a prolonged trial and secure a mutually acceptable resolution, all three states were once again able to work in a collaborative and congenial manner in the last five years to craft the Final Settlement Stipulation and RRCA Ground Water Model that will be used by the RRCA in future compact administration.

OBJECTIVE: PROMOTE COORDINATION AND COLLABORATIVE ACTION  
BETWEEN THE STATES OF COLORADO, KANSAS, AND NEBRASKA WITH  
THE FEDERAL GOVERNMENT

To evaluate the performance of the RRCA in coordinating and collaborating with the federal government in the administration of the Republican River Compact, two actions were researched that influence the outcome measures. The identified actions are: (1) water supply infrastructure improvements; and (2) flood storage development.

Water Supply Infrastructure

The construction of the eight federal reservoirs within the Republican River Basin is a testament to the collaborative working relationship between the RRCA and federal government. The combined storage capacity of approximately 1.7 million acre-feet in the multi-purpose reservoirs provides supplemental water for irrigation, municipal, recreation and other beneficial uses. Further, carryover storage provides a significant measure of confidence to farmers, drinking water providers, and other water users during droughts and to those developing long-term water supply plans. Complementing the reservoir development, the RRCA and federal government have also been instrumental in expanding the surface water delivery system through construction of diversion structures and conveyance channels that are managed by the irrigation districts.

The collaborative efforts between the RRCA and the federal government are not limited to construction of large water supply projects. To aid in daily water

administration activities the U.S. Bureau of Reclamation installed a Supervisory Control and Data Acquisition System (SCADA) on all projects located within the Republican River Basin under their jurisdiction (USDI BOR, 2002). The system collects and transmits real-time data that may be accessed remotely by water users and managers throughout the Republican River Basin. The data includes reservoir gate changes and water levels in streams, canals, and reservoirs. To complement the SCADA system, the U.S. Geological Survey also maintains satellite telemetry equipment on the ten river gaging stations it operates within the Republican River Basin that provides instantaneous flow amounts to the water administration officials in the three states and interested water users. The federal agencies also assist the RRCA in completing the annual accounting of virgin water supply and consumptive use by providing reservoir evaporation, change in reservoir storage, and streamflow information.

In pursuit of better understanding of the water resources within the Republican River Basin, the federal agencies periodically coordinated with the RRCA to conduct investigative studies. Of particular interest to the RRCA was the quantification of return flows. Pursuant to a request from the RRCA, the U.S. Geological Survey conducted an investigation of the feasibility for a Pilot Study of Return Flow in the Republican Basin in Nebraska with intent to extend the findings from the study throughout the basin (RRCA, 1961). The impact of return flows in computation of virgin water supplies was found to be significant. The RRCA recognized the need for a relatively long-term study that would provide factual data on the quantity and timing of return flows to the river. In consultation with representatives from the U.S. Geological Survey, they requested the federal government propose a complete water budget investigation to be financed through

a Federal-State cooperative program (RRCA, 1965: 2). Although the water budget and other recharge project investigations were forestalled by a lack of funding, they are indicative of the cooperative efforts between the RRCA and the federal government in conducting technical investigations designed to maximize the beneficial use of Republican River waters in the most efficient manner possible.

### Flood Storage Development

Mindful of the devastating impacts to life and property caused by the 1935 flood, the RRCA and the federal government dedicated significant flood protection pools in the eight federal reservoir projects. Located on major tributaries and on the mainstem of the Republican River, the eight reservoirs provide over one million acre-feet of reservoir storage to retain floodwaters. The amount of flood storage per reservoir is provided in Table 14 (USDI BOR, 2002).

Table 14. Flood Storage in the Republican River Basin (acre-feet).

Name	River or Tributary	Flood Pool	Capacity
Bonny Dam and Reservoir	South Fork Republican River	128,820	170,600
Trenton Dam and Swanson Lake	Republican River	134,077	246,291
Enders Dam and Reservoir	Frenchman Creek	30,048	72,958
Red Willow Dam & Hugh Butler Lake	Red Willow Creek	48,846	85,070
Medicine Creek Dam & Harry Strunk Lake	Medicine Creek	52,715	88,420
Norton Dam and Keith Sebelius Lake	Prairie Dog Creek	98,803	134,738
Harlan County Dam and Lake	Republican River	500,000	814,111
Lovewell Dam and Reservoir	White Rock Creek	50,465	86,131

To further protect the public from loss of life or major property damage, the Bureau of Reclamation routinely conducts dam safety inspections to assess the structural integrity of the dam and outlet structures. In preparation for an emergency, the federal government installed Early Warning Systems to alert law enforcement and other officials of an impending flood as well as completion of emergency preparedness plans on all federal reservoirs in the Republican River Basin by September 1984 (RRCA, 1984: 5).

Evaluation of the Outcome Measures for the Republican River Compact Objective -  
Promote Coordination and Collaborative Action Between the States of Colorado, Kansas  
and Nebraska with the Federal Government

The actions or performance taken by the RRCA toward meeting the objective to coordinate and collaborate with agencies representing the interests of the federal government are evaluated in perspective of two outcome measures. The measures are: (1) advancement of the efficient use of water in the Republican River Basin; and (2) flood control.

Evaluation Measure: Efficient Use of Water

Prior to ratification of the Republican River Compact in 1943, the collaborative efforts between the RRCA and the federal government was limited primarily to the sharing of streamflow information and informational briefings by various federal agencies conducting technical investigations in the basin. Upon adoption of the compact

and construction of the federal projects, the efficient use of Republican River waters increased dramatically. Excess streamflows from a lack of demand during the winter months and storm-events that historically escaped from the basin unused were captured within eight large reservoirs with a combined storage capacity of approximately 1.7 million acre-feet for subsequent application to beneficial use. Coincident with the increased storage, the consolidation of numerous small irrigating ditches into the large canals operated and maintained by the surface water irrigation districts provided for a much more efficient use of water through enhanced operations and decreases in ditch conveyance losses.

Complementing the large surface water supply and delivery projects, the trend for increased efficiency is manifest through the number of ground water wells developed within the Republican River Basin since 1943. Opposed to the surface water irrigation efficiency percentages prescribed by the compact formulas that range from 60 to 75 percent, center-pivot irrigation systems may achieve efficiencies in the range of 80 to 90 percent.

Parallel with the broad advancements in water use efficiency by ground water well development and the construction of surface water storage and conveyance systems, the Republican River Basin continues to benefit from the conscientious pursuit of maximizing the efficient and beneficial use of water through enhanced reservoir operations, canal lining, and other operational improvements that occur on a structure-by-structure basis.

### Evaluation Measure: Flood Control

The pre- and post-test analysis is appropriate for consideration of flood control because the protection of life and property has consistently been given the highest priority by water administration officials without change over time. Prior to adoption of the Republican River Compact, there were no flood control or prevention structures within the basin. As previously noted, the construction of six federal reservoirs on the major tributaries and two federal reservoirs strategically located on the mainstem of the Republican River have successfully retarded the devastation of periodic storm events in the subsequent 61 years since adoption of the compact in 1943. The proximity of Harlan County Dam on the lower reach of the Republican River, with a substantial 500,000 acre-foot flood pool, provides a measure of confidence and security to downstream residents in Topeka, Kansas and other metropolitan areas. For illustrative purposes, Harlan County Dam and Trenton Dam were credited with preventing \$2.4 million in damages by retaining excessive floodwaters during a 1993 extreme storm event (RRCA, 1995: 11). The accumulated total of flood damages prevented within the Republican River Basin by the eight federal reservoir projects through 2002 are presented in Table 15 (USDI BOR, 2002).

Table 15. Flood Damage Prevented by Republican Projects Reservoirs

Reservoir	Accumulated Total
Bonny	\$2,682,000
Enders	\$3,274,000
Swanson	\$19,063,000
Hugh Butler	\$2,555,000
Harry Strunk	\$4,865,000
Keith Sebelius	\$3,952,000
Harlan County	\$150,064,000
Lovewell	\$146,057,000
Total	\$332,512,000

### Chapter Summary

This research evaluates the effectiveness of the RRCA in its performance toward meeting the primary objectives of the Republican River Compact. Through a comprehensive analysis of the historical decisions and actions taken by the RRCA, the conclusion is the RRCA has generally been successful in meeting the objectives of the compact – particularly in the context of applying Republican River waters to beneficial use in the most efficient manner possible. The research also proves that the system or formulas to allocate water within an interstate river compact can successfully be modified to include ground water. As decision-makers for the Republican River Compact, the RRCA applied an advanced scientific understanding of the ground water resources within the basin with evolving legal standards to modify the allocation system and to adapt the compact accounting and administrative practices to meet the current water management demands within the basin in a holistic manner to include all available sources of water supply.

## CHAPTER 7

### FINDINGS, RECOMMENDATIONS, AND ADDITIONAL RESEARCH NEEDS

The research findings in this dissertation support the premise that ground water may successfully be included within the allocation system of an interstate river compact. These findings are particularly germane to the inclusion of ground water within the majority of existing interstate river compacts in the United States that focus upon the distribution of surface water supplies only. This chapter also presents findings that are relevant to the effectiveness of the Republican River Compact Administration in meeting the principal objectives in the Republican River Compact. Findings are also included that support the use of a case analysis and program evaluation methodology in water resources engineering research.

The recommendations contained in this chapter are intended to provide interstate river compact policy and decision-makers with a template of specific issues and factors that are necessary for analysis as they contemplate the inclusion of ground water within the allocation system of a compact. Additional research needs are outlined at the end of the chapter.

## Research Finding: Incorporation of Ground Water within the Allocation System in an Interstate River Compact

The literature and research findings in this dissertation corroborate the premise that ground water may indeed be successfully included within the allocation system of an interstate river compact – as evidenced by the inclusion of ground water in the Republican River Compact allocation almost sixty years after its ratification (Kansas v. Nebraska and Colorado, 2000). The research conclusion is founded upon analysis of the Republican River Compact as a case study and the use of the program evaluation methodology to assess the performance of the compact administration in meeting the primary objectives of the compact. The Republican River Compact provides an exemplary case analysis because it is indicative of most interstate river compacts that focused exclusively upon the equitable division of surface water supplies, even though the development of ground water wells and subsequent application of ground water to beneficial consumptive use eclipsed the use of surface waters in the Republican River Basin by 1950 as indicated in Chapter 6. The program evaluation methodology was used to seek an understanding of the reasons *why* and *how* ground water was repeatedly deferred from inclusion within the compact allocation system and to construct findings that prove the two hypotheses for deferring the modification of the Republican River Compact allocation system to include ground water. The research findings from the case study were used to prove the two hypotheses to advance the state of knowledge in water resources management and engineering by developing an understanding of the context in

which the problems emerge and offering a mechanism to apply the knowledge gained from the program evaluation to serve as a template in the future for decision makers considering the inclusion of ground water within the allocation system for other interstate river compacts. The research findings for the two hypotheses are provided below:

Hypothesis: If the language contained in an interstate river compact is general in nature, without specificity as to the inclusion of ground water as a source of water supply, the inclusion of ground water within the allocation system will be deferred in the pursuit of continued studies to determine the existence, amount, location, and sustainability of this clandestine resource.

