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INNOVATIONS IN GROUNDWATER MANAGEMENT AND AQUIFER DEPLETION: ANALYZING LEGISLATIVE SUPPORT AT THE FEDERAL LEVEL

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THESIS APPROVAL PAGE

This is to certify that the thesis prepared by L. Andrew Bauerband, entitled *Gender Identity Reflection and Rumination: Development and Psychometric Evaluation* has been approved by the thesis committee as satisfactorily completing the thesis requirements for the degree Master of Arts in Experimental Psychology.

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Abstract

Groundwater management and aquifer depletion had for a long time been issues reserved to state governments. However, with these issues becoming more globalized, and security of natural resource availability becoming a problem, the federal government has found itself involved in the issue as well. This particular research looks at how the voting records of the United States Congress as a whole support or ignore the innovations in groundwater management and aquifer depletion as identified by Emel and Roberts. Emel and Roberts' research is an essential point on which to base such research, as both scholars have published numerous articles on the subject of aquifer depletion and are considered experts on the issue. A database is constructed using the Library of Congress Website and a strict set of search parameters. The Library of Congress website, also known as Thomas LOC, is the most comprehensive and accurate archive of legislative history currently available. Support for innovations in groundwater management is scored and analyzed according to relevance within the United States Congress. The findings of this research suggest that there is significant support for groundwater management innovations in offsetting aquifer depletion, though support varies based on the groundwater innovation in question. A significant implication of this study is that as the issue of aquifer depletion continues to become more globalized, the federal government will find itself working on a multilateral basis with other nations to curtail the problem using groundwater management measures, so it is important that we know and understand how the federal government supports these innovations.

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An Introduction to the Geopolitics of the High Plains Aquifer

The High Plains Aquifer, also known as the Ogallala Aquifer, stands second only to the Great Lakes as the most valuable source of freshwater in the United States. A massive underground reserve of freshwater, the Ogallala spans eight western states, promising prosperity to many who are able to tap into its resources. These states include South Dakota, Nebraska, Kansas, Oklahoma, Texas, New Mexico, Colorado, and Wyoming. The aquifer's promise of growth and prosperity is not unlimited, however. As recently as the 1970's, hydrologists began to notice that water withdrawal from the aquifer was occurring at a rate faster than its recharge rate. This has led to a major problem known as aquifer depletion.

Jacque Emel and Rebecca Roberts' (1992) seminal research on the institutional dimensions underlying aquifer depletion addresses whether this issue is the result of uneven development or a tragedy of the commons. Though these terms will be discussed later, a tragedy of the commons is the inability of society to come to an agreement on how to manage a limited resource, whereas uneven development is the result of one actor using more of a resource than another actor. In later work, Emel and Roberts (1995) elaborate on this research in order to address what effect institutions may have on maintaining aquifer levels. Emel and Roberts mention several innovations, including the geographically oriented measure of water well spacing and the politically oriented measure of water demand management.

Emel and Roberts conclude their research by raising an open ended question: Do the innovations within groundwater management and aquifer depletion receive political support at federal levels, and if not, why? One of the factors that piqued my interest regarding political support for groundwater management innovations at the federal level is the fact that in terms of proximity, the issue of depletion of the Ogallala aquifer is not geographically close to Washington D.C, and yet it is politically close, as aquifer depletion affects eight states. The other factor is that aquifer depletion is no longer just a local or state issue, due to the trans-boundary nature of groundwater.

Building from the earlier work of Emel and Roberts, but moving in a more explicitly political direction, this thesis addresses how the voting records of the United States Congress as a whole supports, ignores, or contradicts the innovations regarding groundwater management and aquifer depletion, as identified by Emel and Roberts in their research.

Chapter 1 - A Review of Earlier Literature

This literature review has four objectives. First, it will demonstrate an understanding in the literature regarding innovations in groundwater management and aquifer depletion. Second, it will review major debates that are occurring or have occurred in regard to this topic. Third, this section will identify the strengths, as well as the gaps in the works reviewed. Fourth, this review will demonstrate how the proposed research will add to the existing literature on innovations in groundwater management and aquifer depletion. This literature review will consist of three sections. The review begins with the earlier works cited by Emel and Roberts, as well as Emel and Roberts' own research and some critical works not cited specifically by Emel and Roberts. These works are vital to forming a base for this research. This section will address materials from the 1960's until 1995. The second section of this review analyzes the more contemporary literature, from 1996 to the present. The final section of this literature review looks deeper into the innovations that will be evaluated in the data and methods section. For the first two sections, the works cited by Emel and Roberts (1995) will be referred to as the “earlier literature,” while the more recent literature after 1995 will be referred to as “contemporary literature.”

What is Aquifer Depletion?

An aquifer is a massive underground reservoir of water. Aquifer depletion occurs when the withdrawal rate of water from this underground reservoir exceeds the rate at which an aquifer can recharge its water supply. Groundwater management is the phrase used to describe government officials’ and geographers’ attempts to curtail depletion. As far back as the 1970's, it was estimated that the recharge rate for the Ogallala Aquifer was a mere .27 million acre-feet, a common unit of measurement for the amount of water within an aquifer. During the same time period, water withdrawal exceeded 3 million acre-feet (Mapp and Eidman 1976, 391). An acre foot is a unit of measure equal to approximately 43,560 cubic feet of water, and is an international standard of measure. According to scholars Feinerman and Knapp, “concern about wise use of this resource mounts as water [levels] drop, energy costs increase, and surface supplies become limited and more costly” (Feinerman and Knapp 1983, 104).

The Gisser-Sanchez Effect and the Problem of Regulation

Of all topics discussed within the earlier literature, the Gisser-Sanchez effect is clearly the most noted concept, as evidenced from Gisser and Sanchez (1980), Nieswiadomy (1985), and Emel and Roberts (1992). Gisser and Sanchez claimed that by comparing competing strategies of optimal control and groundwater allocation, they could demonstrate that “if the storage capacity of the aquifer is relatively large, the difference between them is so small that it can be ignored for practical consideration" (Gisser and Sanchez 1980, 638). The “it” in the previous statement refers to the difference in competing strategies. The Gisser-Sanchez effect can also be stated as the following:

“If the natural recharge rate and the slope of the demand curve for groundwater are small relative to the area of the aquifer times storavity, and if groundwater rights are exclusively assigned, then the welfare loss due to the intertemporal misallocation of pumping effort is negligible" (Nieswiadomy 1985, 619).

This rule simply states that if demand is low, and the recharge rate of water in an aquifer is also low, and if the government has assigned rights on an as-needed basis, then the water lost from a relatively inefficient pumping system in an aquifer that is relatively large will be negligible. Further, if an aquifer is large, demand is low, and the government only gives a few people the ability to pump water, the aquifer will not deplete.

The Gisser-Sanchez rule is a useful means for modeling groundwater intake, export, and recharge based on internal and external factors. But from this rule, an important question regarding government control arises. According to the Gisser-Sanchez rule, government control is necessary to effectively manage groundwater rights, as water rights are exclusively assigned, and water withdrawal is allocated by the state government. The question is simply this: what level of government control is necessary?

Government Control In Aquifer Management: Where Are The Lines Drawn?

Government control can range from full control to practically no control, as suggested in prevailing groundwater doctrines. As Emel and Roberts state, "New Mexico and Texas represent extremes in groundwater management doctrines" (Emel and Roberts 1995, 667). Texas favors free markets and private land ownership, and New Mexico treats groundwater as a public commons. In regard to water withdrawal, private ownership is what is referred to as the “Reasonable Use Doctrine,” which states that an individual has the right to use groundwater “based on appurtenance to land, limited to non-wasteful and beneficial purposes and without significant injury to other right holders" (Emel and Brook 1988, 244). This is also related to the “Absolute Ownership Doctrine,” which only varies from the language of the reasonable use doctrine slightly, stating that an individual is the sole owner of the water that lies beneath their land (Emel and Roberts 1992, 256).

On the other end of the spectrum lies New Mexico, which as stated before, treats groundwater as common property among the public, and applies a "Common Law Doctrine.” Under this doctrine, groundwater use is closely regulated. For example, a user in New Mexico has limited consumptive use water rights, and aquifer depletion levels in one area may not exceed certain limits (Gisser 1983, 1004). When it comes to state management of groundwater resources and pumpage, there is on one end of the spectrum a free market and reasonable use doctrine approach, while on the other end there exists a public use common law doctrine, in other words a regulated market for groundwater access.

Economic Issues Reviewed in Earlier Literature

Thus far this research has looked at political doctrines regarding water usage, as well as the terms recharge and management. This review has also discussed what the Gisser-Sanchez effect entails. As noted in earlier research regarding aquifer depletion, one of the major problems faced by the state of New Mexico was that previous appropriation laws needed to become more flexible, so that irrigation could expand and contribute to possible growth in the economy (Emel and Roberts, 1992, 252).

If pumpage rates are not maintained, an agricultural region cannot sustain steady economic growth, the region may very well suffer economically. Regarding depletion of the Ogallala aquifer, the situation is somewhat reversed. According to scholar Edward Renshaw, if all farmers with land overlaying the Ogallala aquifer had to cut their pumping by 50%, they would see a 25% decrease in income. Estimates suggest that if water supplies within the aquifer can be stretched from 30 years to 60 years, farmers would still receive a return of 4% in profits (Renshaw 1963, 286). A concurring study was conducted for Kern County, California. This study demonstrated that if the Gisser-Sanchez model were used, and if water was continuously withdrawn at a steady rate that did not threaten total depletion of the source, benefits from irrigation could reach $116 per irrigated acre. These numbers were calculated using a theoretical model developed by Renshaw. Renshaw holds that a long term low return is better than a short term high return, (i.e. 60 years of 4% profit). Though this region falls outside of the Ogallala Aquifer, it is still subject to limited groundwater resources and requires groundwater management measures, indicating that if this concept were practiced within the high plains region, economic benefits might also be observed.

