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The Efficient Water Market of the Northern Colorado Water Conservancy District: Colorado, USA

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Executive Summary

Introduction

The case study presented is focused on the use of tradable and rentable water permits designed to maximise the efficiency of the use of water resources in Colorado (USA). The State of Colorado is divided into two distinct regions: the eastern, dry plains and the western areas that start with the Rocky Mountains and extend through rugged lands to the western border of the State. Rainfall and snow are heavy on the western side of the Rockies, while the eastern slopes of the mountains (the "East Slope") and the plains are semi-arid. In order to compensate this unequal distribution of the water resources, a complicated project of water transfer has been designed. The Colorado-Big Thompson Project is the largest trans-mountain water diversion project in Colorado. Built between 1938 and 1957, the C-BT Project provides supplemental water to 30 cities and towns and is used to provide supplemental irrigation to 693,000 acres of north-eastern. In order to efficiently manage the "foreign water provision" ensured by the CB-t project, it was founded the Northern Colorado Water Conservation District (NCWCD). It was established in 1937 to contract with the Federal Government to build the large trans-mountain water transfer project. NCWCD is responsible for the diversion works of the project and for the allocation of water on the eastern side of the mountains.

Definition of the analysed EPI and purpose

The EPI in this case study is the efficient water market that has evolved within the administration of the Northern Colorado Conservancy District. The market described here has evolved through institutional and economic change over more than 60 years, partly by design, partly by trial and error. This evolution has taken place within the framework of western U.S. water law known as the "appropriations (or priority) doctrine", a doctrine that responded to the semi-arid climate of the region and to the need to move water away from the streams to more remote points of use. These needs contrasted with in the situation in "well watered" regions (especially the eastern U.S., Canada, and U.K.) where the primary uses historically had been for riverside water-powered mills, i.e. non-consumptive uses.

For orderly administration, it is necessary to maintain records of all water rights and their transfers. It is also necessary to enforce the "no injury" requirement at the time of a water right transfer. These functions are carried out by a state agency, e.g. the water courts in Colorado, the Water Commission in Wyoming or the Office of the State Engineer in New Mexico. A large part of the associated costs are imposed on the transferor and transferee, becoming part of the "transaction costs" of the transfer (the other costs are search costs). Naturally, it is desirable to keep transaction costs to a minimum required by effective administration.

Legislative setting and economic background

In the past, water resources were managed, in the US, following the simple principle of "first in time, first in right", under which a particular pattern of water use was assigned a priority date according to time of first use. State courts (first in Colorado in 1886) later ruled that these quantified and prioritized water uses constituted property rights that could be bought and sold. It was also ruled that when these water rights were transferred to different uses, the priority of the right was maintained. In the U.S. and Canada, regions that have used other legal frameworks like the old English riparian doctrine are increasingly changing to more flexible rules, e.g. tradable water extraction permits in the eastern U.S. Agricultural water use constitutes over 80% of total use in Colorado and in the NCWCD, both in terms of withdrawals and consumption. The District has pursued educational and demonstration projects to assist farmers in achieving economic water conservation. The adoption of strategies like these and the efficient water right markets allowed to save more than 30% of water in the last years respect to the past.

Brief description of results and impacts of the proposed EPI

The NCWCD is located in the northeastern quadrant of Colorado as shown in Figure 5. The District serves Front Range cities from Fort Collins to Broomfield, the richest farmlands of Colorado in Larimer and Weld Counties and agricultural lands bordering the South Platte River to the northeastern corner of the State

NCWCD contains 1.6 million acres in portions of Boulder, Larimer, Weld, Broomfield, Morgan, Logan, Washington and Sedgwick counties. The District was established as the local agency to contract with the federal government to build the Colorado-Big Thompson Project under the federal Reclamation Program. The project stores water from the Colorado River headwaters in a series of reservoirs on Colorado's West Slope that is transported, via the 13-mile Alva B. Adams Tunnel, through the mountains in Rocky Mountain National Park to the District's seven-county service area on the East Slope

The long term average annual runoff from the mountain water sheds of the region is about 1.1 million acre-feet. The region is semi-arid with average annual precipitation of 13.7 inches. The natural ground cover was a rich growth of drought resistant blue gramma and buffalo grasses. The Colorado-Big Thompson Project is the largest transmountain water diversion project in Colorado. Built between 1938 and 1957, the C-BT Project provides supplemental water to 30 cities and towns and is used to provide supplemental irrigation to 693,000 acres of northeastern Colorado farmland. The complex collection, distribution and power system is comprised of twelve reservoirs, 35 miles of tunnels, 95 miles of canals and 700 miles of transmission lines. The C-BT system spans roughly 150 miles east to west and 65 from north to south