1. The Republican River Compact refers to “waters of the Republican River Basin” and does not contain a specific reference to ground water or surface water. The compact refers to water supply and beneficial use in general terms without distinction as to the source of supply.
2. Review of the historical documentation indicates the negotiators to the Republican River Compact were aware of the existence of ground water in the Ogallala aquifer and as a potential source of water supply through citation in water supply investigations conducted by various federal agencies. However, at the time of compact ratification in 1943, ground water use was minimal. Alluvial ground water pumping served individual homes and small town domestic needs, stock watering, and limited irrigation of small parcels of land in the river valleys. Ground water wells in the table-lands that pumped from the Ogallala aquifer provided drinking water to farm homesteads and for stock watering purposes only in the early 1940’s.
3. The total volume of ground water contained within the Ogallala aquifer and the annual sustainable rate of withdrawal was unknown at the time of compact

ratification. In contrast, the allocation of the annual average amount of streamflow available for distribution from the Republican River and its tributaries was calculated for each major sub-basin based upon a series of hydrographic records. The total volume of ground water retained in the Ogallala aquifer, or the sustainable amount that may be economically extracted each year, remained a mystery to successive Republican River Compact administrators and has yet to be quantified.

4. The RRCA recognized the potential impact of ground water in the equitable division of waters within the Republican River Basin. At their inaugural meeting in 1959 they directed the Committee on Procedure (precursor to the Engineering Committee) to investigate the applicability of including ground water within the computation of virgin water supplies and consumptive use.
5. In 1960, the Committee on Procedure cited the potential impact to the Republican River and its tributaries from ground water diversions, but recommended including only the alluvial ground water wells in the assessment of virgin water supply. The Committee was unable to determine the affect of ground water pumping from the table-land wells upon streamflows in the Republican River and its tributaries. The Committee recommended deferring inclusion of these wells in the allocation system until the affects were better understood. The RRCA adopted their recommendation and initiated a pattern of deferring the inclusion of ground water pumping from the bedrock aquifer system in pursuit of additional technical investigations designed to quantify the amount of ground water available for distribution among the three states and to address the potential

impacts of ground water pumping upon the streamflows in the Republican River system.

6. Although the assessment of ground water supply available for distribution from the ground water aquifers remains elusive, the computation of ground water withdrawals and net consumptive use may be determined on an annual basis. Annual ground water withdrawals and consumptive use can reliably be measured through totalizing flow meters or through application of empirical techniques that calculate the net consumptive use of ground water based upon crop irrigation demand
7. Through advanced technology and increased knowledge of the physical ground water aquifer systems, interstate river compact administrators may now calculate the impacts of ground water pumping to the river system. The RRCA Ground Water Model is able to determine the amount, timing, and location of depletions to the Republican River and its tributaries from ground water pumping. This tool allows the RRCA to properly account for both surface water and ground water impacts within the Republican River Basin.

Hypothesis: If the interstate river compact does not include enforcement language or a dispute resolution mechanism, the compact's administrative body will defer inclusion of ground water in the allocation system due to a perceived lack of authority.

1. The Republican River Compact does not contain an enforcement provision or other language that conveys authority to the compact administrative body to issue orders or to initiate other forms of compliance to the compact. The general responsibility for compact compliance rests with the three participatory states to

the compact on an individual basis and Article IX reflects that intent through the statement “it shall be the duty of the three States to administer this compact through the official in each State who is now or may hereafter be charged with the duty of administering the public water supplies”.

2. Absent specific authoritative language in the Republican River, the RRCA was unsure of their authority to include ground water within the allocation system. The question was first raised in the 1970’s and the RRCA continued to defer inclusion of ground water pumping from the Ogallala aquifer system for the next two decades. In response to growing discontent and a need to address the issue, the RRCA directed a legal committee composed of attorneys representing each of the three states to research the issue in 1992. Two years later the legal committee reported they were unable to reach a consensus on the question of whether, or not, the RRCA has authority to modify the allocation system to include ground water. The legal committee did reach consensus and reported the RRCA could adopt and enforce rules and regulations to administer the provisions of the compact as long as they are not inconsistent with the intent and substance of the Republican River Compact.
3. The RRCA recognized the need to adopt formulas to calculate the consumptive use of water to complement the determination of annual virgin water supply. In 1963 they assigned the task to develop said formulas to the Engineering Committee. The original “Formulas for the Computation of Annual Virgin Water Supply and Consumptive Use were adopted in 1964 and subsequently revised in 1982 and 1990. The diversion and consumptive use of ground water

from alluvial wells was included in the original computations and carried through the revisions.

4. The Republican River Compact does not contain a provision for dispute resolution. Passage of any action or resolution by the RRCA requires a unanimous vote by all three members. Therefore, since the RRCA did not adopt rules or regulations to resolve issues in contention, aggrieved party(s) to a dispute did not have another venue within the Republican River Compact administrative body to make a conclusive decision regarding the inclusion of ground water within the compact allocation system.
5. Upon failure of the mediation between the States of Kansas and Nebraska, the only forum left to resolve the issues in dispute was litigation before the United States Supreme Court. In 1998, the case *Kansas v. Nebraska and Colorado*, No. 126 Original was filed to ultimately resolve the issue of including ground water in the Republican River Compact allocation system.
6. The interim ruling in 2000 by the Special Master appointed to hear the case *Kansas v. Nebraska and Colorado*, No. 126 Original that held all sources of tributary ground water were to be included within the computation of virgin water supplies and beneficial consumptive use served as a pivotal point in Republican River Compact administration by providing the authority to compact administrators to include ground water within the compact's allocation system.
7. The three states that are parties to the Republican River Compact recognized the advantage to craft a mutually acceptable solution over litigation in a prolonged trial. Their efforts culminated with acceptance of a Final Settlement Stipulation,

that among other provisions, includes all ground water pumping and consumptive use within the compact allocation system.

8. During the settlement negotiations, the RRCA members recognized the Republican River Compact does not include an enforcement clause or other mechanism for dispute resolution. The omission of an intermediate procedure or forum to address contentious issues before filing an interstate lawsuit was rectified by the three states through inclusion of a formal dispute resolution process, including binding arbitration, in the Final Settlement Stipulation.
9. In their acceptance of the Final Settlement Stipulation and dismissal of the lawsuit, the United States Supreme Court shared their preference for the resolution of disputes through other means than litigation by restating an earlier decision:

“[t]ime and again we have counseled States engaged in litigation with one another before this Court that their dispute is one more likely to be wisely solved by cooperative study and by conference and mutual concession on the part of the representatives of the States which are vitally interested than by proceedings in any court however constituted [Texas v. New Mexico, 462 U.S. at 575 (1987)].

#### Research Finding: Effectiveness of the Republican River Compact Administration in Meeting the Compact Objectives

The research conclusion is the RRCA has achieved overall success in meeting the principal objectives in the Republican River Compact. Since ratification of the compact in 1943, the greatest achievement within the Republican River Basin is maximizing the efficient and beneficial use of water resources. The RRCA has also enjoyed significant

success in collaborating with the federal government to maximize the beneficial use of water and increase flood protection to the citizens of the Republican River Basin. Over the course of 61 years the interstate comity among the States of Colorado, Kansas, and Nebraska has varied. As previously indicated, the RRCA working relationship for many years was collegial and administrative actions were routinely passed by unanimous vote. However, as the controversy over ground water pumping impacts and alleged depletions to the Republican River streamflows grew, the effectiveness of the RRCA to perform in a collaborative manner deteriorated in the 1990's. Subsequent to the filing of the interstate lawsuit *Kansas v. Nebraska and Colorado*, all members of the RRCA recognized the tangible benefits of working together as a unit to serve water users within the Republican River Basin as well as the peril of subjecting water administrative decisions to the judicial system. Their resiliency to perform as a collaborative entity is exhibited through the recent success in achieving a mutually acceptable and binding settlement that obviated an interstate lawsuit and it sets forth the accounting and administrative practices for the Republican River Compact in the future. The RRCA has been least effective in modifying the allocation or equitable division of waters within the Republican River Basin. Specific findings are provided below:

1. The RRCA has been effective in coordinating with water users in the Republican River Basin and the federal government to maximize the beneficial use of surface water. As a measure of their effectiveness, approximately 53,500 additional acres of croplands are irrigated with surface water supplies within the basin since adoption of the Republican River Compact in 1943.

2. The efficiency of surface water irrigation has also increased within the Republican River Basin since 1943. Construction of improved streamflow diversion structures, ditch and canal lining, installation of measuring devices, and other improvements to the water supply infrastructure has contributed to the efficient delivery of surface water to irrigated croplands and other beneficial uses. The management of surface water supplies improved through incorporation of mutual ditch companies and irrigation districts. The consolidated management organization promotes timely delivery of water to meet crop demands and to share or rotate limited water supplies among the shareholders in a mutually incorporated ditch/canal system when supplies are inadequate to meet demand.
3. The RRCA has been successful in its quest in maximize the beneficial use of Republican River waters by capture of excess streamflows in reservoir storage. Subsequent to ratification of the Republican River Compact, eight federal reservoirs with a combined storage capacity of approximately 1.7 million acre-feet were constructed within the basin. The reservoir storage provides a valuable supplemental source of water supply to municipalities, industries, irrigators, and other water users. The reservoirs also enhance the recreational and fishing opportunities within the Republican River Basin.
4. The explosive growth of ground water development within the Republican River Basin since 1943 is a testament to the ingenuity and resourcefulness of water users. Ground water is the predominant source of water supply and application to beneficial use within the Republican River Basin. An additional 2.6 million acres of croplands are served by ground water pumping. Ground water is also the sole

source of water supply to meet the domestic and drinking water demands for most of the 257,000 residents in the Republican River Basin.