The earlier literature also lent itself to an economic concept known as the "Pareto Optimum." Godwin and Shepard (1979), Gisser (1983), and Braden (1985) all mention this concept and its importance to groundwater management. The Pareto optimum, developed by Italian economist Vilfredo Pareto in the 1890's, is part of an efficiency scale. This scale measures how efficient the use of goods is among a group of people. The scale has three intervals: optimum, efficient, and inefficient. As one scholar notes, "a change that makes at least one individual better off and leaves no individual worse off represents an increase of welfare," or as we would refer to it, Pareto efficient (Ciriacy-Wantrup, 1971, page 38). Pareto inefficiency is when a change made by one individual negatively affects another individual. The Pareto optimum is a condition that exists when no other improvements can be made. This economic theory has clear applicability to groundwater and aquifer management. Suppose in the instance of two farmers, farmer A withdrawals water from an aquifer at a rate that does not threaten farmer B's supply. This would be considered Pareto efficient. In the case where all farmers are able to withdrawal for their benefit without causing water supplies to deplete for any other farmer, this would be an instance of Pareto optimum, simply because no other improvements could be made.

The Prisoner's Dilemma and the Tragedy of the Commons

The earlier literature discusses a phenomenon known as the "Prisoner’s Dilemma," which exists in regions that implement the absolute ownership doctrine. This dilemma is a situation in which the players (in this case those who withdrawal from the aquifer in an absolute ownership environment) have two choices: to cooperate or defect. If a person defects, they are essentially withdrawing a scarce resource with no limitation, and if a person cooperates, they come to an agreement on restriction among those who withdrawal from the same source (Braden 1985, 357). It may at first seem advantageous for an individual to defect in order to maximize their water withdrawal. But as the number of people who defect increase, the quicker the resource would be depleted, and everyone would lose economically. On the other hand, if people choose to cooperate, the agreed upon water withdrawal rate will be maintained, allowing greater stability and resource access for all. With either choice, however, they are still prisoners of the same resource, and economic return remains a function of supply and access. The prisoner's dilemma is just one choice in what is known as the “tragedy of the commons," where an individual attempting to maximize profits independently of others who are attempting the same ensures that no one will win. The dilemma derives from the actions of rational and irrational actors. In Garrett Hardin’s classic example of the tragedy of the commons from 1968, there is a pasture open to all. The rational herdsman will see that adding cattle to the pasture for grazing could hurt the pasture’s carrying capacity, but nonetheless, all herdsmen feel compelled to increase the number of cattle that graze, until the pasture is destroyed, and nobody is able to sustain growth (Godwin and Shepherd 1979, 265).

Simply stated, a tragedy of the commons occurs when the lack of a mutual agreement leads to resource depletion.

Gaps Identified in the Literature

Emel and Roberts (1995, 680) left us with an open-ended question regarding political support for innovations in groundwater rights. Political opinion is divided when it comes to groundwater rights and regulation, especially at the federal level. As noted in Francis (1990, 264), one of the reasons that there is such a gray area at the national level is because the research done regarding depletion of the Ogallala Aquifer is conducted in the west, in the proximity of the aquifer itself. What Francis means by this is that those who are conducting field research in the west do not always present their results directly to Congress. They go through other channels, and Congress may not always get the information it needs. This notion is reflected by Rangeley (1986, 358) when he notes that “In most situations, modernization will be both slow and costly to implement.” In Rangeley’s study, “modernization” refers to the rate at which information is passed from irrigation management institutions to various levels of government. Another problem identified by the literature is a gap in reliability that can be experienced in all fields of study relating to aquifer depletion: the lack of data. As noted by Nieswiadomy (1985, 619) "In many western states, examination ... has been hindered by a paucity of reliable irrigation data." Simply put, previous decades of research employed methods that did not supply continuous or comparable data. An important component of political science is statistical analysis. Without a comparable and continuous set of data, how could the federal government, let alone any individual researcher take decisive action?

Concluding the First Section of the Literature Review

The importance of first reviewing the earlier literature cited by Emel and Roberts has now been demonstrated. Emel and Roberts' research gave mention to the Gisser Sanchez effect, identified prevailing groundwater doctrines, and inspired the question that this research aims to answer. This review of literature has demonstrated how the commonly cited Gisser-Sanchez effect helped identify the governmental aspects of groundwater management, including the extremes between reasonable use and common law doctrines. The reviewed literature also demonstrated that economic tools of analysis, including the Pareto formulations are important for understanding aquifer depletion. The tragedy of the commons and the prisoner's dilemma demonstrated important theoretical frameworks for understanding groundwater access. Equally important is the information gap that is evident within earlier data sets, which emphasizes the significance of such research. The next step in this literature review will be to analyze the more contemporary research that surrounds the issue of groundwater management and aquifer depletion. The following will address how this more contemporary research supports, contradicts, or rejects the previous literature.

Chapter 2 - A Review of the More Contemporary Literature

The more contemporary literature, from approximately 16 years ago to the present, is analyzed in this section. In addition to the four primary objectives of this literature review, this section will also explain how more contemporary research has developed since Emel and Robert's work from the early 1990's.

A More Globalized View

Compared to the earlier literature, contemporary research offers a more globalized perspective regarding the issue of aquifer depletion and groundwater management. Scholar Peter Gleick implies that the issue of water sustainability is a human problem, stating that it is important "that we meet and identify basic allocations for humans and ecosystems, which are to be satisfied before other demands" (Gleick 1998, 578). Notice how the statement is not about Americans, Chinese, or Australians, for example, but rather humans and ecosystems. Scholars S.D. Foster and P.J. Chilton add to this language of a global commons by noting that groundwater is the world's most extracted raw material (Foster and Chilton 2003, 1957). Additionally, Foster and Chilton's research includes a simplified hydro-geological map of the world, which shows the existence of major aquifers on five of the seven continents. These include but are not limited to the Ogallala Aquifer in North America, The Guarani Sandstone Aquifer in South America, The Nubian Aquifer in North Africa, The Gangetic Plain Aquifer in India, The North China Plain Aquifer in North China, and the Great Artesian Basin of Australia. There are also aquifers present within Europe, though not shown on this map. Showing the issue of aquifer depletion on a world map certainly demonstrates that the issue is just as globalized as it is localized.

Contemporary literature also demonstrates that it is not just the arid and semi-arid regions of the United States that are at risk, but also the semi-arid regions of the world. Scholar Consuelo Ortega and several other researchers note that "In arid countries worldwide, social conflicts between irrigation based human development and the conservation of water ecosystems are widespread and attract many public debates" (Varela Ortega, et al. 2008, 604). In semi-arid nations such as Spain, policy innovations are being implemented to help maintain the irrigation network within rural communities. These policies include the Water Abstraction Approach (WAP), a quota system which forbids drilling new wells or deepening existing ones. The Water Framework Directive (WFD) aims to attain good ecological status for all bodies of water within the next decade (Gutierrez, et al. 2010, 642). The federal government of Spain currently carries out the implementation of these policies. Other methods of groundwater management, such as integrated water resource management (IWRM), have been effectively implemented in a large number of semi-arid countries, including Spain and Portugal. IWRM incorporates a series of principles that help balance social and economic development, and ecological preservation. In Portugal, for instance, IWRM has been successful at keeping groundwater usage rates steady in regions where rainfall varies from heavy downpour to drought levels (Stigter, et al 2009, 1186).

Potentially Challenging Emel and Roberts

In the concluding arguments of Emel and Roberts (1992), the authors stated that "We find that a serious tragedy of the commons ... can not be said to occur," instead attributing the issue of aquifer depletion to uneven development. The more contemporary literature challenges Emel and Roberts' research by asserting that aquifer depletion does indeed result from a tragedy of the commons.

One of the best examples of this lies in West Texas where "landowners are free to use as much nonrenewable groundwater as desired with little regulation" (Somma 1997, 3). Somma additionally states that any efforts by one farmer to conserve water are offset by another farmer’s overuse of the resource. Similarly, Cash, Clark, Alcock, Dickson, Eckley, Guston, Jager, and Mitchell, (2003, 8087) state that throughout the region overlaying the Ogallala Aquifer, "there have been signs of over-pumping and resultant economic and social costs, as well as multiple attempts to solve this commons problem.” In other words, over-pumping throughout the region is still occurring, aquifer depletion continues, and the problem of managing a commons remains. Many of those who view aquifer depletion and groundwater management as a global issue also view it as a tragedy of the commons. A good example of this comes from an article that discusses groundwater as an example of a common pool resource (CPR) that is global in scale and the consequences of which will increase, given the history of unsuccessful attempts at management (Ostrom, et al 1999, 278). While there is a significant amount of evidence suggesting that aquifer depletion is the result of a tragedy of the commons, there exists no research that directly challenges the conclusions offered by Emel and Roberts.

Increased Importance of Technology

One of the most interesting and critical components of the more recent literature is in regard to the emergence of technology as a tool in managing groundwater, in particular groundwater pollution. As one scholar notes, "New science emerged ... and made possible new instrumental methods of chemical analysis and suggested remedial approaches" in regard to pollutants in groundwater (Jackson 2004, 77). In other words, technology from the 1970's has continued to improve over the last 40 years to help identify dangerous chemicals that pollute groundwater and aquifers. Another study noted that aggregate models for environmental impact from policy changes on pollution come from "regional or national linear programming models" (Wu and Segerson, 1995, 1035). What we can gather is that as technology progresses, so will the usefulness of computer modeling in managing groundwater. As computational speed increases, more factors will be added to simulations, increasing the accuracy of predictions.

Rains, Mount, and Larsen (2004, 205) utilize a unique computer model to simulate groundwater recharge rates based on reservoir operations and surrounding vegetation in a region. The study concludes that large changes in reservoir operations (which include withholding, releasing, and treating water, etc) can have noticeable effects on groundwater recharge in shallow water regions. Similarly, another study has noted that "new computer visualization tools have advanced our understanding of the effects of variability in aquifer properties on groundwater flow patterns" (Alley, et al 2002, 1987). Groundwater flow patterns are particularly important in determining how and at what rate aquifers will recharge.

Economic Cost-Benefit Analysis

Economic analysis remains an important tool in managing groundwater and aquifer depletion. Weinberg and Kling (1996, 65) assert that "Nearly all agricultural production decisions are affected in some form by policies that distort input or output markets." The examples offered by Weinberg and Kling (1996) include the Clean Water Act and the Endangered Species Act, both of which affect farm practices and the price of crops. There are many examples for why the Clean Water Act distorts output by raising the cost of crops, one of which is that farmers use pesticides that can mix with runoff water used for irrigation. Joshi, Krishnan, and Lave (2001, 174) concludes that there are both visible and invisible costs when environmental regulations are followed, but invisible costs hurting those that depend upon the aquifer because they aren't calculated into net profits. These invisible costs (also known as hidden costs) include administrative costs that fall into other categories, so that they are not counted as environmental costs. They also include physical costs like pollution (Weinberg and Kling, 1996, page 67).