The C-BT Project annually delivers an average of 213,000 acre feet of water to northeastern Colorado for agricultural, municipal and industrial uses

As a result of the active NCWCD market and rapid urban growth, ownership of the District allotments has shifted steadily toward urban users as shown in the first panel of Figure 8. While ownership has shifted, changes in actual use have been less dramatic. Cities typically buy water rights in excess of average needs to protect against drought. In average years, they then rent substantial amounts of water back to agriculture

The long term effect of increases in urban and industrial demand has been to drive up the prices of C-BT allotments

Conclusions and lessons learnt

The existence of a flexible water market motivates water conservation by all users by confronting the user with the real opportunity cost of the water. It can thus overcome the distorting effects of inappropriate pricing policies that are often in place;

The economic impacts of water transfers out of agriculture depend on (1) whether the new uses are in the same economic region and on (2) the economic vitality of the economy of the area or origin. If water transfers are being induced by the growth of new, more valuable economic activity, the transfers reinforce growth. In depressed areas of origin, transfers out of the area reduce activity with little hope for replacement activities.

In the case of transfers out of a depressed region, extra-market compensation may be warranted. When C-BT was built, additional reservoir storage on the West Slope (Green Mountain Reservoir) was included in the design to compensate for reduced streamflows ("compensatory storage"). When out-of-basin transfers occur from economically depressed areas, the buyers frequently negotiate cash payments to local governments to compensate for reduced tax bases.

Cumulative impacts of transfers out of agriculture cause increasingly negative impacts, sometimes approaching a "tipping point" at which agriculturally-related businesses begin to fail.

Recent experimental research on water markets (Goemans, DiNataly et al) shows that the markets for permanent transfers (water rights) and water rental markets interact. Where efficient, expeditious leasing arrangements are available, water rights prices are likely to be reduced since permanent transfers and leases are, to some extent, substitutes.

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Table of Contents

1. A Preface on Water Law and Water Markets in the U.S.A.

The market described below has evolved through institutional and economic change over more than 60 years, partly by design, partly by trial and error. This evolution has taken place within the framework of western U.S. water law known as the "appropriations (or priority) doctrine", a doctrine that responded to the semi-arid climate of the region and to the need to move water away from the streams to more remote points of use. These needs contrasted with in the situation in "well watered" regions (especially the eastern U.S., Canada, and U.K.) where the primary uses historically had been for riverside water-powered mills, i.e. non-consumptive uses.

To facilitate orderly administration of water claims and protect established uses, a system of priorities was established: "first in time, first in right" under which a particular pattern of water use was assigned a priority date according to time of first use. These practices were incorporated into State laws and constitutions. State courts (first in Colorado in 1886) later ruled that these quantified and prioritized water uses constituted property rights that could be bought and sold. It was also ruled that when these water rights were transferred to different uses, the priority of the right was maintained.

Because of water scarcity and the variability of streamflows in the western regions of the U.S., the return flows to the stream from one use (via surface runoff or via groundwater) were always used by others downstream and claimed as property rights. To avoid infringing those return flow-dependent rights, the courts required that the pattern of return flows be maintained whenever transfers of rights took place. This return flow protection was incorporated into a somewhat broader policy of no injury to other water users that became a legal requirement of all water right transfers.

For orderly administration, it is necessary to maintain records of all water rights and their transfers. It is also necessary to enforce the "no injury" requirement at the time of a water right transfer. These functions are carried out by a state agency, e.g. the water courts in Colorado, the Water Commission in Wyoming or the Office of the State Engineer in New Mexico. A large part of the associated costs are imposed on the transferor and transferee, becoming part of the "transaction costs" of the transfer (the other costs are search costs). Naturally, it is desirable to keep transaction costs to a minimum required by effective administration.

One exception to the protection of return flows evolved: the case of importation of water from another hydrologicly independent basin (or "foreign water" as it is often called). The courts reasoned that no claims to return flows from the newly imported water could exist at the time of the new import (by definition), so the importing party could claim ownership over all uses of any return flows from the newly imported water (they could "use the water to extinction"). This "foreign water" provision (FWP) was eventually adopted by all western states of the U.S. It should be noted

that, while the importing party could conceivably sell the first set of return flows for use by other parties, it would be impossible to identify all subsequent return flows for possible sale. Nonetheless the provision does mean that the importer can't be required to protect those return flows.