5. The RRCA was successful in modifying the allocation system relevant to surface water factors when additional technical information became available and new reservoirs were constructed within the basin. The RRCA adopted modifications to improve the computation formulas for virgin water supply and consumptive use by including changes in reservoir storage, depletions from evaporation, return flow percentages, and other surface water related information.
6. The RRCA was ineffective in modifying the Republican River Compact allocation system to include the annual or long-term volume of ground water supply available in the subterranean aquifers. Although the RRCA initiated numerous investigative studies, the quantification and availability of ground water within each of the designated drainage basins in the Republican River for distribution in an equitable manner among the three states remains unresolved.
7. The RRCA, in cooperation with the U.S. Geological Survey and other federal agencies, is successful in monitoring surface water supply availability and use. The RRCA and federal agencies coordinate activities in the measurement of Republican River streamflows and its tributaries, surface water diversions, and change in reservoir storage. The RRCA is effective in measuring the consumptive use associated with surface water diversions and storage within the basin.
8. Until adoption of the RRCA Ground Water Model by the States of Colorado, Kansas, and Nebraska and endorsement of the model by the United States

Supreme Court on October 20, 2003, the RRCA was unable to measure the depletions caused by ground water pumping to the Republican River and its tributaries. Through application of the model, the RRCA is currently able to quantify the depletions from ground water pumping and include ground water impacts within the computations of virgin water supply and consumptive use.

9. The three participatory states to the Republican River Compact adhere to the Doctrine of Prior Appropriation and are relatively consistent in their administration of surface water rights within their respective boundaries.
10. The three participatory states to the Republican River Compact do not have uniform or consistent ground water laws or enforcement authority within their respective territory. The Colorado State Engineer and Kansas Chief Engineer retain authority to administer ground water resources within their states. In contrast, the authority to enforce ground water development and use in Nebraska has been delegated to local district control. Succinctly, the disparity in legal definitions of ground water and administrative authority has proven to be an impediment to consistent and effective ground water administration in the basin.
11. The RRCA members worked in a collegial and cooperative manner for most of the 45 years since organization as the administrative body to the Republican River Compact in 1959. They coordinated with the federal government and water users in the construction of reservoir projects and in conducting technical investigations. In regard to surface water administration, the RRCA has consistently operated in a collaborative manner.

12. In representation of their respective states, the RRCA failed to reach harmonious agreement in the debate of including ground water within the allocation system. Although Special Master Vincent McKusick and the Supreme Court ultimately resolved the issue in 2000, the members of the RRCA set aside their differences and led the settlement negotiations in a professional and consolidated manner that culminated in the mutually acceptable stipulation that is currently being used in the administration of all waters in the Republican River Compact.
13. The RRCA and the federal government have consistently worked in an effective and collaborative manner within the Republican River Basin. Construction of the eight federal reservoir projects and enlargement of the surface water diversion and conveyance systems that maximize the beneficial use of water within the basin is a testament to their effective working relationship.
14. The RRCA and federal government have increased the efficient use of Republican River waters through coordinated reservoir operations and sharing streamflow measurements, reservoir elevation, reservoir storage releases, and other water administration information.
15. The RRCA and the federal government have been successful in protecting life and property within the Republican River Basin through effective flood control measures. Strategically located throughout the basin, the eight federal reservoirs provide over one million acre-feet of flood storage capability. Further, the federal agencies coordinate with local emergency response coordinators to prepare for potential flood events and have installed an Emergency Warning System to

communicate with law enforcement officials to alert the citizens in the Republican River Basin of an impending emergency.

Research Finding: Use of Case Studies and Program Evaluation Methodology in Water Resources Engineering

The growing need to conduct new and innovative research into water resources engineering and interstate water administration is manifest in the recognition that the increased competition for water supplies leads to more complexity and potential conflict, particularly when the water supply transcends local regions to include multiple jurisdictions and different governments such as those found in an interstate river system (Grigg, 1985; Barton, 1967). The application of a case study and program evaluation methodology is a shift in the traditional water resources engineering research paradigm that focused upon quantitative data and variables to also include the analysis of non-technical variables and qualitative information that is critical in complex water management decision-making. The findings in this dissertation indicate the use of a case study and program evaluation methodology is an effective and appropriate research design to systematically analyze the integrated decision-making processes in interstate river compact administration and water resources engineering. Specific findings are provided below:

1. The Republican River Compact case history confirms interstate river compact administration, particularly the distribution of water supplies amongst

neighboring states is a complex natural resource management process that often leads to conflict and litigation.

2. The research indicates the use of case studies is an appropriate and effective research design in water resources engineering because it is a systematic approach that includes qualitative research of non-numeric or unstructured data in addition to the traditional quantitative research methods. The ability to capture and use non-numeric data is paramount in interstate river compact administration because the decision-making processes include, and often are dominated by, political, economic, and legal implications to complement the traditional hydrology, geology, and other scientific disciplines that may be quantitatively measured and enforced.
3. The Republican River Compact case study demonstrates the contribution to knowledge from failures, as well as successes. As indicated previously, the research indicates the omission of explicitly including ground water within the compact narrative and omission of enforcement authority contributed to the repeated deferral of including ground water within the allocation system. Further, the case demonstrates how non-technical decisions fail or cause adverse impacts when they are made in isolation or prior to securing sound technical and engineering decisions (failure to consider depletions from ground water pumping resulted in an interstate lawsuit).
4. The use of a case study that researches qualitative data invites researcher subjectivity. This dissertation reveals the proper design of a case study, such as the five-component research design offered by Yin (1994), may be applied to

develop a scientifically rigorous research methodology that will minimize bias and subjectivity.

5. The research indicates the program evaluation methodology is an effective analytical instrument to systematically extract information and explain the complex decision-making processes in interstate river compact administration. However, the objective interpretation of qualitative data is difficult and requires additional care and effort to meet the dual demands of conformance with defined accuracy standards and to minimize potential researcher bias or subjectivity.

#### Summary of Findings

The Republican River Compact is representative of most other interstate river compacts created to distribute and administer water supplies. In 1943 when the Republican River Compact was adopted, it focused exclusively upon the distribution of surface waters. It is also consistent with the other compacts enacted during the early to mid-20<sup>th</sup> century that do not include explicit narrative that grants the compact's administrative body the authority to modify the water allocation system, nor does it contain a dispute resolution procedure to resolve contested issues. Evaluation of the Republican River Compact as a case study provides insight into the technical, legal, and administrative factors that warrant consideration by others contemplating the modification of an interstate river compact allocation system. It also provides a cogent

example of the potential perils encountered when the administrative body to an interstate river compact repeatedly defers contested issues.

The research illuminates the differences between administration of surface water and ground water resources. The physical concealment of ground water historically has made the assessment of subterranean water available for distribution, in location and amount, more difficult than quantifying the surface water yield from a river system. This disparity has also prompted different legal statutes within a multi-state river basin to govern surface water and ground water supplies, sometimes between the two types of water supply within the same state.

The research indicates ground water may indeed be successfully incorporated within the allocation system of an interstate river compact. The research findings for the Republican River Compact case study prove the two hypotheses and serve to illustrate that once the amount of ground water available for distribution is determined with a reasonable and accepted degree of confidence, and there is a form of enforcement authority to include ground water (such as a judicial decision), ground water may successfully be included as a supplemental source of water supply within the allocation system of an interstate river compact (RRCA Groundwater Model, 2003; Kansas v. Nebraska and Colorado, 2000). The research also indicates the RRCA has been effective in promoting the efficient and beneficial use of water within the Republican River Basin since 1943. This dissertation describes the historical actions taken by the Republican River Compact administrators, technical factors, and legal parameters that warrant consideration and are instructive to policy and decision-makers in other interstate river

compacts that may contemplate including ground water within the equitable distribution of all water resources in an interstate river system.

The integrated disciplines of water resources engineering and interstate river compact administration are complex and require a systematic approach to understand the technical and non-technical issues in an attempt to improve the overall decision-making process. Case studies and program evaluation methodologies offer an effective research design to gain this understating and develop equitable solutions that address the increased complexity and conflict in current water resources management and engineering.

### Recommendations

The focus of this dissertation was upon the correlation of ground water to interstate river compacts. Through this research, the knowledge gained from considering how ground water may be effectively introduced into a compact allocation system may also be applied to other areas of water management. The first alternative identified is other local or regional water management forums that envelop multiple jurisdictions. Intrastate water management entities such as conservancy districts, water user associations, and multiple-municipality consortiums often follow the pattern of interstate river compact administrations that initially focused upon management of surface water supplies but currently rely upon supplemental ground water resources to meet their increasing demands for water. Within said local entities, the ground water regulations that govern the rate of withdrawal, use, and conservation may differ dramatically and often prompt conflict among different factions within an intrastate or regional water management

agency. Parallel with the technical, legal, and political issues that surround interstate river compact water management, the findings and recommendations in this dissertation may prove useful to abating conflicts and constructing mutually acceptable resolutions within local intrastate water management agencies as well as regional management forums that are not governed by an interstate compact.

This research may also be extended into the planning aspects of ground water and interstate river compact management. Effective water management is based upon the perpetual ability to recognize changes in both water supply and demand and to adapt to evolving technical, legal, economic, social, and political factors. Planning is a fundamental task in the water management process and its value is predicated upon reliable and advancing knowledge (Grigg, 1985). Although the focus of this dissertation was upon the administration of ground water in an interstate compact, or the implementation phase in the water management process, the knowledge garnered from this research may also be useful to compact officials developing plans to increase water supplies or plans that address the change in use of water such as the conversion from an agriculture-dominated demand toward consumption by municipal or recreational interests.

The following recommendations are offered as a template of specific factors and work assignments that are necessary for analysis by those policy and decision-makers that are contemplating the inclusion of ground water within the allocation system of an interstate river compact:

A. Conduct a thorough and comprehensive historical analysis of information prior to the date of compact ratification. Recommend segmenting the historical analysis into three primary components: technical, legal, and administrative. The technical review is conducted to ascertain the types of water supply (surface water, ground water, reservoir storage, transbasin or imported water supplies, recharge, etc.) available for distribution. Review and analysis of historical streamflow records, reservoir storage, and engineering reports will provide insight into the amount, location, and timing of water supplies available in a tributary river system. It is also important to determine the minimum, average, and maximum amount of water availability for the period of record. To complement the amount of water available, it is also necessary to determine the amount and location of water consumption at the time the compact was ratified. The review of climatological data, geological reports, reconnaissance surveys for surface water diversions and reservoirs, and other technical reports further assist in developing a comprehensive scientific foundation of total water resources availability within a river basin and the amount used by each state at the time the subject compact was being negotiated. In a similar manner, a study of the applicable statutory and case laws in each state and the legislative history of the compact is required to gain an understanding of the legal parameters at the time of compact negotiations. It is instructive to defining and understanding the legal constraints each state was operating within to administer waters within their respective boundaries, as well as across state lines, at the time the compact allocation system was formulated. The administrative component includes a review of ancillary letters, meeting minutes, and miscellaneous documentation that often provides insight into the reasons why and

how certain terms and conditions in an interstate river compact were constructed by revealing the social and/or political influences that inevitably occur in an interstate river compact negotiation – especially in context of the decisions and actions taken by the federal government that influence interstate river compact water apportionment.