Doctrines Have Remained

The prevailing groundwater doctrines mentioned in the earlier literature have, for the most part, remained intact in the more contemporary literature. According to White and Kromm (1996, 438), four legal doctrines prevail within the fifty states. These include absolute ownership, reasonable use, correlative rights, and prior appropriation. Templer (2001, 599) adds to this notion, stating that today "New Mexico's centralized system was in no way superior [to] Texas' local district approach." By using the word "superior," Templer was simply grading the effectiveness of each approach. The centralized system can be attributed to a commons, while a local district approach is more characteristic of reasonable use philosophy. Templer shows that New Mexico still utilizes the common law doctrine. While the centralized common law approach of New Mexico continues, the decentralized reasonable use approach on the other side of the state border also continues.

An Increased Role for the Federal Government

Under the 10th Amendment of the United States Constitution, all powers not delegated to the federal government are left to the states. This would include the regulation of groundwater resources, as regulatory provisions at the federal level remain uncodified. So why do the EPA, USDA, and Bureau of Land Management participate in groundwater management? To ask a more generalized question, why has the federal government stepped into state government territory in regard to authority to regulate?

According to the contemporary literature, two answers to this question emerge. First, the federal government is better equipped to handle a situation that transcends state boundaries, such as groundwater management and aquifer depletion. Howe (1997, 600) states that "The greatest opportunity [for achieving sustainability] occurs at the national level." In other words, the federal government has the capacity to manage interregional issues by accessing markets, mobilizing labor, and introducing regulations. As Howe notes though, market and regulations stretch from local, to national, to global. Eventually, since the issue of aquifer depletion and groundwater management is one of global interest, nations will have to actively engage one-another on the issue. As Lopez-Gunn (2008, 40) states:

> "The nature of the problem, the sharing of trans-boundary groundwater resources – in fact exceeds the scope of national sovereignty. Increasingly, to solve trans-boundary issues, sovereign states will have to engage with other sovereign states."

This statement reinforces what was stated above, that nations will eventually have to engage one another on the issue if they haven't done so already, given the issue of trans-boundary groundwater.

Another reason for the increased role of federal government in managing groundwater and aquifer depletion lies in security. As Pringle (2000, 976) notes, a large number of threats confront water resources in national parks, wildlife preserves, and forests in the western United States. As Pringle suggests, these threats come from hydrological effects outside of the boundaries of protected regions. More specifically, humans have already cumulatively allocated over 50% of accessible freshwater globally. Withdrawals from the high plains aquifer affect other regions, and thus as the decades have passed, the federal government has increased its role in regulating the resources for the purpose of keeping the hydrological integrity of United States intact.

Concluding the Second Section of the Literature Review

Today the issues of groundwater management and aquifer depletion have become increasingly globalized as issues of human and ecological concern transcend the boundaries of states and countries. In addition, the debate regarding uneven development and the tragedy of the commons in aquifer depletion is certainly not over. It appears as though contemporary scholars argue in favor of the latter, in contrast to Emel and Roberts' (1992) identification of uneven development as the underlying factor. However, this research does not aim to resolve the disagreement over which theory holds more merit. The increased importance of technology is demonstrated in the more contemporary literature as evidenced by the increasing usefulness of computer simulations. As computer modeling and data computation continue to advance, the quality of data acquisition and analysis will also improve. The fact that aquifer depletion still has an underlying economic component is not surprising, as our nation is still invested in agricultural growth. Finally, the increased role of the federal government, stemming from the trans-boundary nature of groundwater and the increased need for resource security, helps lay the groundwork for the importance of this research.

Chapter 3 – A Review of Innovations in Groundwater Management

The first two sections reviewed both the earlier and the more contemporary literature in regard to debates, emerging trends, and weaknesses in studies. This final section delves further into the literature to better understand the innovations enumerated by Emel and Roberts (1995) that will be analyzed. The five innovations discussed by Emel and Roberts (1995) are water well spacing, conservation tillage, soil-water conservation, water demand management, and limited irrigation.

Water Well Spacing

One of the first innovations to be reviewed is the practice of water well spacing. The concept of water well spacing was originally the product of the riparian doctrine, which held that those who have appurtenance to water are the ones who have the right to withdrawal it. Appurtenance to water simply means that an individual has access to water via their land, and therefore has the right to withdrawal it. So what is water well spacing? Underground water wells that are drilled for withdrawal are spaced based on the plots of land in which they are drilled. In other words, for those who have exclusive rights to water, and follow the doctrine of reasonable use, water wells must be spaced in a manner that is effective for them, but does not hinder the ability of another individual who has appurtenance to groundwater to sufficiently withdrawal it. Today, water withdrawal rules designated by the state are well received by those who possess riparian rights (Choe 2004, 1947). From this research, it is reasonable to suggest that because water well spacing is not a technologically intensive process, nor a controversial innovation, that contemporary research regarding this particular innovation is fairly scarce and uncontroversial.

Conservation Tillage

Emel and Roberts (1995) cite conservation tillage as one of the more effective innovations in groundwater management. Conservation tillage, simply put, is a series of methods used to leave previously tilled ground uncovered, so that water runoff is reduced as well as soil erosion. As several scholars note, "Any tillage process that reduces soil or water loss ... is considered conservation tillage" (Gebhardt, et al 1985, 625). More specifically, in most cases of conservation tillage, the surface residue from the previous crop planting is left mostly intact. The surface materials prevent runoff and absorb rainfall better than on land that is conventionally tilled. Important examples of conservation tillage include stubble mulching and "no-till" practices. The purpose of conservation tillage can generally be defined within the following eight objectives, as outlined by Gebhardt, et al (1985, 626):

1) To prepare a location and desirable soil structure for seeds and seedlings

2) To control wind and water erosion

3) To control the flow of water, air, and heat into and through the soil

4) To control weeds, insects, and plant diseases

5) To manage crop residue disposition on or in the soil

6) To establish surface configurations, such as beds and furroughs for irrigation and drainage

7) To incorporate fertilizers, pesticides, and manures

8) To remove foreign materials, such as rocks or roots

As promising as conservation tillage sounds, it leaves farmers and environmental regulators with a problem, and that is "efficiency improvements do not always reduce overall water use" (Petersen and Ding 2005, page 147). Conservation tillage is an efficiency measure as well as a resource conservation measure. Theoretically, a farmer using conservation tillage produces the same amount of crops with less water usage. But in many cases, farmers view conservation tillage as a cost reducing measure, and simply use the additional water they save to produce more crops. So in the end, farmers will have used just as much water and produced even more crops, rather than using less water and maintaining previous crop production. This problem was originally cited as an issue for those participating in limited irrigation practices, but also applies to any measure that reduces water use. Despite this problem, conservation tillage is used in nearly 40% of farms that depend on the Ogallala Aquifer for water resources.

Soil-Water Conservation

Soil-water conservation is an innovation that at first appears somewhat similar to conservation tillage, but with some explicit differences. Whereas conservation tillage aims at maintaining soil quality and efficiency in water use, soil-water conservation seems to lend itself to using more significant physical barriers to prevent soil erosion, which in turn also traps water. Kent (2002, 50) notes that in particular scenarios "contour barriers are employed to reduce soil movement on tilled land and thus enable ... production on highly erodible soils." Chapin, Fetcher, Kelland, Everett, and Linkins (1988, 693) note that certain farms in Alaska use track and non-track areas to maintain soil integrity. Digging tracks within farms to produce a physical barrier to prevent erosion is not the erosion reducing approach that conservation tillage calls for.

The other difference between soil-water conservation and conservation tillage is that the track and non-track farming areas have a primary focus on drainage. Conservation tillage makes drainage more of a secondary process. The track areas "collect water from their surroundings and serve as subsurface drainage channels down slope" (Chapin, et al 1988, Page 694). While conservation tillage aims to retain water, soil-water conservation helps drain water for the purpose of preventing crops from becoming waterlogged in areas with heavy rainfall.

The final difference between soil-water conservation and conservation tillage is that soil-water conservation has the backing of a program known as the Conservation Reserve Program, (CRP), which was instituted in 1985 within a provision of the 1985 Food Security Act (Young, Walker, Kanjo, 1985, page 1053). The CRP is a series of criteria that the USDA uses to gauge a farmer's compliance when it comes to soil conservation, a provision not included within the innovation of conservation tillage.

Limited Irrigation

Limited irrigation comes from the increasing importance of technology in regard to improving water pumping and disbursement techniques. In its simplest form, limiting irrigation could simply involve a farm investing in a newer pumping and distribution system to save water. But there are actually three types of limited irrigation systems. They are flooding, center pivot sprinkler, and subsurface drip (Petersen and Ding 2005, 148). The adoption of the sprinkler and drip methods is normally done so by farmers who possess lower quality lands. The center pivot sprinkler is a low energy sprinkler that disburses a very specific amount of water in one particular area. This type of sprinkler is normally placed throughout a field in a grid-like fashion. Subsurface drip involves implementing a water recycling system underneath the field that recycles and redistributes the water as it passes through. The phrase “flooding” in this situation is simply the process of retaining water on land until the land is once again arable, and then releasing the water to drain back into an aquifer (Caswell, Lichtenberg and Zilberman 1990, 889).

One of the most important components of limited irrigation involves irrigation scheduling. There are many different methods and models for scheduling irrigation, but an interesting example presented by the literature is structured around root growth. McGuckin, Mapel, Lansford, and Sammis (1987, 124) outlined details for a sixty-day irrigation schedule based on root growth. Deeper roots allow for better water storage, so irrigating when a crop is able to better store water makes more sense than simply irrigating at all times with varying effectiveness.

Water Demand Management

Water demand management is a series of economic measures taken to control the factors that influence water usage. One example recommended by economists is to raise water taxes on residential and rural communities. But as Renwick and Archibald (1998, 343) note, the "residential water demand price is inelastic, making a relatively ineffective demand side management policy." To clarify, this policy is utilized on farms, as farms are both residential and rural in nature. Other measures include adopting water efficient technology, such as low-flow toilets and low-flow showerheads. These are measures that are implemented in urban, suburban, and rural regions of the United States.

One important aspect of water demand management is that it applies to fresh drinking water in urban and suburban areas, and not just the supply of water for purposes of irrigation. Emel and Roberts (1995) have noted this as an innovation worth investigating for groundwater management in the high plains, despite Renwick and Archibald's comment about the inelasticity of water demand. This is a reasonable suggestion, given that the existing groundwater doctrines are examples of how both demand and usage are (or are not) regulated.