The water generated by the Colorado-Big Thompson importation project and distributed by The Northern Colorado Water Conservancy District (described below) carries the "foreign water provision" that frees NCWCD from the obligation of protecting return flows. This means that water transfers within the NCWCD are not required to be reviewed by the State's water courts, a process that usually is quite costly to the transferring parties. This freedom and the consequent low transaction costs have facilitated an active, nearly continuous water market in the District. This is seen in the high volume and continuity of transfers in the NCWCD as exhibited in the case study.

While the "foreign water provision" is a major factor underlying the efficiency and continuity of NCWCD's water market, that provision has been adopted by all western U.S. States and is capable of adoption in any region whose water law permits tradable property rights in water.

2. Characteristics of the Efficient Market Region

The Northern Colorado Water Conservation District (NCWCD) was established in 1937 to contract with the Federal Government to build a large trans-mountain water transfer project, The Colorado-Big Thompson Project (C-BT) that transfers water from the water plentiful western side of the Rocky Mountains in Colorado to the much drier eastern side of the mountains. NCWCD is responsible for the diversion works of the project and for the allocation of water on the eastern side of the mountains (the Eastern Slope C-BT is one of hundreds of federal water projects undertaken by the U.S. Bureau of Reclamation under authorization of the 1902 Reclamation Act that was intended to provide subsidized water for the continuing economic development of the western U.S., especially for irrigated agriculture. To understand this policy, it is necessary to understand the regional climate characteristics of the United States.

To understand this policy, it is necessary to understand the regional climate characteristics of the United States. Figure 1 shows that the western 1/3 of the country is mountainous and uneven terrain while the eastern 2/3 has superior soils and much heavier precipitation, the latter shown in Figure 2.

Figure 1: topographic map of U.S.

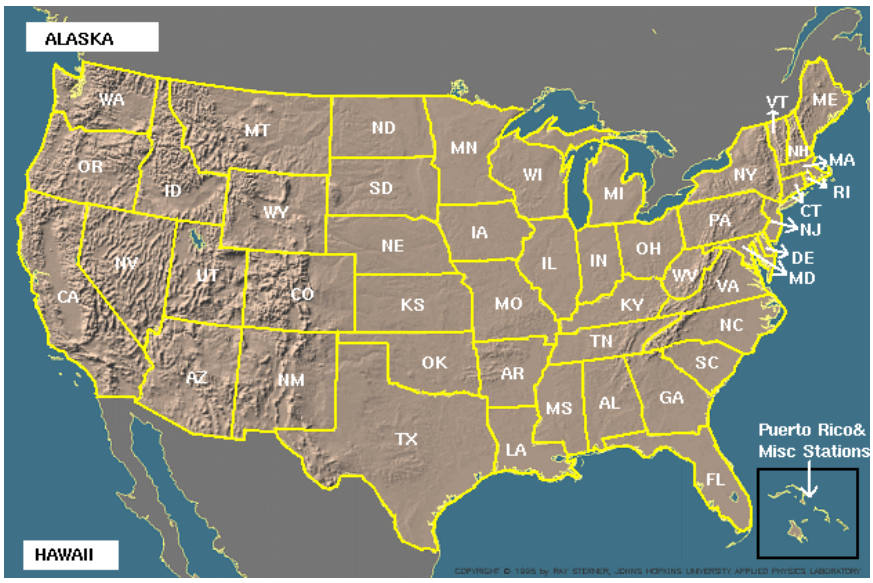
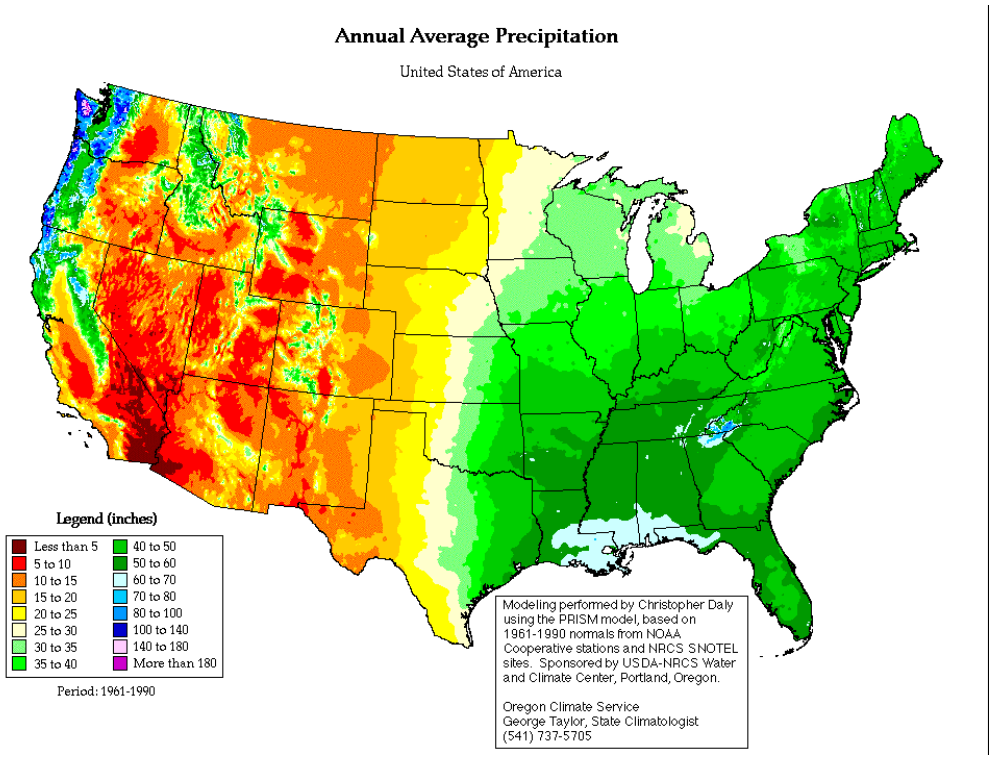