B. Recommend the administrative body to the interstate river compact secure adequate fiscal and human resources to create a Technical Committee to perform the following tasks:

1. Compile all water supply and water use information available from the time of compact negotiation to the present. The states and federal agencies should agree to freely and immediately share all available data, information, expert knowledge, and other information necessary to build an equal and uniform knowledge base of the interstate river basin to all parties of interest. Common data sets and information should be posted on a website accessible to committee members to facilitate data access and assure transparency among the committee members performing collaborative technical analyses. Non-confidential information should also be posted on the website and be available to the general public for informational purposes only.
2. Complete all task assignments, including documentation of results or findings, by the timelines pre-established by the compact administrative body.
3. Construct a comprehensive ground water model to quantify the impact of ground water use within the interstate river basin. As a sub-committee under the

authority of the compact administrative body, the suggested composition of the Modeling Committee and task assignments are:

- i. Composition of the Modeling Committee should be an equal number of representatives from each state that have been delegated decision-making authority (recommend a limit of three representatives from each state). Each state may include other technical participants to observe the proceedings and advise their respective representatives to the committee, but their inquiries and opinions should be confined to vocalization through their respective committee members. The compact administrative authority should designate a chair to the Modeling Committee who is charged with management of the task assignments, to provide periodic status reports, and to document decisions, actions, and committee findings.
- ii. The United States may designate one technical representative from each federal agency that has a vested interest in the administration of the interstate river compact.
- iii. Attendance to the Modeling Committee should be restricted to water resource engineers and other technical experts only. District water management officials or individual water users may be invited to provide local or case-specific information.
- iv. Each state should have one vote and a unanimous vote is necessary to pass any action or decision. The representative of the federal agencies are encouraged to participate and provide technical assistance, but they may

not vote if the federal government is not a formal party to the interstate river compact.

- v. The Modeling Committee should construct a comprehensive ground water model that represents the ground water flow system in the interstate river basin to a reasonable degree. The primary purpose of the model is to determine the amount, location, and timing of streamflow depletions to the interstate river system caused by well pumping and to determine streamflow accretions from recharge by imported water supplies.
- vi. Present the completed model to the compact administrative body with complete documentation of the ground water model architecture, parameters, procedures and calibration targets.

- 4. Incorporate the streamflow depletions attributed to well pumping and accretions from imported water supplies within the interstate river compact's accounting procedures and/or allocation system.

C. Recommend the administrative body to the interstate river compact secure adequate fiscal and human resources to create a Legal Committee to research applicable water administration statutory law in each state, federal law, judicial decisions, and legislative history. The Legal Committee should be charged to develop a comprehensive and mutually acceptable brief of the legal constraints in water administration within each state that is party to the interstate river compact and in context of the legal authority afforded by the compact itself. The Legal Committee

may also be utilized to share resources and expert knowledge in providing legal counsel to the compact administrative body.

D. Recommend the interstate compact administrative body adopt an alternative dispute resolution process to resolve contentious issues before they escalate to litigation, if there is no intermediate form of mediation or dispute resolution process contained in the subject compact. Further recommend the dispute resolution process be constructed in a manner that the compact administrative body first addresses contentious issues in a timely and effective manner amongst themselves before more formal binding or non-binding arbitration is initiated with contract mediators. Based upon personal professional experience, many of the contested issues that inevitably arise in water resources management may be effectively addressed and resolved by the parties of interest if they seek to fully understand the technical and legal parameters surrounding the issue, the perspective or concern of the other party(s), and actively seek a mutually acceptable solution. Resolution of contested issues in an informal and collegial environment among the compact administration or water management officials, before extensive delay and escalation that may invite political influences, is preferable to more formal mediation processes. For illustrative purposes, the dispute resolution process adopted by the States of Colorado, Kansas, and Nebraska in the Final Settlement Stipulation in *Kansas v. Nebraska and Colorado*, No. 126 Original is provided in Appendix D.

E. Recommend the compact administrators acknowledge that the quantification of ground water resources remains elusive and it is difficult to administer to the same degree of confidence as the allocation of surface water supplies that are measured at river gaging stations. However, the perpetual deferral of ground water within the administration and allocation of waters in an interstate river compact in pursuit of continued studies will expose the offending party(s) to unnecessary and expensive litigation. Succinctly, the United States Supreme Court has consistently affirmed the omission of ground water from the allocation system in an interstate compact does not relieve a state from meeting its compact delivery obligations, including the depletions to the interstate river that occur from ground water pumping (*Texas v. New Mexico*, 1987; *Nebraska v. Wyoming*, 1998; *Kansas v. Nebraska and Colorado*, 2000). Therefore, the appointment of technical and/or legal committees that meet at a predetermined frequency and are tasked with discrete assignments under specified timelines will afford the compact administration officials with a mechanism to address contested issues before they escalate in conflict and also provide a collegial and professional working environment. The collaborative and proactive actions by interstate river compact officials suggested herein, to quantify and incorporate ground water within the allocation system, are strongly encouraged to save fiscal resources and time, as well as striving to meet the primary goal of an interstate river compact – the equitable distribution of water among neighboring states.

## Additional Research Needs

The need for wise and effective stewardship of water resources continues to escalate to meet advancing demands for limited water supplies. The use of interstate river compacts, as a formal and defensible mechanism to equitably apportion the shared water resources among neighboring states, has proven effective. This dissertation extends the viability of interstate river compacts by addressing the need and issues surrounding the potential inclusion of ground water within the allocation system as a complementary source of water supply. Due to the increasing demand for water resources and scrutiny upon compact administration, other facets of research that are relevant to the ground water/interstate river compact topic warrant additional study.

The relationship between the ground water development and use, interstate river compact administration, and the ecosystem in a river basin merits additional research. Water managers face the inextricable challenge of distributing surface water and ground water supplies in amount, location, and time in the attempt to meet the demands for drinking water, irrigation, industrial, recreation, and a host of other beneficial uses within the natural environment that warrants protection. This challenge is magnified when multiple states and jurisdictions are party to an interstate river compact. For foundation, it is important to recognize that interstate river compacts are a necessary, reliable, legal, and effective mechanism to distribute water resources among neighboring states that share a river system. The need for additional research does not pertain to an assessment of the value of regulation of water resources through an interstate river compact versus the need to protect the environment. Rather, the need for research is manifest through the

recognition that effective water managers already employ sound engineering and legal practices to administer water supplies in concert with instream flow requirements, water quality standards, and protection of the river ecosystem on a local basis. The proposed research would extend these management principles and practices beyond the local intrastate confines to regional or multi-state boundaries and work within the parameters of the interstate river compact.

As a natural resource, ground water retains unique economic, social, and political aspects that also justify further consideration and study. Although the predominant form of analysis has targeted the *supply* of ground water, the impacts that are pertinent to the *demand* for ground water resources also needs further research. The economic impacts of ground water directly correlate to the vast amounts of new croplands that are irrigated by ground water wells. The combination of additional irrigated acreage and increased crop yield per acre from efficient center-pivot irrigation has increased the gross revenue generated by individual farmers and agricultural communities. To support ground water irrigation, industries have developed that provide pumps, center-pivot irrigation systems, pipe, mechanical services, and power to the ground water wells. Farm machinery, fuel, fertilizer, and other agricultural related commodities also generate revenue and supplement the tax base necessary to support schools and other government services. In many regions, ground water irrigation and its related industries dominate the economy of agricultural communities. In perspective of societal impacts, the division of labor reflects a change in the culture of an agricultural area. Surface water irrigation is time-intensive and requires unskilled labor where salaries are typically minimal. However, surface water irrigation does offer a source of employment and revenue to the youth in a farming

community and to others that otherwise would not be available. The trend in crop irrigation in arid regions is the conversion of surface water irrigated lands to “push-button” ground water applications, which curtails the demand for irrigation labor. The change in labor requirements causes an incremental transformation in the agrarian society, by incurring a net savings in labor in terms of cost and time. When economic and labor issues are impacted, political influences inevitably follow in representative governments to protect the interests of the society. Additional research into the correlation between the economic, societal, and political influences surrounding water management practices with administration of interstate river compacts would provide insight to the intervening variables that often control the decision to change an interstate river compact, including the allocation system, or in negotiating a new compact.

Another suggested topic for continued research is the design of an allocation system that would equitably apportion the ground water resources in a regional aquifer among the overlying states. There are many difficult challenges foreseen in the crafting on an interstate aquifer allocation system such as the quantification of the amount of ground water available for distribution to the overlying states, assignment of a sustainable rate of annual ground water withdrawal, and integration of the allocation system within a fragmented set of regulatory controls and ground water laws unique to each state. The interstate aquifer allocation systems would also have to be carefully crafted to not conflict with existing interstate river compacts in which the ground water aquifers are in hydraulic connection with the river system. However, the research does offer the potential to manage ground water resources in a holistic approach opposed to disparate ground water administration based upon artificial state boundaries. The research may

also address the composition and functionality of an administrative body or compact to regulate the aquifer allocation system and to alleviate present and future disputes over claims of excessive ground water withdrawals between neighboring states.

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APPENDIX A

REPUBLICAN RIVER COMPACT

## Republican River Compact

The states of Colorado, Kansas, and Nebraska, parties signatory to this compact (hereinafter referred to as Colorado, Kansas, and Nebraska, respectively, or individually as a state, or collectively as the states), having resolved to conclude a compact with respect to the waters of the Republican River Basin, and being duly authorized therefore by the Act of the Congress of the United States of America, approved August 4, 1942, (Public No. 696, 77th Congress, chapter 545, 2nd Session) and pursuant to acts of their respective legislatures have, through their respective governors, appointed as their commissioners:

M. C. Hinderlider, for Colorado

George S. Knapp, for Kansas

Wardner G. Scott, for Nebraska

Who, after negotiations participated in by Glenn L. Parker, appointed by the President as the representative of the United States of America, have agreed upon the following articles:

### Article I

The major purposes of this compact are to provide for the most efficient use of the waters of the Republican River Basin (hereinafter referred to as the "Basin") for multiple purposes; to provide for an equitable division of such waters; to remove all causes, present and future, which might lead to controversies; to promote interstate comity; to recognize that the most efficient utilization of the waters within the Basin is for beneficial consumptive use; and to promote joint action by the states and the United States in the efficient use of water and the control of destructive floods.