Making the Case for this Research

This review of the literature on groundwater management and aquifer depletion has identified key points, relevant debates, and existing gaps within the literature. While many of the points discussed in this literature review suggest an initial understanding of groundwater management and aquifer depletion, one additional component is particularly important to note. The innovations described in this review are regulated by the federal government. Howe (1997, 600) notes that the national government is best equipped to handle aquifer depletion, particularly in the Ogallala region, because the issue transcends state boundaries. Lopez-Gunn (2008, 40) adds that the issues of groundwater management and aquifer depletion transcend state boundaries, indicating a need for national regulatory coordination.

It is also important to acknowledge that within the innovations themselves, federal regulation is required. Regarding soil-water conservation, it is the USDA that puts forth criteria for a farmer's compliance when utilizing the innovation as noted in Young, Walker, and Kanjo (1985, 1053). Further, farmers who utilize innovations in groundwater management and aquifer depletion are subject to receive federal tax breaks, as the reader will see in the data gathered on legislation in the following section.

Chapter 4 - Data and Methodology

Within the earlier literature, it is evident that there is a lack of political data regarding groundwater management and aquifer depletion. In addition, the trans-boundary nature of groundwater demonstrates the need for the federal government to coordinate regulatory efforts. This research analyzes support for innovations at a congressional level because the United States Congress is where tax incentives for innovation users is passed, and it is where the USDA receives its funding, among several other reasons. With this in mind, the most important part in analyzing congressional support for innovations in aquifer management will involve a reasonable, replicable, and strictly outlined methodology. This methodology presents a listing of legislation that pertains to each innovation discussed in the previous section, and gauges the congressional support given to each. The methodology addresses the following two goals:

1) Establishes criteria for obtaining and cataloging legislation regarding aquifer innovations
2) Establishes criteria for gauging the level of support for innovations on a "per bill" level

Step 1: Establishing Criterion for Obtaining and Cataloging Legislation

The most accurate and comprehensive source for locating legislation is the Library of Congress. Brown (1998, 229) notes that "The Library of Congress is undoubtedly the world's greatest repository of human memory," which includes legislative history within the United States. The Library of Congress currently runs a website known as Thomas LOC, named after Thomas Jefferson, which catalogs United States federal legislation based on congressional session, year, and topic. This website is located at http://thomas.loc.gov/home/thomas.php.

The steps laid out for a replicable and reliable search within this website are as follows:

1) Click on "Try The Advanced Search"
2) Select "Search Multiple Congresses"
3) Click on the "Check All" box
4) Enter innovation – type as derived from Emel Roberts (1995)
5) Beneath the search bar, select the "Exact Match Only" button
3) Under the "Which Bills?" section, select the "All" button
7) Under the "From Where?" section, select the "Both House and Senate" button
8) Search result must contain phrase exactly as entered
9) For this type of search, Thomas LOC offers the most accurate results, but will only allow a search back to 1988. These results are the most accurate, because a manual search within the Library of Congress could overlook important legislation. It is important to choose quality over quantity in this scenario, because we need to be sure that the legislation being analyzed does in fact contain key words regarding the specified innovation.

Step 2: Establishing Criterion for Gauging Level of Support

In order to properly gauge support, this study will be using ordinal level data in a similar manner to the data used in Barrett and Eshbaugh-Soha (2007, 104), which analyzes legislative support of a president's policy within five levels. For this study, support for a piece of legislation will be considered based on the following five levels of support.

- **1** Proposed bill was referred to committee and died
- **2** Proposed bill was referred to committee and debated
- **3** Proposed bill was referred to committee and passed. Brought to a vote on floor. Vote did not pass on floor. [1]
- **4** Proposed bill was referred to committee and passed. Brought to a vote on floor and passed on floor. Bill did not become law.[2]
- **5** Proposed bill was referred to committee and passed. Brought to a vote on floor and passed on floor. Bill became law.

All repeated bills will be removed. Repeated bills are simply proposed bills that are just amended and sent back and forth between the chambers. This is so the final calculated score is not skewed. In addition, the most reasonable naming convention will be used when searching for a bill. Generalized terms will be avoided, so as to avoid unrelated legislation. Only legislation with the innovation exactly as presented by phrase will be used. The innovations presented are done so verbatim and are directly mentioned in Emel and Roberts (1995):

---

[1] It is important to note that House and Senate bills should be analyzed separately, even if they are regarding the exact same topic. The reason for this is that Senate bills and House bills stand the possibility of having different legislative success.

[2] It is important to note the difference between 4 and 5, because there is an assumption that the bill became law because Congress did a veto override, and that the bill might not have become a law because congress didn't do a veto override. The possibility exists that the vote was supported by voice vote, but was rejected in favor of placing the bill in another amendment. In either case, the bill would not have the same level of support for a bill that was passed without complication.

- Conservation Tillage
- Water Well Spacing
- Limited Irrigation
- Water Demand Management
- Soil-Water Conservation

In addition, a bill will be deemed "in support of legislation" if it contains any supportive clause or phrase promoting the innovation. For example, if the bill contains a clause which appropriates funds to furthering research for an innovation, it would be considered supportive. If a bill includes a tax credit for those who utilize the innovation, it will be considered supportive. If the bill penalizes those who do not properly use the innovation, it will be considered a supportive bill.

Following the steps and criteria outlined above will result in a compiled list of bills regarding the five discussed innovations, along with a congressional support score. With this dataset in hand, we can begin to see what is presented in regard to support or opposition by Congress for innovations in groundwater management. The master data is organized in figure 1.1, at the end of this research.

Chapter 5 - Results and Analysis

Pie Chart Observations

Figure 2.1 - Number of Bills Introduced

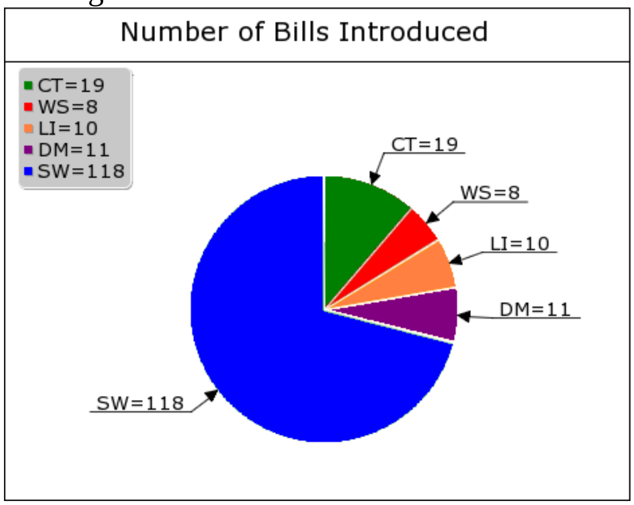


Figure 3.1 shows us that in the last 23 years, a total of one hundred sixty-six bills pertaining to the innovations were introduced in both chambers of the United States Congress. Of these one-hundred sixty-six, nineteen were in regard to conservation tillage (CT, 11.4%), ten were in regard to limited irrigation (LI, 6.1%), eight concerned water well spacing (WS, 4.8%), eleven dealt with water demand management (DM, 6.6%), and one hundred eighteen were specific to soil-water conservation (SW, 71.1%). From this data table, it is clear that soil-water conservation was the innovation that received the most search results when following the criterion established above. The following five graphs will break down support based on individual innovations. It is important to note that all bills found were in support of the innovation being researched. This topic will be addressed in the discussion section, but the answer could partially be attributed to the strict search parameters mentioned above.

Figure 2.2 - Conservation Tillage - Legislative Support

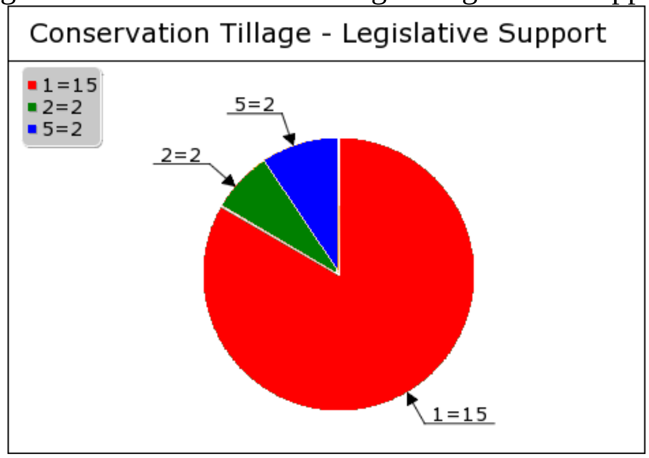
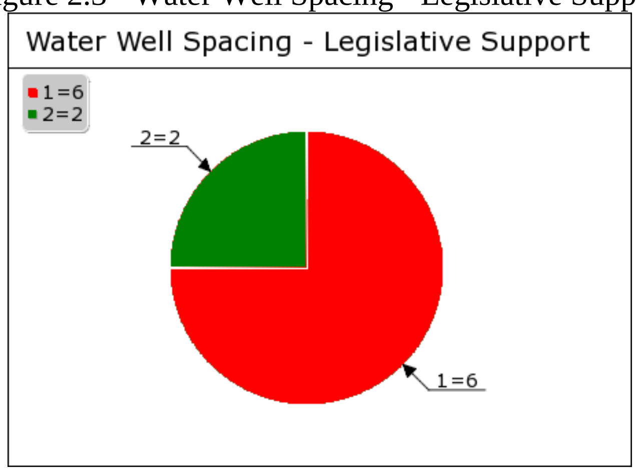


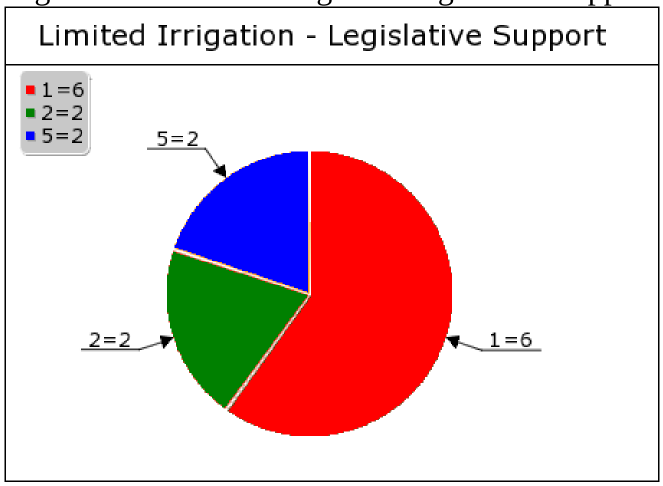
Figure 2.2 shows the legislative support score for conservation tillage. Fifteen out of nineteen bills introduced in the last 23 years received a score of 1, meaning they died in committee, roughly 79%. Two bills were debated in committee, receiving a score of 2, and 2 bills passed and became law, receiving a score of 5, roughly 10.5%. Based on table 1.1, the average score for legislative support of conservation tillage is 1.47.