The physical and other conditions peculiar to the Basin constitute the basis for this compact, and none of the states hereby, nor the Congress of the United States by its consent, concedes that this compact establishes any general principle or precedent with respect to any other interstate stream.

### Article II

The Basin is all the area in Colorado, Kansas, and Nebraska, which is naturally drained by the Republican River, and its tributaries, to its junction with the Smoky Hill River in Kansas. The main stem of the Republican River extends from the junction near Haigler, Nebraska, of its North Fork and the Arikaree River, to its junction with Smoky Hill River near Junction City, Kansas. Frenchman Creek (River) in Nebraska is a

continuation of Frenchman Creek (River) in Colorado. Red Willow Creek in Colorado is not identical with the stream having the same name in Nebraska. A map of the Basin approved by the commissioners is attached and made a part hereof.

The term "Acre-foot," as herein used, is the quantity of water required to cover an acre to the depth of one foot and is equivalent to forty-three thousand, five hundred sixty (43,560) cubic feet.

The term "Virgin Water Supply," as herein used, is defined to be the water supply within the Basin undepleted by the activities of man.

The term "Beneficial Consumptive Use" is herein defined to be that use by which the water supply of the Basin is consumed through the activities of man, and shall include water consumed by evaporation from any reservoir, canal, ditch, or irrigated area.

Beneficial consumptive use is the basis and principle upon which the allocations of water hereinafter made are predicated.

### Article III

The specific allocations in acre-feet hereinafter made to each state are derived from the computed average annual virgin water supply originating in the following designated drainage basins, or parts thereof, in the amounts shown:

North Fork of the Republican River drainage basin in Colorado, 44,700 acre-feet;

Arikaree River drainage basin, 19,610 acre-feet;

Buffalo Creek drainage basin, 7,890 acre-feet;

Rock Creek drainage basin, 11,000 acre-feet;

South Fork of the Republican River drainage basin, 57,200 acre-feet;

Frenchman Creek (River) drainage basin in Nebraska, 98,500 acre-feet;

Blackwood Creek drainage basin, 6,800 acre-feet;

Driftwood Creek drainage basin, 7,300 acre-feet;

Red Willow Creek drainage basin in Nebraska, 21,900 acre-feet;

Medicine Creek drainage basin, 50,800 acre-feet;

Beaver Creek drainage basin, 16,500 acre-feet;

Sappa Creek drainage basin, 21,400 acre-feet;

Prairie Dog Creek drainage basin, 27,600 acre-feet;

The North Fork of the Republican River in Nebraska and the main stem of the Republican River between the junction of the North Fork and Arikaree River and the lowest crossing of the river at the Nebraska-Kansas state line and the small tributaries thereof, 87,700 acre-feet.

Should the future computed virgin water supply of any source vary more than ten (10) per cent from the virgin water supply as hereinabove set forth, the allocations hereinafter made from such source shall be increased or decreased in the relative proportions that the future computed virgin water supply of such source bears to the computed virgin water supply used herein.

#### Article IV

There is hereby allocated for beneficial consumptive use in Colorado, annually, a total of fifty-four thousand, one hundred (54,100) acre-feet of water. This total is to be derived from the sources and in the amounts hereinafter specified and is subject to such quantities being physically available from those sources:

North Fork of the Republican River drainage basin, 10,000 acre-feet;

Arikaree River drainage basin, 15,400 acre-feet;

South Fork of the Republican River drainage basin, 25,400 acre-feet;

Beaver Creek drainage basin, 3,300 acre-feet; and

In addition, for beneficial consumptive use in Colorado annually, the entire water supply of the Frenchman Creek (River) drainage basin in Colorado and the Red Willow Creek drainage basin in Colorado.

There is hereby allocated for beneficial consumptive use in Kansas, annually, a total of one hundred ninety thousand, three hundred (190,300) acre-feet of water. This total is to be derived from the sources and in the amounts hereinafter specified and is subject to such quantities being physically available from those sources:

Arikaree River drainage basin, 1,000 acre-feet;

South Fork of the Republican River drainage basin, 23,000 acre-feet;

Driftwood Creek drainage basin, 500 acre-feet;

Beaver Creek drainage basin, 6,400 acre-feet;

Sappa Creek drainage basin, 8,800 acre-feet;

Prairie Dog Creek drainage basin, 12,600 acre-feet;

From the main stem of the Republican River upstream from the lowest crossing of the river at the Nebraska-Kansas state line and from water supplies of upstream basins otherwise unallocated herein, 138,000 acre-feet; provided, that Kansas shall have the right to divert all or any portion thereof at or near Guide Rock, Nebraska; and

In addition there is hereby allocated for beneficial consumptive use in Kansas, annually, the entire water supply originating in the Basin downstream from the lowest crossing of the river at the Nebraska-Kansas state line.

There is hereby allocated for beneficial consumptive use in Nebraska, annually, a total of two hundred thirty-four thousand, five hundred (234,500) acre-feet of water. This total is to be derived from the sources and in the amounts hereinafter specified and is subject to such quantities being physically available from those sources:

North Fork of the Republican River drainage basin in Colorado, 11,000 acre-feet;

Frenchman Creek (River) drainage basin in Nebraska, 52,800 acre-feet;

Rock Creek drainage basin, 4,400 acre-feet;

Arikaree River drainage basin, 3,300 acre-feet;

Buffalo Creek drainage basin, 2,600 acre-feet;

South Fork of the Republican River drainage basin, 800 acre-feet;

Driftwood Creek drainage basin, 1,200 acre-feet;

Red Willow Creek drainage basin in Nebraska, 4,200 acre-feet;

Medicine Creek drainage basin, 4,600 acre-feet;

Beaver Creek drainage basin, 6,700 acre-feet;

Sappa Creek drainage basin, 8,800 acre-feet;

Prairie Dog Creek drainage basin, 2,100 acre-feet;

From the North Fork of the Republican River in Nebraska, the main stem of the Republican River between the junction of the North Fork and Arikaree River and the lowest crossing of the river at the Nebraska-Kansas state line, from the small tributaries

thereof, and from water supplies of upstream basins otherwise unallocated herein, 132,000 acre-feet.

The use of the waters hereinabove allocated shall be subject to the laws of the state, for use in which the allocations are made.

#### Article V

The judgment and all provisions thereof in the case of Adelbert A. Weiland, as state engineer of Colorado, et al. v. The Pioneer Irrigation Company, decided June 5, 1922, and reported in 259 U. S. 498, affecting the Pioneer irrigation ditch or canal, are hereby recognized as binding upon the states; and Colorado, through its duly authorized officials, shall have the perpetual and exclusive right to control and regulate diversions of water at all times by said canal in conformity with said judgment.

The water heretofore adjudicated to said Pioneer Canal by the district court of Colorado, in the amount of fifty (50) cubic feet per second of time is included in and is a part of the total amounts of water hereinbefore allocated for beneficial consumptive use in Colorado and Nebraska.

#### Article VI

The right of any person, entity, or lower state to construct, or participate in the future construction and use of any storage reservoir or diversion works in an upper state for the purpose of regulating water herein allocated for beneficial consumptive use in such lower state, shall never be denied by an upper state; provided, that such right is subject to the rights of the upper state.

#### Article VII

Any person, entity, or lower state shall have the right to acquire necessary property rights in an upper state by purchase, or through the exercise of the power of eminent domain, for the construction, operation and maintenance of storage reservoirs, and of appurtenant works, canals and conduits, required for the enjoyment of the privileges granted by Article VI; provided, however, that the grantees of such rights shall pay to the political subdivisions of the state in which such works are located, each and every year during which such rights are enjoyed for such purposes, a sum of money equivalent to the average annual amount of taxes assessed against the lands and improvements during the ten years preceding the use of such lands, in reimbursement for the loss of taxes to said political subdivisions of the state.

#### Article VIII

Should any facility be constructed in an upper state under the provisions of Article VI, such construction and the operation of such facility shall be subject to the laws of such upper state.

Any repairs to or replacements of such facility shall also be made in accordance with the laws of such upper state.

#### Article IX

It shall be the duty of the three states to administer this compact through the official in each state who is now or may hereafter be charged with the duty of administering the public water supplies, and to collect and correlate through such officials the data necessary for the proper administration of the provisions of this compact. Such officials may, by unanimous action, adopt rules and regulations consistent with the provisions of this compact.

The United States geological survey, or whatever federal agency may succeed to the functions and duties of that agency, in so far as this compact is concerned, shall collaborate with the officials of the states charged with the administration of this compact in the execution of the duty of such officials in the collection, correlation, and publication of water facts necessary for the proper administration of this compact.

#### Article X

Nothing in this compact shall be deemed:

(a) To impair or affect any rights, powers or jurisdiction of the United States, or those acting by or under its authority, in, over, and to the waters of the Basin; nor to impair or affect the capacity of the United States, or those acting by or under its authority, to acquire rights in and to the use of waters of the Basin;

(b) To subject any property of the United States, its agencies or instrumentalities, to taxation by any state, or subdivision thereof, nor to create an obligation on the part of the United States, its agencies or instrumentalities, by reason of the acquisition, construction, or operation of any property or works of whatsoever kind, to make any payments to any state or political subdivision thereof, state agency, municipality, or entity whatsoever in reimbursement for the loss of taxes;

(c) To subject any property of the United States, its agencies or instrumentalities, to the laws of any state to any extent other than the extent these laws would apply without regard to this compact.

#### Article XI

This compact shall become operative when ratified by the legislature of each of the states, and when consented to by the Congress of the United States by legislation providing, among other things, that:

(a) Any beneficial consumptive uses by the United States, or those acting by or under its authority, within a state, of the waters allocated by this compact, shall be made within the allocations hereinabove made for use in that state and shall be taken into account in determining the extent of use within that state.