Figure 2.3 - Water Well Spacing - Legislative Support



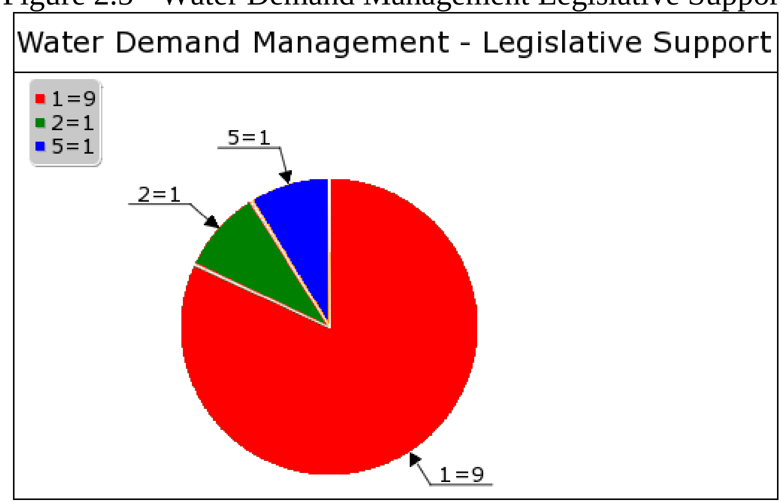
Water well spacing received the lowest number of results when the search criterion within the Library of Congress was followed. Of the 8 bills that turned up, six died in committee (75%), and two were debated in committee (25%). The average legislative support score for water well spacing was 1.25.

Figure 2.4 - Limited Irrigation Legislative Support



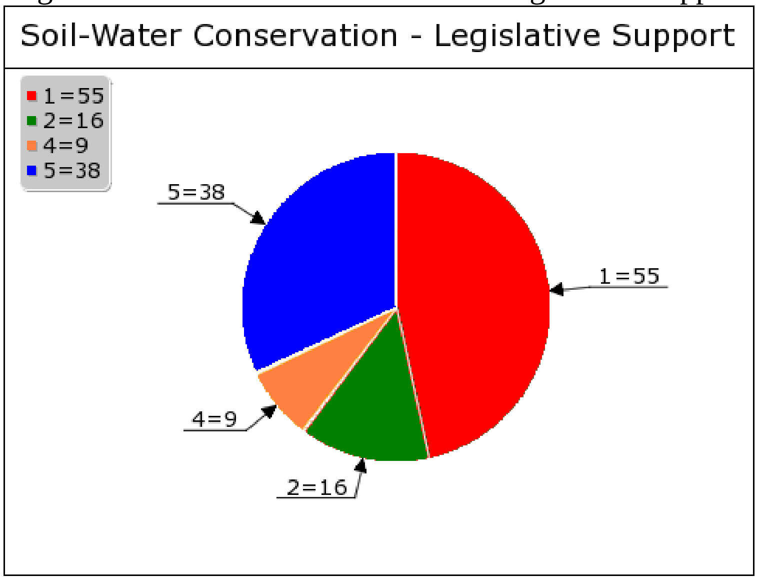
Ten bills in support of limited irrigation were found. Of the ten bills, six died in committee (60%), two were debated in committee (20%), and two passed and became law (20%). Limited irrigation received an average legislative support score of 2.00.

Figure 2.5 - Water Demand Management Legislative Support



Eleven bills supporting water demand management were found. Of the eleven bills, nine died in committee (roughly 82%), one bill was debated in committee (roughly 9%), and one bill became law (roughly 9%). Water demand management received an average legislative support score of 1.45.

Figure 2.6 - Soil-Water Conservation Legislative Support

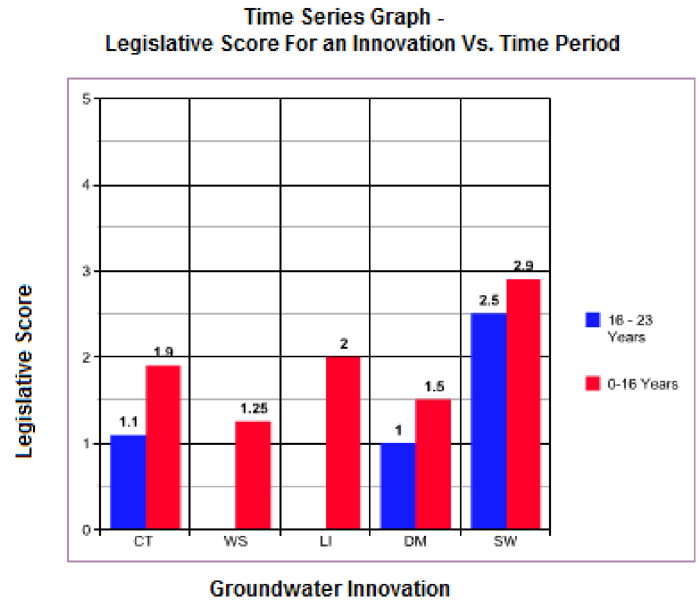


One hundred and eighteen bills were found on the Library of Congress website. Of the one hundred and eighteen bills, fifty-five died in committee (roughly 46%), fourteen were debated in committee (approximately 14%), nine passed the House and Senate but did not become law (approximately 8%), and thirty-eight became law (approximately 32%). Soil-water conservation received the highest average legislative support score, 2.65.

Time-Series Analysis

Because the first two sections of the literature review were broken down by time period (early literature 16 years and older, and contemporary literature 16 years or newer), it was necessary to compare legislative support averages between these two time periods. When the data is plotted in such a fashion, it is referred to as a time series analysis. Time series analysis is useful when comparing differences between two time periods.

Figure 3.1 - Time Series Analysis



From the table above, it is evident that in more recent years (16 years or newer) the available data demonstrates that innovations in groundwater management receive on average more support than innovations did over 16 years ago. On an individual basis, the average legislative support score for conservation tillage increased 72.7%, while the average score for water demand management rose 50% and the score for conservation tillage rose 16%. We cannot determine a percentage for water well spacing or limited irrigation, as no support existed prior to 1996. This means that prior to the 16 year period, water-well spacing and limited irrigation had no federal legislation introduced.

Average Comparison Ratio Analysis

Figure 4.1 - Average Comparison Ratios

A\B	CT	WS	LI	DM	SW
CT (1.47)	1.00	1.18	0.74	1.01	0.55
WS (1.25)	0.85	1.00	0.63	0.86	0.47
LI (2.00)	1.36	1.60	1.00	1.38	0.75
DM (1.45)	0.99	1.16	0.73	1.00	0.55
SW (2.65)	1.80	2.12	1.33	1.83	1.00

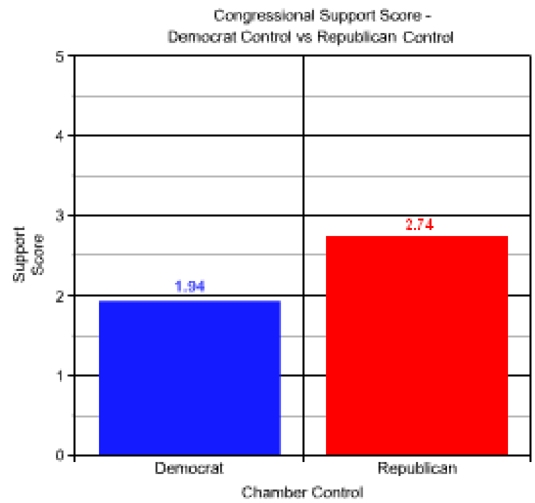
Figure 4.1 compares the average legislative support scores of each innovation. The results are displayed to facilitate simple comparison, note the initial pie chart that showed the number of results each innovation received based on the outlined search criteria.

This table is a simple division table, where A (columns) and B (rows) are compared. The equation followed is simply A divided by B. If we wanted to compare the average legislative support of water well spacing to the average legislative support of conservation tillage, we would divide A over B, which in this case is 1.25 divided by 1.47. The result is that the average legislative support for water well spacing is 85%, or .85 of what it was for conservation tillage (highlighted in yellow). The reciprocal for this would allow a comparison of the average legislative support for conservation tillage as compared to the average support for water well spacing, which is 118% or 1.18 (highlighted in red). This means that conservation tillage receives 1.18 times the support that water well spacing receives on average. There are 5 diagonal columns where the ratio is simply 1.00. The cell highlighted in blue is the ratio of support for limited irrigation divided by itself (highlighted in green).

What we can gather from this chart is the degree to which each innovation is supported when compared to other innovations. The innovation that fares the best is soil-water conservation, which scored 1.8 against conservation tillage, 2.12 against water well spacing, 1.33 against limited irrigation, and 1.83 against water demand management. The innovation that fares the worst is water well spacing, which scores a .85 against conservation tillage, a .63 against limited irrigation, a .86 against water demand management, and a .47 against soil-water conservation.

House and Senate Control in Regards to Innovation

Figure 5.1 - Congressional Support and Control



The above bar chart indicates the average legislative support score for each party during the time that they controlled a particular chamber of Congress. For instance, the Democratic Party held control of the Senate in 2005 when the Paul Simon Water for the Poor Act passed and became law. The Democratic score would have a five included in the average. As we can see, the average legislative support score for bills introduced when Democrats controlled a chamber is only 1.94, whereas the average legislative support score for bills introduced when Republicans controlled a chamber was 2.74.

Chapter 6 - Discussion

Summarizing the Results

The results are fairly straightforward. Soil-water conservation has the most introduced legislation, the highest average support score, and the highest percentage (and number) of bills that became law. Water well spacing had the least number of introduced bills, the lowest average support score, and had a high percentage of bills that died in committee - though not the highest, water demand management had 82% compared to water well spacing's 60%. Overall, support for innovations strictly on the basis of average support scores has increased between the two outlined time periods as well. From these results, it is evident that the most supported innovation within Congress is soil-water conservation, while the least supported innovation is water well spacing.