(b) The United States, or those acting by or under its authority, in the exercise of rights or powers arising from whatever jurisdiction the United States has in, over and to the waters of the Basin shall recognize, to the extent consistent with the best utilization of the waters for multiple purposes, that beneficial consumptive use of the waters within the Basin is of paramount importance to the development of the Basin; and no exercise of such power or right thereby that would interfere with the full beneficial consumptive use of the waters within the Basin shall be made except upon a determination, giving due consideration to the objectives of this compact and after consultation with all interested federal agencies and the state officials charged with the administration of this compact, that such exercise is in the interest of the best utilization of such waters for multiple purposes.

(c) The United States, or those acting by or under its authority, will recognize any established use, for domestic and irrigation purposes, of the waters allocated by this compact which may be impaired by the exercise of federal jurisdiction in, over, and to such waters; provided, that such use is being exercised beneficially, is valid under the laws of the appropriate state and in conformity with this compact at the time of the impairment thereof, and was validly initiated under state law prior to the initiation or authorization of the federal program or project which causes such impairment.

IN WITNESS WHEREOF, the commissioners have signed this compact in quadruplicate original, one of which shall be deposited in the archives of the department of state of the United States of America and shall be deemed the authoritative original, and of which a duly certified copy shall be forwarded to the governor of each of the states.

Done in the city of Lincoln, in the state of Nebraska, on the 31st day of December, in the year of our Lord, one thousand nine hundred forty-two.

M. C. Hinderlider Commissioner for Colorado

George S. Knapp Commissioner for Kansas

Wardner G. Scott Commissioner for Nebraska

I have participated in the negotiations leading to this proposed compact and propose to report to the Congress of the United States favorably thereon.

Glenn L. Parker Representative of the United States

APPENDIX B

SURVEY QUESTIONNAIRE

**INTERSTATE COMPACT QUESTIONNAIRE**  
Ken Knox, Ph.D. Candidate at Colorado State University  
April 2001

**Is your State a party to an Interstate River Compact?**      Yes \_\_\_\_ No \_\_\_\_

If the answer is yes, please provide information to the following questions for each interstate compact.

Name of Compact \_\_\_\_\_

River or Creek \_\_\_\_\_

Date of Compact \_\_\_\_\_

Other signatory states to the Compact \_\_\_\_\_

Is there Federal or Regional representation?      Yes \_\_\_\_ No \_\_\_\_

Is a primary intent of the Compact to govern the allocation of water among states?  
Yes \_\_\_\_ No \_\_\_\_

If the primary intent is allocation, what is the method used to distribute supplies?

Division based upon measured flow at key streamflow gaging stations \_\_\_\_

Division based upon a prescribed formula or set amount \_\_\_\_

Division based upon historic beneficial use \_\_\_\_

Other, please specify \_\_\_\_\_

What is the type of water law that governs water allocation to your state?

Doctrine of Prior Appropriation (first in time, first in right) \_\_\_\_

Riparian Doctrine \_\_\_\_

Permit \_\_\_\_

Other, please specify \_\_\_\_\_

Is a primary intent of the Compact relevant to water quality?      Yes \_\_\_\_ No \_\_\_\_

Is a primary intent of the Compact relevant to navigation?      Yes \_\_\_\_ No \_\_\_\_

Is a primary intent of the Compact relevant to hydropower generation?      Yes \_\_\_\_ No \_\_\_\_

Is a primary intent of the Compact relevant to sanitation?      Yes \_\_\_\_ No \_\_\_\_

Is a primary intent of the Compact relevant to flood control?      Yes \_\_\_\_ No \_\_\_\_

Is a primary intent of the Compact relevant to fishing or wildlife?      Yes \_\_\_\_ No \_\_\_\_

Is a primary intent of the Compact relevant to municipal/industrial use? Yes \_\_\_ No \_\_\_

Is there a different intent of the Interstate Compact that is not previously specified?

If so, please describe \_\_\_\_\_

Is there a mechanism or procedure to measure or assure compliance with the Compact?

Annual or periodic reports \_\_\_\_\_

Streamflow and/or water quality monitoring \_\_\_\_\_

Other, please describe \_\_\_\_\_

What sources or types of water does the Compact govern?

Surface \_\_\_\_\_ Ground water \_\_\_\_\_ Reservoir storage/releases \_\_\_\_\_

◆ Alluvial \_\_\_\_\_

◆ Bedrock or non-tributary \_\_\_\_\_

Is there a governing committee or commission for the Compact?

If so, please describe \_\_\_\_\_

Is there a specified forum or resolution procedure within the compact that is intended to resolve interstate conflicts? Yes \_\_\_ No \_\_\_

If yes, please describe \_\_\_\_\_

Has the Compact ever been subject to litigation?

If so, please specify the jurisdictional court and case \_\_\_\_\_

When was the interstate lawsuit initiated and by what state? \_\_\_\_\_

**Is your State party to an Interstate Compact that governs natural lakes, reservoirs, or coastal waters?**

If the answer is yes, please provide information to the following questions for each interstate compact.

Name of Compact \_\_\_\_\_

Lake, Reservoir, Coastal Area \_\_\_\_\_

Date of Compact \_\_\_\_\_

Other signatory states to the Compact \_\_\_\_\_

Is there Federal or Regional representation? Yes \_\_\_ No \_\_\_

Please provide a brief description of the Compact \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Is your State party to an Interstate Compact that governs ground water and/or aquifers?**

If the answer is yes, please provide information to the following questions for each interstate compact.

Name of Compact \_\_\_\_\_

Ground water aquifer or formation \_\_\_\_\_

Date of Compact \_\_\_\_\_

Other signatory states to the Compact \_\_\_\_\_

Is there Federal or Regional representation?      Yes \_\_\_\_      No \_\_\_\_

Please provide a brief description of the Compact \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Other Interstate Compacts related to water resources**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Are paper or electronic copies of the Interstate Compacts available?

If so, please provide source/cost information \_\_\_\_\_  
\_\_\_\_\_

**Would you like to receive a paper or electronic copy of the Interstate Compact database?**

If so, please specify your name, mailing address, phone number, and e-mail

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

APPENDIX C

TABULATION OF WATER RIGHTS AND PERMITS  
1940

**Ground Water Use and Water Right Summary – Main Stem Republican River**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
Dave Jones	10	39.0			
T.E. Ellis	20				
Roy Lingo	65	56.0			
R.R. Haines	60				
T.M. Hardwick	28				
Wm. Bauerle	120	78.0			
E.L. Holcomb	35	98.0			
F.E. McConnell	60	92.5			
L.S. Hall	10	47.5			
A.R. Reagan	40	118.0			
A.R. Reagan	40	91.0			
H.W. Kleinsmith	30				
H. Conner	20	52.0			
H. Conner	50	84.0			
Pycha	70				
Harry Wilcox	120				
Trenchard	70				
E. Cochran	25	25.0			
Levi Burton	60	78.0			
G.W. Toller	30	15.0			
A.J. Helm	20				
J.R. Frederickson	30	36.0			
W.C. Fitch	39	39.0			
Mrs. Frank Cain	50	50.0			

### Ground Water Use and Water Right Summary – Main Stem Republican River

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
Fred Adams	20	50.0			
E.E. Smith & Son	200	180.0			
J.E. Kelly	75				
L.A. Wideman	120				
H. Swanson	30				
Red Willow County	26	28.0			
Gerald Wilcox	256	306.0			
City of Indianola		73.0			Municipal Well
City of McCook		1310.0			Municipal Well
J.C. Sayer	115	70			
S.C. Smith	60	120			
Benjamin Hilton	25	28			
Butler and Olson	100	175			
Breinig Brothers	55				
Pete Jacobs	25				
E.T. Purington	30	185			
C.S. Paine	100	42			
A.F. Broeker	15	9	7-12-33	0.57	Irrig. Pump
Tom Hayes	3				
George Duval	50				
City of Holbrook		28			Municipal Well
City of Arapahoe		168			Municipal Well
City of Oxford		168			Municipal Well
City of Edison		17			Municipal Well

**Ground Water Use and Water Right Summary – Main Stem Republican River**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
City of Cambridge		155			Municipal Well
Mrs. A. Godekin	50				
M.H. Haskins	80				
F.A. Grable	60				
D. Fach	15	25			
A.C. Shallenberger	24				
C. Wolfe	70				
John Sylvester	27				
A.W. Urbon	40				
City of Stamford		14			Municipal Well
City of Orleans		121			Municipal Well
City of Alma		163			Municipal Well
Republican City		25			Municipal Well
City of Holdredge		280			Municipal Well
H. Hubert, Jr.	50	32.4			
Larrick Est.	60		8-21-36	1.11	Irr. Turkey Ck
City of Naponoo		11			Mun. Well
Charlos Howell	35				
City of Bloomington		26			Mun. Well
City of Franklin		137			Mun. Well
Earnest Blank	40				
Hevenor Serum Co.	40		8-5-31	4.66	Irrig. Pump (River Pump Abandoned)
H.B. Cyr	40				
William Sindt	85				
Wontworth	35				
City of Riverton		17			Municipal Well

**Ground Water Use and Water Right Summary – Main Stem Republican River**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
City of Hardy		59			Municipal Well
City of Superior		338			Municipal Well
Russel Pierce	2				
Henry Huffman	5	31.1			
V.H. Kiel	20	14.8			
George Ohmstede	40	47.2			
Henry Pederson	18	14.8			

**Ground Water Use and Water Right Summary – North Fork of the Republican River**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
Yenter Est.	30				

**Ground Water Use and Water Right Summary – South Fork of the Republican River**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
Akers	17				
City of Bethune		4.6			Municipal
City of Stratton		15.4			Municipal
City of Flagler		35			Municipal
Foster Farms			52	4.60	160 acres
Foster Well #2			53	4.20	150 acres in Sec. 17 & 18
E. Romkee	16				
J. Keller	70				
F. Confer	2				
B. Judy	30				
R.L Harrison	30				
L.A. Merklin	1				
P.E. O'Brien	120				
C.L. Case	1 ½				

**Ground Water Use and Water Right Summary – Arikaree**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
H.W. Brullinger	10				
J. Hartzman	5				
Loomis Brothers	15	33			
Spencer	4				

**Ground Water Use and Water Right Summary – Beaver Creek**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
W.S. Langmaid	35				
S.D. Nichols	40				
William Angus	45				
R. W. Parrish	3				
City of Kanarado		201			Municipal
Walter Eggers	90				
A.H. Busse	40				
R. Weaver	5				
Bird City		58			Municipal
Paul Weisphal	35				
H.F. Berndt	6				
C.E. Henneberger	9				
City of Herndon		27			Municipal
City of McDonald		28			Municipal
City of Atwood		204			Municipal
Waid Waldo			8-16-39	2000.0	
F.W. Clark	135	297			
F.W. Clark	107				
E. Morris	45		5-10-39	0.64	
City of Burlington		184			Municipal
Paul Nitsch	40				

### Ground Water Use and Water Right Summary – Sappa Creek

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
J.R. Anderson	5	16.7			
Jones Bros.	35	37.4			
C.C. Cooper	18				
W.W. Savage	20	13			
N.A. Brown	35				
N.A. Brown	5				
Redman	60				
J.A. Paddock	35	30			
George Gardner	14				
A.L. Miller, Jr.			12-27-39	6.0	
A.L. Miller, Sr.			12-27-39	6.0	
S.D. Cathcart	3				
C.V. Cocoran	20	7			
Paul Resch	1				
H.F.G. Euchus	35	94			
City of Oberlin		268			Municipal
City of Colby		398			Municipal
City of Rexford		29			Municipal
Cedclie Vacura	41	50		0.84	
T.E. Frank	8				
Cecil Huff	1				
Kansas State Hospital					3 wells

**Ground Water Use and Water Right Summary – Prairie Dog Creek**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
City of Clayton		8			Municipal
City of Alemena		60			Municipal
City of Norton		373			Municipal
E.P. Nichols	1				
City of Long Island		11			Municipal

**Ground Water Use and Water Right Summary – Medicine Creek**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
City of Stackville		10			Municipal
City of Curtis		103			Municipal

**Ground Water Use and Water Right Summary – Frenchman Creek**

Name	Acres Irrigated Well	Amount Used Annually (AF)	Priority Date or Order No.	Grant (Second feet, or AF)	Remarks
City of Fleming		13.8			Municipal
G.A. Marks	40	35			
City of Holyoke		29.4			Municipal
City of Haxton		20			Municipal
Higginbothum	200	200			
J. Doe	140	140			
City of Imperial		113			
E. Moody	70				
Peak	160				
Kilpatrick Bros.	80				
City of Imperial			2-7-17	55.0	Municipal Power City
Krotter Bros.	52				
F. Rice	33	133			
Oliver Bros.	65	150	4-28-13 4-28-13	3.20 50.0	Irrig. Canal Power
O.E. Nutzman	80		10-5-39 4-15-40	0.95 0.36	67 Ac. 25 Ac. Irrig. Pump
H.B. Ashmore	60				
City of Palisade		64			Municipal
City of Culbertson		101			Municipal
McCormick Bros.	80	152			

APPENDIX D

REPUBLICAN RIVER COMPACT  
DISPUTE RESOLUTION PROCESS

United States Supreme Court  
Kansas v. Nebraska and Colorado, No. 126 Original  
Final Settlement Stipulation  
December 15, 2002

Republican River Compact Administration (RRCA)

Dispute Resolution

A. Initial Submission to the RRCA:

1. Any matter relating to Republican River Compact administration, including administration and enforcement of the Stipulation in which a State has an Actual Interest, shall first be Submitted to the RRCA. The United States and its agencies may attend all meetings of the RRCA. Proposed agendas, including any regular issue that may be raised, shall be distributed by the chairperson to all RRCA members at least 30 days in advance of any regular meeting and as soon as possible prior to any special meeting.
2. Each member of the RRCA shall have one vote on each issue Submitted to the RRCA. RRCA action must be by unanimous vote. Action of the RRCA shall be by formal resolution or as reflected in the approved minutes. A request for formal resolution may be made by any member.
3. Any dispute that the State raising the issue for RRCA determination believes requires immediate resolution shall be designated as a "fast-track" issue. Any "fast-track" issue will be Addressed by the RRCA within 30 days of being Submitted to the RRCA unless otherwise agreed to by all States. Nothing in this Section shall prohibit the RRCA from Addressing a dispute prior to the expiration of the 30-day period.
4. Any dispute which the State raising the issue for RRCA determination believes does not require immediate resolution shall be designated as a "regular" issue. Any "regular" issue raised no later than 30 days prior to the next regularly scheduled meeting will be Addressed by the RRCA at that meeting.
5. The RRCA will hold regular meetings pursuant to its rules and regulations. Specially scheduled meetings to address any issue that is Submitted to the RRCA and designated as a "fast-track" issue or for any other emergency purposes shall be held if requested by any member. All members shall make a good faith effort to arrange a mutually agreeable date, time, and place for all meetings. A

meeting may be conducted only when all members or their designees are available to attend. In the event a member requests a specially scheduled meeting to address a “fast-track” issue or for any other emergency purposes, such meeting shall be held as soon as reasonably possible, but in no event more than 30 days after the request is made unless more time is agreed to by all members. If scheduling a meeting in person is not possible within 30 days of a request, the members may conduct a telephone conference or use other means available. If any such meeting is not held within thirty days because of the failure of any member other than the requesting member to attend or to agree to the date and place for the meeting, the State represented by the requesting member shall be relieved of any obligation to submit any dispute to the RRCA for potential consideration and resolution pursuant to the Stipulation.

6. Any issue Submitted to the RRCA by a State will include a specific definition of the issue, supporting materials and a designated schedule for resolution.

7. The RRCA will attempt to resolve any dispute submitted to the RRCA pursuant to this Section VII. If such a dispute cannot be resolved by the RRCA at the regular or special meeting at which the issue is addressed or within a schedule agreed to by all States, and the State raising the dispute desires to proceed, the dispute shall be submitted to non-binding arbitration unless otherwise agreed to by all States with an Actual Interest. The States involved in the dispute may agree that the arbitration shall be binding, but no State shall be subject to binding arbitration without its express written consent.

B. General Dispute Resolution Provisions:

1. Unless otherwise agreed to by all States, non-binding arbitration shall be initiated as follows: Any State, pursuant to Subsection VII.A.7., may invoke arbitration by providing written notice to the other States. A copy of any notice will be provided to the United States at the same time. Notice for the purposes of this Section shall include the time frame designation, a written description of the scope of the dispute, with sufficient detail to provide the States with an understanding of the substance of the dispute and all related issues, and sufficient information for the other States with an Actual Interest to identify the technical skills that should be possessed by potential arbitrators necessary to resolve the dispute.

2. The arbitrator(s) shall be selected as follows: Upon receipt of notice of a dispute, the States shall confer within the deadlines set forth below to choose an arbitrator(s) and the States will in good faith attempt to agree on an arbitrator(s).
3. Any person submitted as a possible arbitrator by any State, or selected by CDR Associates or other such entity, shall not be an employee or agent of any State, shall be a person generally knowledgeable of the principles of the issues in the dispute, and shall disclose any actual or potential conflict of interest and all current or prior contractual and other relationships with any person or entity who could be directly affected by resolution of the dispute. Any person who has a contractual relationship with any State shall be automatically disqualified for conflict of interest unless the other States expressly agree in writing.
4. The arbitrator(s)' decision shall include a determination of the merits of the dispute and determination of a proposed remedy.
5. The arbitrator(s)' decision shall be provided to the States and the United States by facsimile and mail or comparable means.
6. Within 30 days of the issuance of the arbitrator's decision, the States that are parties to the dispute shall give written notice to the other States and the United States as to whether they will accept, accept and reject in part, or reject the arbitrator's decision.
7. No State shall object to admission of the arbitrator(s)' decision in any subsequent proceedings before the Court, but no State shall assert that the decision is conclusive on any issue. Further, no State shall call the arbitrator(s) as a witness with regard to the dispute.
8. A State that has submitted a disputed issue to the RRCA and to arbitration as provided in this Section VII shall be deemed to have exhausted its administrative remedies with regard to such issue.

C. Fast Track Dispute Resolution Schedule:

1. Upon receipt of notice under Subsection VII.B.1., each State with an interest in the dispute will have ten business days to amend the scope of the dispute to address additional issues, unless all States agree to a longer schedule. If unforeseen issues are identified after the deadline for amending the scope of the dispute, they may be added upon agreement of all States or at the discretion of the arbitrator.

2. Within ten business days of receipt of the initial notice, each State shall submit the names of proposed arbitrators, including qualifications, to the other States. Within seven business days of receipt of the proposed names, the States will meet, in person or by telephone conference, and confer to agree on an arbitrator(s). If the States with an Actual Interest cannot agree on an arbitrator(s), the selection of the arbitrator will be submitted to CDR Associates, of Boulder, Colorado, or such other person or entity that may be agreed to by the RRCA. Every two years the RRCA will review the entity that will select an arbitrator(s), if the States cannot choose. The States will be bound by the selection of an arbitrator by CDR Associates or such other person or entity.
3. Upon selection of an arbitrator(s), the arbitrator(s) shall, within seven business days, hold an initial meeting/conference with the States, to set the schedule for submission and resolution of the pending dispute. The arbitrator shall set a schedule not to exceed six months unless the States agree otherwise. The States agree to provide all information, except privileged information, requested by the arbitrator(s).
4. The arbitrator(s) shall issue a decision resolving the dispute within the shortest reasonable time, not to exceed 60 days from the date of final submission by the State parties.

D. Regular Dispute Resolution Schedule:

1. The States with an Actual Interest will agree upon the schedule for amending the scope of the dispute.
2. The States will agree upon the method and schedule for selecting an arbitrator(s).
3. The States and the arbitrator(s) will agree on a schedule for submission and resolution of the pending dispute.
4. The States will agree on a schedule for issuance of a decision by the arbitrator(s).