How Do The Results Answer the Initial Research Question?

The original research question asks how the voting records of the United States Congress as a whole support, ignore, or contradict the innovations regarding groundwater management and aquifer depletion as identified by Emel and Roberts 1995. The answer is somewhat ambiguous.

As stated before, all legislation identified by the search criteria was found to be in support of the innovation in question. In addition, the results indicate that soil-water conservation is the most discussed and supported innovation, with the most number of bills located, the highest average congressional support score, and the highest percentage of bills that passed and became law. Though the research also showed us that the other four innovations had a substantially large number of bills die in committee (60% from water well spacing, 82% from water demand management, 79% from conservation tillage, and 60% from limited irrigation), they were sponsored bills that were referred to committee, nonetheless. These factors indicate that Congress has taken interest in supporting innovations in groundwater management and aquifer depletion.

On the other hand, nearly 5,000 bills are introduced within both chambers of the United States Congress each year. To say that the five significant innovations outlined by Emel and Roberts (1995) scored well is not enough, given that the criteria only returned

166 results. Perhaps future studies will find a way to make the criteria more flexible, allowing for a larger sample size.

Why is Soil-Water Conservation so "Popular"?

Soil-Water Conservation was a highly supported measure, according to this study. The question is obviously why? One of the answers lies within the concept known as the Conservation Reserve Program (CRP). As noted in the innovations section of the literature review, CRP establishes criteria that the USDA uses to gauge a farmer's compliance. If a farmer does not comply with CRP, then the USDA is essentially forbidden to give benefits to that farmer.

CRP is supported by both Democrats and Republicans. Democrats see CRP compliance as an incentive for farmers to conserve natural resources and maintain soil integrity, while Republicans could potentially see CRP as a cost cutting measure, by reducing benefits to those who do not comply. As Boggess and Heady (1981, 628) state, "a conservation oriented land retirement policy can be designed to achieve an increase in net farm income … while simultaneously achieving a significant reduction in gross soil erosion." Young, Walker, and Kanjo (1991, 1060) agree by stating that CRP makes the innovation of soil-water conservation more cost-effective. Simply put, the innovation of soil-water conservation is a means of preserving resources while growing income and cutting costs.

Why do the Republicans have a Higher Average Congressional Support Score?

While it may seem convenient to label Democrats as environmentalists given party history, table 5.1 shows us that under Republican leadership, innovations earned a higher average legislative support score. It is very possible that the reason for this is that

Democrats have always pushed through environmental issues regardless of which party controlled which chamber, but more recent literature suggests there are other factors at play besides ideological priorities.

Scholars Gimple, Lee, and Kaminski (2006, 628) state that between 1992 and 2004, Republicans held a broader geographic base than Democrats in regions including the upper mid-west, the plains states, and the mountain west. Republicans have strongholds in the mountain states, as well as throughout the Bible Belt and Texas, thus it is likely that Republicans' desire to appeal to their constituents, many of whom are farmers. Further support for this interpretation is that after the Republican Revolution in 1994, the Republicans passed the Federal Agricultural Improvement and Reform (FAIR) Act. This act gave increased flexibility to farmers in terms of determining their own acreage for each crop (which was previously dictated by USDA rules), and issued a cap on loan rates for wheat and feed grains (Dixon and Hapke, 2003, page 158). This bill was a product of the Republican majority.

Addressing Universal Support of Innovations

It is important to note that the methodology explained above produced a data set in which all bills identified were in support of the innovation they included. The question to ask here is why this is the case. First, the strict methodology limited the sample size, so it is reasonable to suggest that with a limited sampling, the results were mostly supportive. Second, looking at the dataset, a large number of bills died in committee. This notion itself is a testament to the idea that congress is careful when it comes to passing legislation in regards to these innovations. This implies a level of care and support for the innovations mentioned above. Finally, as it has been demonstrated within Soil Water

Conservation, these innovations may not be so controversial, so it wouldn’t be sensible to pass a bill which hindered an innovation.

Potential Weaknesses of the Study

One of the weaknesses encountered in this research was the inability to individually weight each bill in terms of its strength. Though the methods established criteria for gauging the support for each bill in regards to each innovation, I was unable to determine a viable way to weight each bill according to its importance. For example, the Herbicide Reduction Act of 1991 may not hold the same level of significance as the Rural Development, Agriculture, and Related Agencies Appropriations Act of 1990. The appropriations act, by changing funding for agencies, changes the entire executive landscape regarding all agencies related to groundwater research. The Herbicide Reduction Act, however, only directly affects one aspect of farming. How to effectively weight these bills by some measure of importance would require another methodological approach, as well as reconstruction of data acquisition.

The other weakness of the study lies within the data regarding support for innovations. The data in this research suggests that there is only legislation that supports each innovation, and not legislation that opposes each innovation. The answer could simply be that the opposition lies in the fact that many of these bills simply die in committee, and that it would be politically unpopular to introduce a bill against support for an innovation. The answer could also be part of a balancing game; while there are numerous bills aimed at spending more to improve innovations, there are also bills aimed at offering tax credits for utilizing the discussed innovations. Further research is needed to better understand why the strict criteria set forth only located innovations that supported each measure.

The Implications of this Research within the Social Sciences

As demonstrated in this research, there is indeed an interest in groundwater innovations on a national level. Political scientists can further study the level of support that these innovations receive by simultaneously using and improving the criteria listed above. Weighted scores must be given to bills based on their "importance," for example, and if possible, the criteria must be adjusted to allow for a larger return in sample size. This research contributes to a better understanding for why legislators support certain innovations, while they have virtually no interest in others. It would be revealing to track where these legislators "call home."

For geographers the implications are clear. I suspect that there are more innovations than just those included in Emel and Roberts (1995), which means there are more innovations to study. Geographers will recognize that groundwater management and aquifer depletion are now global concerns, now extending beyond national boundaries.

Chapter 7 - Conclusion

Analyzing groundwater issues on a state-by-state basis will produce limited results. An analysis of support for innovations listed in Emel and Roberts' research shows that the federal government has an interest in a number of these innovations. A key question is where do researchers go from here? The discussion outlines some possibilities. Perhaps more innovations and global innovations (such as policy networks) can be analyzed. This research offers some interesting results and indicates productive directions to proceed. This research suggests a workable and repeatable template for further possible research. As noted before, the criteria can be further modified, expanded, and revised to assist political scientists and geographers in better understanding which innovations gain the most support, and whether or not increasing support is positive.

Appendix A
Table 1.1 – Main Data Set

1	Innovation	Bill Number	Bill Name	Introduced	Session	Passed?	Bill Status	Score	Chamber Control
2	Conservation Tillage	S.203	Ground Water Research and Education Act of 1990	1989	101	No	Debated in Cmtte	2	Democrat
3	Conservation Tillage	H. R. 5621	Farm and Forestry Energy Conservation Act of 1990	1990	101	No	Died in committee	1	Democrat
4	Conservation Tillage	H.R.4509	Sustainable Agriculture and Clean Water Act of 1990	1990	101	No	Died in committee	1	Democrat
5	Conservation Tillage	S.2392	Farm Stewardship Act of 1990	1990	101	No	Died in committee	1	Democrat
6	Conservation Tillage	S.2156	Forestry Conservation and Promotion Act of 1990	1990	101	No	Died in committee	1	Democrat
7	Conservation Tillage	S.970	Farm Conservation and Water Protection Act of 1989	1990	101	No	Died in committee	1	Democrat
8	Conservation Tillage	H.R.1418	Farm and Forestry Energy Conservation Act of 1991	1991	102	No	Died in committee	1	Democrat
9	Conservation Tillage	S. 1916	Herbicide Reduction Act of 1991	1991	102	No	Died in committee	1	Democrat
10	Conservation Tillage	H. R. 3714	Herbicide Reduction Act of 1991	1991	102	No	Died in committee	1	Democrat
11	Conservation Tillage	H.R.941	Soil and Water Protection Act of 1992	1992	103	No	Died in committee	1	Democrat
12	Conservation Tillage	S.1422	Farm Risk Management Act for the 21st Century	1997	110	No	Died in committee	1	Republican
13	Conservation Tillage	S.1833	Energy Security Tax Act of 1999	1999	106	No	Died in committee	1	Republican
14	Conservation Tillage	S.2251	Risk Management for the 21st Century Act	1999	106	Yes	Voted on Senate Flo	5	Republican
15	Conservation Tillage	H.R.2559	Risk Management for the 21st Century Act	1999	106	Yes	Voted on House Flo	5	Republican
16	Conservation Tillage	H.R.2375	Working Lands Stewardship Act of 2001	2001	107	No	Died in committee	1	Republican
17	Conservation Tillage	S.1571	Farm and Ranch Equity Act of 2001	2001	107	No	Died in committee	1	Republican
18	Conservation Tillage	S.2228	Farm, Ranch, Equity, Stewardship, and Health Act of 2007	2007	110	No	Died in committee	1	Democrat
19	Conservation Tillage	S.317	Electric Utility Cap and Trade Act of 2007	2007	110	No	Died in committee	1	Democrat
20	Conservation Tillage	H. R. 5858	Combating Climate Change Through Individual Action Act of	2008	110	No	Died in committee	1	Democrat
21								**1.47**	
22									
23	Water Well Spacing	S.1920	To improve the administration of oil and gas leases on Federa	1998	105	No	Died in committee	1	Republican
24	Water Well Spacing	S.1049	Federal Oil and Gas Lease Management Improvement Act of	1999	106	No	Died in committee	1	Republican
25	Water Well Spacing	H.R. 1985	Federal Oil and Gas Lease Management Improvement Act of	1999	106	No	Died in committee	1	Republican
26	Water Well Spacing	H.R.5316	Energy Independence for America Act of 2000	1999	106	No	Died in committee	1	Republican
27	Water Well Spacing	S.2557	National Energy Security Act of 2000	1999	106	No	Debated in Cmtte	2	Republican
28	Water Well Spacing	H.R.4805	National Energy Security Act of 2000	1999	106	No	Died in committee	1	Republican
29	Water Well Spacing	S.388	National Energy Security Act of 2001	2001	107	No	Debated in Cmtte	2	Republican
30	Water Well Spacing	S.389	National Energy Security Act of 2001	2001	107	No	Died in committee	1	Republican
31								**1.25**	
32									
33	Limited Irrigation	S.1230	Small Reclamation Water Resources Project Act of 1997	1997	105	No	Died in committee	1	Republican
34	Limited Irrigation	H.R.2398	Small Reclamation Water Resources Project Act of 1997	1997	105	No	Died in committee	1	Republican
35	Limited Irrigation	S.2881	The Small Reclamation Water Resources Project Act of 2000	1999	106	No	Died in committee	1	Republican
36	Limited Irrigation	H.R.5120	Small Reclamation Water Resources Project Act of 2000	2000	106	No	Died in committee	1	Republican
37	Limited Irrigation	H. R. 2828	Klamath Basin Emergency Operation and Maintenance Refun	2001	107	Yes	Voted on House Flo	5	Republican
38	Limited Irrigation	S. 1824	Klamath Basin Emergency Operation and Maintenance Refun	2001	107	Yes	Voted on House Flo	5	Republican
39	Limited Irrigation	S.1882	Small Reclamation Water Resources Act of 2001	2002	107	No	Debated in Cmtte	2	Democrat
40	Limited Irrigation	H.R.1985	Western Water Enhancement Security Act	2002	107	No	Debated in Cmtte	2	Republican
41	Limited Irrigation	H.R.5569	Comprehensive Natural Resources Protection Act of 2002	2002	107	No	Died in committee	1	Republican
42	Limited Irrigation	S.993	Small Reclamation Water Resources Project Act of 2003	2003	108	No	Died in committee	1	Republican
43								**2.00**	
44									
45	Water Demand Management	S.2093	Water Pollution Prevention and Control Act of 1994	1994	103	No	Died in committee	1	Democrat
46	Water Demand Management	H.R.1973	Senator Paul Simon Water for the Poor Act of 2005	2005	109	Yes	Voted on House Flo	5	Republican
47	Water Demand Management	H. R. 6297	Climate Change Drinking Water Adaptation Research Act	2008	110	No	Died in committee	1	Democrat
48	Water Demand Management	S. 2970	Climate Change Drinking Water Adaptation Research Act	2008	110	No	Died in committee	1	Democrat
49	Water Demand Management	H. R. 2969	Water System Adaptation Partnerships Act of 2009	2009	111	No	Died in committee	1	Democrat
50	Water Demand Management	S. 1035	Drinking Water Adaptation, Technology, Education, and Rese	2009	111	No	Died in committee	1	Democrat
51	Water Demand Management	H. R. 3727	Drinking Water Adaptation, Technology, Education, and Rese	2009	111	No	Died in committee	1	Democrat
52	Water Demand Management	S. 1712	Water Efficiency, Conservation, and Adaptation Act of 2009	2009	111	No	Died in committee	1	Democrat
53	Water Demand Management	H. R. 3747	Water Efficiency, Conservation, and Adaptation Act of 2009	2009	111	No	Died in committee	1	Democrat
54	Water Demand Management	H.R.2998	Clean Energy Jobs and American Power Act	2009	111	No	Debated in cmmit	2	Democrat
55	Water Demand Management	H. R. 2738	Water Infrastructure Resiliency and Sustainability Act of 2011	2011	112	No	Died in committee	1	Republican
56								**1.45**	
57									
58	Soil Water Conservation	H.R.4509	Sustainable Agriculture and Clean Water Act of 1990	1989	101	No	Died in Committee	1	Democrat
59	Soil Water Conservation	H.R.802	Agricultural Program Reporting and Recordkeeping Improvem	1989	101	No	Died in Committee	1	Democrat
60	Soil Water Conservation	S.970	Farm Conservation and Water Protection Act of 1989	1989	101	No	Died in Committee	1	Democrat
61	Soil Water Conservation	H.R.3574	Agriculture and Ground Water Policy Coordination Act	1989	101	No	Died in Committee	1	Democrat
62	Soil Water Conservation	H.R.987	Tongass Timber Reform Act	1989	101	Yes	Voted on House Flo	5	Democrat
63	Soil Water Conservation	S.1063	Conservation Enhancement and Improvement Act of 1989	1989	101	No	Died in Committee	1	Democrat
64	Soil Water Conservation	H.R.2883	Rural Development, Agriculture, and Related Agencies Appro	1989	101	Yes	Voted on House Flo	5	Democrat
65	Soil Water Conservation	S. 2508	To strengthen public involvement in soil and water conservati	1990	101	No	Died in Committee	1	Democrat
66	Soil Water Conservation	H.R.3552	Sustainable Agricultural Adjustment Act of 1989	1990	101	No	Died in Committee	1	Democrat
67	Soil Water Conservation	H.R.4584	Conservation Forestry Act of 1990	1990	101	No	Died in Committee	1	Democrat
68	Soil Water Conservation	H.R.4218	Environmental Reserve Program Act of 1990	1990	101	No	Died in Committee	1	Democrat
69	Soil Water Conservation	S.2409	Conservation Promotion Act of 1990	1990	101	No	Died in Committee	1	Democrat
70	Soil Water Conservation	H.R.4663	Conservation Promotion Act of 1990	1990	101	No	Died in Committee	1	Democrat
71	Soil Water Conservation	S.2156	Forestry Conservation and Promotion Act of 1990	1990	101	No	Died in Committee	1	Democrat
72	Soil Water Conservation	S.2024	Agriculture and Ground Water Policy Research and Education	1990	101	No	Died in Committee	1	Democrat
73	Soil Water Conservation	S.2394	Farm Income and Flexibility Act of 1990	1990	101	No	Died in Committee	1	Democrat
74	Soil Water Conservation	H.R.4640	Comprehensive American Wetlands Act of 1990	1990	101	No	Died in Committee	1	Democrat
75	Soil Water Conservation	S.2259	Agricultural Research and Extension Planning, Priority Setting	1990	101	No	Died in Committee	1	Democrat
76	Soil Water Conservation	H.R.4713	Agricultural Resources Conservation Act of 1990	1990	101	No	Debated in cmte	2	Democrat
77	Soil Water Conservation	H.R.5968	Wetlands Conservation and Management Act of 1990	1990	101	No	Died in Committee	1	Democrat
78	Soil Water Conservation	S.2392	Farm Stewardship Act of 1990	1990	101	No	Died in Committee	1	Democrat
79	Soil Water Conservation	H.R.3950	Food and Agricultural Resources Act of 1990	1990	101	Yes	Voted on House Flo	5	Democrat
80	Soil Water Conservation	S.2386	National Agricultural Research, Extension, and Teaching Polic	1990	101	No	Died in Committee	5	Democrat
81	Soil Water Conservation	S.2251	Farm Flexibility Act of 1990	1990	101	No	Died in Committee	1	Democrat
82	Soil Water Conservation	S.203	Ground Water Research and Education Act of 1990	1990	101	No	Debated in cmte	2	Democrat
83	Soil Water Conservation	H.R.5268	Rural Development, Agriculture, and Related Agencies Appro	1990	101	Yes	Voted on House Flo	5	Democrat
84	Soil Water Conservation	S.2830	Food, Agriculture, Conservation, and Trade Act of 1990	1990	101	Yes	Voted on Senate Flo	5	Democrat
85	Soil Water Conservation	H.R.3523	Wetlands Disposition and Protection Act of 1991	1991	102	No	Died in Committee	1	Democrat
86	Soil Water Conservation	S.1463	Comprehensive Wetlands Conservation and Management Ac	1991	102	No	Died in Committee	1	Democrat