APPENDIX E

TABULATION OF INTERSTATE COMPACTS

Water Related Compacts in the United States

Ken Knox

Name of Compact	Stream or Lake	Groundwater Aquifer	Date of Compact	Compact States	Federal or Regional Represent.	Primary Intent	Compliance Mechanism	Sources of Water	Formal Dispute Resolution	Subjected to Litigation
Alabama-Coosa-Tallapoosa River Basin Compact	Alabama, Coosa, & Tallapoosa Rivers		1997	Alabama, Georgia	Yes	Water allocation, planning & development	Riparian	Surface	Compact Article XIII	
Animas-La Plata Project Compact	Animas and La Plata Rivers		1969	Colorado, New Mexico	No	Water allocation		Surface, reservoir storage		
Apalachicola-Chattahoochee-Flint River Basin Compact	Apalachicola, Chattahoochee, & Flint Rivers		1997	Alabama, Georgia, Florida	Yes	Water allocation, planning & development	Riparian	Surface	Compact Article XIII	
Arkansas River Compact	Arkansas River		1948	Colorado, Kansas	Yes	Water allocation	DOPA/ streamflow monitoring, prescribed formula, annual reports	Surface/ storage in John Martin Reservoir	Arbitration	Kansas v. Colorado in 1904, 1944, and 1985
Arkansas River Compact Arkansas-Oklahoma	Arkansas River		1970	Oklahoma	Yes	Water allocation, water quality	Riparian, prescribed formula, streamflow monitoring, annual reports	Surface	Arbitration	No

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Name of Compact	Stream or Lake	Groundwater Aquifer	Date of Compact	Compact States	Federal or Regional Represent.	Primary Intent	Compliance Mechanism	Sources of Water	Formal Dispute Resolution	Subjected to Litigation
Arkansas River Compact Kansas-Oklahoma	Arkansas River		1965	Kansas, Oklahoma	Yes	Water allocation, water quality	Riparian, prescribed formula, streamflow monitoring, annual reports	Surface, Conser. storage	No	No
Bear River Compact	Bear River	Tributary ground water	1978	Idaho, Wyoming, Utah	Yes	Water allocation, development	DOPA/ prescribed formula, accounting, annual reports	Surface, alluvial groundwater reservoir releases	No	No
Belle Fourche River Compact	Belle Fourche River		1943	Wyoming, South Dakota	No	Water allocation	DOPA/ Prescribed formula, streamflow monitoring	Surface, reservoir releases	No	No
Big Blue River Compact	Big Blue River	Alluvial	1971	Kansas, Nebraska	Yes	Water allocation, water quality	DOPA/ flow targets, streamflow & observation well monitoring, annual reports	Surface, ground water	No	
Bi-State Development Compact			1949	Illinois, Missouri	No	Development			No	

Name of Compact	Stream or Lake	Groundwater Aquifer	Date of Compact	Compact States	Federal or Regional Represent.	Primary Intent	Compliance Mechanism	Sources of Water	Formal Dispute Resolution	Subjected to Litigation
Caddo Lake Compact	Caddo Lake		1979	Louisiana, Texas	Yes	Water allocation		Surface	No	
California-Nevada Interstate Compact	Truckee River, Carson River, Walker River	Tributary ground water	1971	California Nevada	Yes	Water allocation	DOPA/ prescribed formula, streamflow monitoring	Surface, Reservoir releases	No	No
Canadian River Compact	Canadian River		1950	New Mexico, Oklahoma Texas	Yes	Water allocation	DOPA/ prescribed formula, reservoir storage	Surface, reservoir releases	No	Texas and Oklahoma v. New Mexico, 1987
Colorado River Compact	Colorado River		1922	Arizona, California Nevada, New Mexico, Utah, Colorado, Wyoming	Yes	Water allocation, development	DOPA/ prescribed formula, streamflow monitoring, annual reports	Surface	No	Arizona v. California, 1964
Connecticut River Flood Control Compact	Connecticut River		1951	Connecticut, Mass. New Hamp. Vermont	No	Flood protection	Compensatory payment of tax loss	Surface	No	
Costilla Creek Compact (Amended)	Costilla Creek		1963	Colorado, New Mexico	No	Water allocation	DOPA/ prescribed formula, accounting	Surface, reservoir storage	No	

Name of Compact	Stream or Lake	Groundwater Aquifer	Date of Compact	Compact States	Federal or Regional Represent.	Primary Intent	Compliance Mechanism	Sources of Water	Formal Dispute Resolution	Subjected to Litigation
Delaware River Basin Compact	Delaware River	All ground water	1961	Delaware New York New Jersey Penn.	Yes	Planning & development, water allocation, water quality, management & control	Riparian, equitable apportionment, streamflow monitoring, annual reports	Surface, alluvial & non-tributary groundwater reservoir releases	No	Yes
Great Lakes Basin Compact	Great Lakes Basin		1955	Ohio, Illinois, Indiana, Quebec, Ontario, Michigan, New York Minnesota Wisconsin Penn.	No	Development, water supply, water quality, navigation, fishing		Lakes Erie, Huron, Michigan, Ontario, St. Clair, Superior, and St. Lawrence River	No	
Interstate Sanitation Commission	NY, NJ, & CN coastal areas		1941	New York New Jersey, Conn.	No	Water quality			No	
Jennings Randolph Lake Project Compact	Jennings Randolph Lake		1993	Maryland, West Virginia	Yes	Flood Protection, water allocation, water quality, recreation	Cooperation with U.S. Army Corps of Engineers	Surface	No	

Name of Compact	Stream or Lake	Groundwater Aquifer	Date of Compact	Compact States	Federal or Regional Represent.	Primary Intent	Compliance Mechanism	Sources of Water	Formal Dispute Resolution	Subjected to Litigation
Kansas-Missouri Flood Prevention and Control Compact	Missouri River		1985	Kansas, Missouri	Yes	Flood Protection			No	
Klamath River Basin Compact	Klamath River	Specifically omit ground water	1957	California, Oregon	Yes	Water allocation, flood protection	Streamflow monitoring, annual reports	Surface, reservoir storage	Arbitration	
La Plata River Compact	La Plata River		1922	Colorado, New Mexico	No	Water allocation	DOPA/ prescribed formula, accounting, annual reports	Surface	No	Hinderlider v. La Plata River & Cherry Creek Ditch Co. (1938)
Merrimack River Flood Control Compact	Merrimack River		1957	Massachusetts, New Hamp.	No	Flood protection	Compensatory payment of tax loss	Surface	No	
Natural Energy and Water Resources Compact			1979	Arkansas, Louisiana, New Mexico, Oklahoma Texas	No	Hydropower		All water resources	No	

Name of Compact	Stream or Lake	Groundwater Aquifer	Date of Compact	Compact States	Federal or Regional Represent.	Primary Intent	Compliance Mechanism	Sources of Water	Formal Dispute Resolution	Subjected to Litigation
New England Interstate Water Pollution Control	Multiple water bodies		1947	Conn., Maine, Mass., New Hamp., Rhode Island, Vermont	Yes	Water quality, sanitation	Riparian, annual reports	Surface, lakes, coasts	No	
New Hampshire-Vermont Interstate Public Water Supply Compact			1995	New Hamp. Vermont	No	Construction of water supply facilities			No	
Ohio River Valley Water Sanitation Compact	Ohio River		1948	Ohio, Penn, New York Virginia, Kentucky, Illinois, Indiana, Tennessee	Yes	Water quality, sanitation	Riparian, biennial reports, state audits	Surface, ground water	No	Dyer v. Sims, 1950
Pecos River Compact	Pecos River		1948	New Mexico, Texas	Yes	Water allocation, development	DOPA/ prescribed formulas, streamflow monitoring, annual reports	Surface, reservoir storage	No	Texas v. New Mexico, 1974

Name of Compact	Stream or Lake	Groundwater Aquifer	Date of Compact	Compact States	Federal or Regional Represent.	Primary Intent	Compliance Mechanism	Sources of Water	Formal Dispute Resolution	Subjected to Litigation
Potomac River Basin Compact	Potomac River		1940	Maryland, Penn. Virginia, D.C.	Yes	Water quality	Riparian, annual reports	Surface, reservoir releases	No	
Potomac River Compact	Potomac River		1958	Maryland, Virginia	No	Fishing	Licenses, taxes	River	No	
Red River Compact	Red River		1978	Arkansas, Louisiana, Oklahoma Texas	Yes	Water allocation, water quality	DOPA/ prescribed formulas, reservoir storage, streamflow monitoring, annual reports	Surface, reservoir storage	No	No
Republican River Compact	Republican River		1943	Colorado, Kansas, Nebraska	No	Water allocation	DOPA/ calculations of beneficial use, annual report	Surface	No	Kansas v. Nebraska and Colorado (1998)
Rio Grande River Compact	Rio Grande River		1938	Colorado, New Mexico, Texas	Yes	Water allocation	DOPA/ prescribed formulas, streamflow monitoring, annual reports	Surface, reservoir storage	No	Texas v. New Mexico & MRGCD, 1935 & 1951; Texas & New Mexico v. Colorado, 1966

Name of Compact	Stream or Lake	Groundwater Aquifer	Date of Compact	Compact States	Federal or Regional Represent.	Primary Intent	Compliance Mechanism	Sources of Water	Formal Dispute Resolution	Subjected to Litigation
Sabine River Compact	Sabine River		1953	Louisiana, Texas	Yes	Water allocation	DOPA/ prescribed formulas, reservoir storage, streamflow monitoring, annual reports	Surface, reservoir storage	Arbitration	No
Snake River Compact	Snake River		1949	Idaho, Wyoming	No	Water allocation, flood control	Prescribed formula/ DOPA, water development reports	Surface	USGS appoints federal rep.	No
South Platte River Compact	South Platte River		1923	Colorado, Nebraska	No	Water allocation	DOPA/ target streamflows	Surface	No	
Susquehanna River Basin Compact	Susquehanna River	All ground water	1970	Penn., Maryland, New York	Yes	Planning & development, water allocation, water quality, management & control	Riparian, permit reports, streamflow & WQ monitoring	Surface, groundwater	No	
Thames River Valley Flood Control Compact	Thames River		1957	Connecticut, Massachusetts	No	Flood protection	Compensatory payment of tax loss	Surface	No	

Name of Compact	Stream or Lake	Groundwater Aquifer	Date of Compact	Compact States	Federal or Regional Represent.	Primary Intent	Compliance Mechanism	Sources of Water	Formal Dispute Resolution	Subjected to Litigation
Upper Colorado River Compact	Colorado River		1948	Arizona, New Mex. Utah, Colorado, Wyoming	Yes	Water allocation	DOPA/ formula, streamflow monitoring, annual reports	Surface, reservoir storage	No	
Upper Mississippi River Basin Association	Mississippi River		1981	Wisconsin Iowa, Illinois, Missouri	Yes	Water quality, navigation, power generation, flood fishing/wildlife, M&I			No	No
Upper Niobrara River Compact	Niobrara River	Tributary ground water	1962	Nebraska, Wyoming	No	Water allocation	Streamflow measurement & ground water monitoring	Surface, ground water, reservoir storage	No	
Wabash Valley Compact	Wabash River		1959	Illinois, Indiana	Yes	Development, flood protection	Riparian Doctrine	Surface	No	
Wheeling Creek Watershed Protection and Flood Prevention Compact	Wheeling Creek		1957	Pennsylvania, West Virginia	No	Flood Protection			No	
Yellowstone River Compact	Yellowstone River		1950	Montana, Wyoming, North Dakota	Yes	Water allocation	DOPA/ prescribed formula, streamflow monitoring	Surface, reservoir storage	Federal vote	