87	Soil Water Conservation	H.R.1330	Comprehensive Wetlands Conservation and Management Ac	1991	102	No	Debated in cmte	5	Democrat
88	Soil Water Conservation	S. 1573	To reduce the paperwork required of farmers to sign-up and pa	1992	102	No	Died in Committee	1	Democrat
89	Soil Water Conservation	H.R.4255	Wetlands Reform Act of 1992	1992	102	No	Died in Committee	1	Democrat
90	Soil Water Conservation	H.R.5487	Agriculture, Rural Development, Food and Drug Administratio	1992	102	Yes	Voted on House Flo	5	Democrat
91	Soil Water Conservation	S.1736	Energy and Environment Tax Act of 199	1993	103	No	Died in Committee	1	Democrat
92	Soil Water Conservation	H.R.350	Wetlands Reform Act of 1993	1993	103	No	Debated in cmte	2	Democrat
93	Soil Water Conservation	S.1195	Wetlands Reform Act of 1993	1993	103	No	Died in Committee	1	Democrat
94	Soil Water Conservation	S.1304	Wetlands Conservation and Regulatory Improvements Act	1993	103	No	Debated in cmte	2	Democrat
95	Soil Water Conservation	H.R.2493	Agriculture, Rural Development, Food and Drug Administratio	1993	103	Yes	Voted on House Flo	5	Democrat
96	Soil Water Conservation	H. R. 2708	To amend the Internal Revenue Code of 1986 to provide taxpa	1994	103	No	Died in Committee	1	Democrat
97	Soil Water Conservation	S.1691	To amend the Internal Revenue Code of 1986 to provide taxpa	1994	103	No	Debated in cmte	2	Democrat
98	Soil Water Conservation	H.R.4010	Rio Puerco Watershed Act of 1994	1994	103	No	Debated in cmte	2	Democrat
99	Soil Water Conservation	S.1919	Rio Puerco Watershed Act of 1994	1994	103	No	Voted on Senate Flo	4	Democrat
100	Soil Water Conservation	S.2100	Stewardship End-Result Contracts Demonstration Act	1994	103	No	Voted on Senate Flo	4	Democrat
101	Soil Water Conservation	S.2385	Sustainable Ecosystems and Economies (SEE) Demonstratio	1994	103	No	Died in Committee	1	Democrat
102	Soil Water Conservation	S.2292	Waterways Restoration Act of 1994	1994	103	No	Died in Committee	1	Democrat
103	Soil Water Conservation	H.R.3171	Department of Agriculture Reorganization Act of 1994	1994	103	No	Voted on House Flo	4	Democrat
104	Soil Water Conservation	S.1970	Department of Agriculture Reorganization Act of 1994	1994	103	No	Voted on Senate Flo	4	Democrat
105	Soil Water Conservation	H.R.4217	Federal Crop Insurance Reform and Department of Agricultur	1994	103	Yes	Voted on House Flo	5	Democrat
106	Soil Water Conservation	S.2506	Wetlands Regulatory Reform Act of 1995	1994	103	No	Died in Committee	1	Democrat
107	Soil Water Conservation	H.R.1330	Comprehensive Wetlands Conservation and Management Ac	1994	103	No	Debated in cmte	2	Democrat
108	Soil Water Conservation	S.2490	Comprehensive Wetlands Conservation and Management Ac	1994	103	No	Died in Committee	1	Democrat
109	Soil Water Conservation	H.R.4554	Agricultural, Rural Development, Food and Drug Administratio	1994	103	Yes	Voted on House Flo	5	Democrat
110	Soil Water Conservation	S.1407	Energy Crop Production Act of 1995	1995	104	No	Died in Committee	1	Republican
111	Soil Water Conservation	H.R.2542	Conservation Consolidation and Regulatory Reform Act of 1	1995	104	No	Debated in cmte	2	Republican
112	Soil Water Conservation	S.363	Rio Puerco Watershed Act of 1995	1995	104	No	Debated in cmte	2	Republican
113	Soil Water Conservation	S. 626	Waterways Restoration Act of 1995	1995	104	No	Died in Committee	1	Republican
114	Soil Water Conservation	H.R.1268	Comprehensive Wetlands Conservation and Management Ac	1995	104	No	Debated in cmte	2	Republican
115	Soil Water Conservation	S.352	Comprehensive Wetlands Conservation and Management Ac	1995	104	No	Died in Committee	1	Republican
116	Soil Water Conservation	S.1155	Agricultural Competitiveness Act of 1995	1995	104	No	Died in Committee	1	Republican
117	Soil Water Conservation	H.R.1976	Agriculture, Rural Development, Food and Drug Administratio	1995	104	Yes	Voted on House Flo	5	Republican
118	Soil Water Conservation	H.R.961	Clean Water Amendments of 1995	1995	104	No	Voted on House Flo	4	Republican
119	Soil Water Conservation	S.1895	To amend the Internal Revenue Code of 1986 to allow certain	1996	104	No	Died in Committee	1	Republican
120	Soil Water Conservation	H.R.2029	Farm Credit System Reform Act of 1996	1996	104	Yes	Voted on House Flo	5	Republican
121	Soil Water Conservation	S.1662	Oregon Resource Conservation Act of 1996	1996	104	Yes	Voted on Senate Flo	5	Republican
122	Soil Water Conservation	H.R.3592	Water Resources Development Act of 1996	1996	104	Yes	Voted on House Flo	5	Republican
123	Soil Water Conservation	S.640	Water Resources Development Act of 1996	1996	104	Yes	Voted on Senate Flo	5	Republican
124	Soil Water Conservation	H.R.2854	Federal Agriculture Improvement and Reform Act of 1996	1996	104	Yes	Voted on House Flo	5	Republican
125	Soil Water Conservation	S.1541	Federal Agriculture Improvement and Reform Act of 1996	1996	104	Yes	Voted on Senate Flo	5	Republican
126	Soil Water Conservation	H.R.1976	Agriculture, Rural Development, Food and Drug Administratio	1996	104	Yes	Voted on House Flo	5	Republican
127	Soil Water Conservation	H.R.4236	Omnibus Parks and Public Lands Management Act of 1996	1996	104	Yes	Voted on House Flo	5	Republican
128	Soil Water Conservation	H. R. 1164	Rural Environment Tax Credit Act	1997	105	No	Died in Committee	1	Republican
129	Soil Water Conservation	H.R.2762	Wetlands and Watershed Management Act of 1997	1997	105	No	Debated in cmte	2	Republican
130	Soil Water Conservation	H.R.2534	Agricultural Research, Extension, and Education Reauthorizat	1997	105	Yes	Voted on House Flo	5	Republican
131	Soil Water Conservation	H.R.3603	Agriculture, Rural Development, Food and Drug Administratio	1997	105	Yes	Voted on House Flo	5	Republican
132	Soil Water Conservation	S.1150	Agricultural Research, Extension, and Education Reform Act	1997	105	Yes	Voted on Senate Flo	5	Republican
133	Soil Water Conservation	H. R. 2166	To amend the Internal Revenue Code of 1986 to allow certain	1998	105	No	Died in Committee	1	Republican
134	Soil Water Conservation	S.429	To amend the Internal Revenue Code of 1986 to allow certain	1998	105	No	Died in Committee	1	Republican
135	Soil Water Conservation	S.1033	Agriculture, Rural Development, Food and Drug Administratio	1998	105	Yes	Voted on Senate Flo	5	Republican
136	Soil Water Conservation	H.R.2160	Agriculture, Rural Development, Food and Drug Administratio	1998	105	Yes	Voted on House Flo	5	Republican
137	Soil Water Conservation	S.2159	Agriculture, Rural Development, Food and Drug Administratio	1998	105	Yes	Voted on Senate Flo	5	Republican
138	Soil Water Conservation	H.R.4101	Agriculture, Rural Development, Food and Drug Administratio	1998	105	Yes	Voted on House Flo	5	Republican
139	Soil Water Conservation	H.R.1444	Fisheries Restoration and Irrigation Mitigation Act of 2000	1999	106	Yes	Voted on House Flo	5	Republican
140	Soil Water Conservation	H.R.3130	TVA Financial Integrity Act of 1999	1999	106	No	Died in Committee	1	Republican
141	Soil Water Conservation	S.1233	Agriculture, Rural Development, Food and Drug Administratio	1999	106	Yes	Voted on Senate Flo	5	Republican
142	Soil Water Conservation	H.R.1906	Agriculture, Rural Development, Food and Drug Administratio	1999	106	Yes	Voted on House Flo	5	Republican
143	Soil Water Conservation	H.R.2559	Agricultural Risk Protection Act of 2000	1999	106	Yes	Voted on House Flo	5	Republican
144	Soil Water Conservation	S.2756	National Clean Water Trust Fund Act of 2000	2000	106	No	Died in Committee	1	Republican
145	Soil Water Conservation	S.2796	Water Resources Development Act of 2000	2000	106	Yes	Voted on Senate Flo	5	Republican
146	Soil Water Conservation	H. R. 33	Act to authorize a program to encourage agricultural producer	2001	107	No	Died in Committee	1	Republican
147	Soil Water Conservation	S.1326	Working Lands Conservation Act	2001	107	No	Died in Committee	1	Republican
148	Soil Water Conservation	S.1571	Farm and Ranch Equity Act of 2001	2001	107	No	Died in Committee	1	Republican
149	Soil Water Conservation	H.R.325	Fishable Waters Act of 2001	2001	107	No	Died in Committee	1	Republican
150	Soil Water Conservation	S.1731	Agriculture, Conservation, and Rural Enhancement Act of 200	2001	107	Yes	Voted on Senate Flo	5	Republican
151	Soil Water Conservation	H.R.2646	Farm Security and Rural Investment Act of 2002	2001	107	Yes	Voted on House Flo	5	Republican
152	Soil Water Conservation	S.2528	National Drought Preparedness Act of 2002	2002	107	No	Died in Committee	1	Democrat
153	Soil Water Conservation	H.R.4754	National Drought Preparedness Act of 2002	2002	107	No	Debated in cmte	2	Republican
154	Soil Water Conservation	S. 1051	Salt Cedar Council Demonstration Act	2003	108	No	Died in Committee	1	Republican
155	Soil Water Conservation	H.R.2707	Salt Cedar and Russian Olive Control Assessment and Demo	2003	108	No	Voted on House Flo	4	Republican
156	Soil Water Conservation	S.1516	Salt Cedar and Russian Olive Control Assessment and Demo	2003	108	No	Voted on Senate Flo	4	Republican
157	Soil Water Conservation	S.1236	Tamarisk Control and Riparian Restoration Act	2003	108	No	Debated in cmte	2	Republican
158	Soil Water Conservation	H.R.2871	National Drought Preparedness Act of 2003	2003	108	No	Died in Committee	1	Republican
159	Soil Water Conservation	S.1454	National Drought Preparedness Act of 2003	2003	108	No	Died in Committee	1	Republican
160	Soil Water Conservation	H.R.2828	Water Supply, Reliability, and Environmental Improvement Act	2003	108	Yes	Voted on House Flo	5	Republican
161	Soil Water Conservation	H.R.4278	Fishable Waters Act of 2000	2003	106	No	Died in Committee	1	Republican
162	Soil Water Conservation	H.R.4840	Tax Simplification for America's Job Creators Act of 2004	2004	108	No	Voted on House Flo	4	Republican
163	Soil Water Conservation	S.2554	Water Resources Development Act of 2004	2004	108	No	Debated in cmte	2	Republican
164	Soil Water Conservation	H.R.1386	National Drought Preparedness Act of 2005	2005	109	No	Died in Committee	1	Republican
165	Soil Water Conservation	S.802	National Drought Preparedness Act of 2005	2005	109	No	Died in Committee	1	Republican
166	Soil Water Conservation	S.728	Water Resources Development Act of 2005	2005	109	No	Voted on Senate Flo	4	Republican
167	Soil Water Conservation	S.1412	Beginning Farmer and Rancher Opportunity Act of 2007	2007	110	No	Died in Committee	1	Democrat
168	Soil Water Conservation	H.R.2348	Beginning Farmer and Rancher Opportunity Act of 2007	2007	110	No	Died in Committee	1	Democrat
169	Soil Water Conservation	H.R.1495	Water Resources Development Act of 2007	2007	110	Yes	Voted on House Flo	5	Democrat
170	Soil Water Conservation	S.1248	Water Resources Development Act of 2007	2007	110	Yes	Voted on Senate Flo	5	Democrat
171	Soil Water Conservation	H.R.2419	Food, Conservation, and Energy Act of 2008	2007	110	Yes	Voted on House Flo	5	Democrat
172	Soil Water Conservation	H.R.6124	Food, Conservation, and Energy Act of 2008	2008	110	Yes	Voted on House Flo	1	Democrat
173	Soil Water Conservation	S.787	Clean Water Restoration Act	2009	111	No	Debated in cmte	2	Democrat
174	Soil Water Conservation	S.1816	Chesapeake Clean Water and Ecosystem Restoration Act	2009	111	No	Debated in cmte	2	Democrat
175	Soil Water Conservation	S.3550	Columbia River Basin Restoration Act of 2010	2010	111	No	Died in Committee	1	Democrat
176								**2.65**	
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