Figure 2: U. S. Annual Average Precipitation.

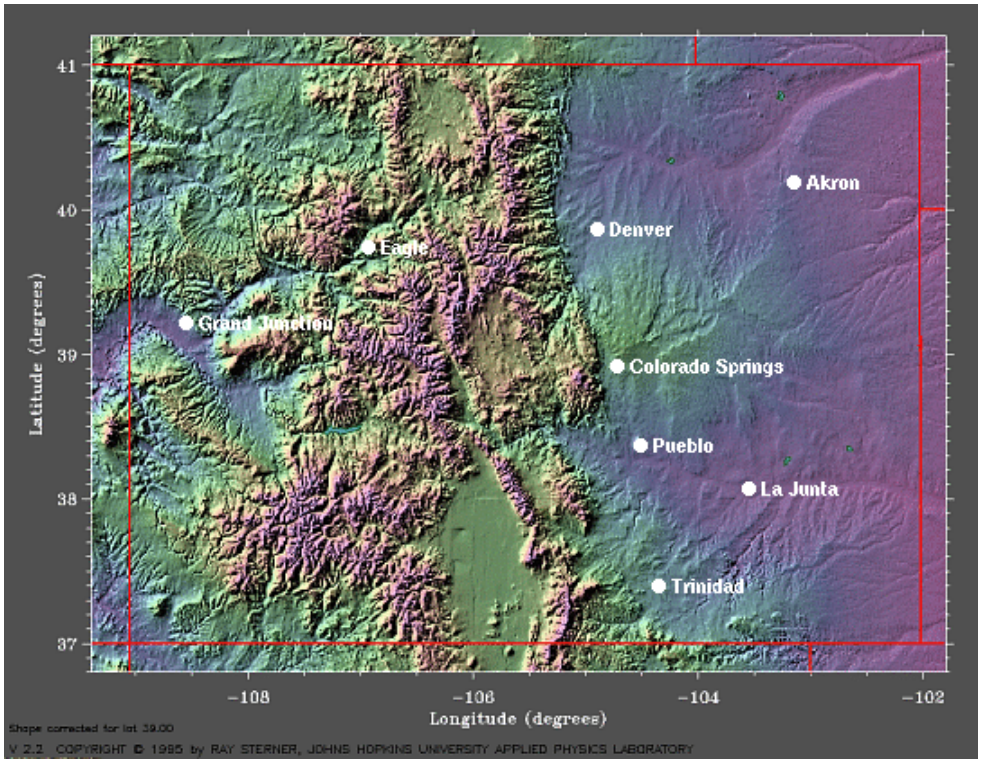


Source: U.S. Geological Survey.

It is clear that the eastern regions of the U.S. experience heavy precipitation with an annual average of about 40 inches, mostly spring and summer rainfall, but the northern and northeastern regions can experience heavy snowfall. West of the 100th meridian, the climate becomes much drier, falling to less than 10 inches is many areas. In that western region, agricultural crops other than small grains (wheat, barley, sorghum) require irrigation.

The State of Colorado is divided into two distinct regions: the eastern, dry plains starting at roughly 105 degrees west longitude and the western areas that start with the Rocky Mountains and extend through rugged lands to the western border of the State. Rainfall and snow are heavy on the western side of the Rockies, while the eastern slopes of the mountains (the "East Slope") and the plains are semi-arid.

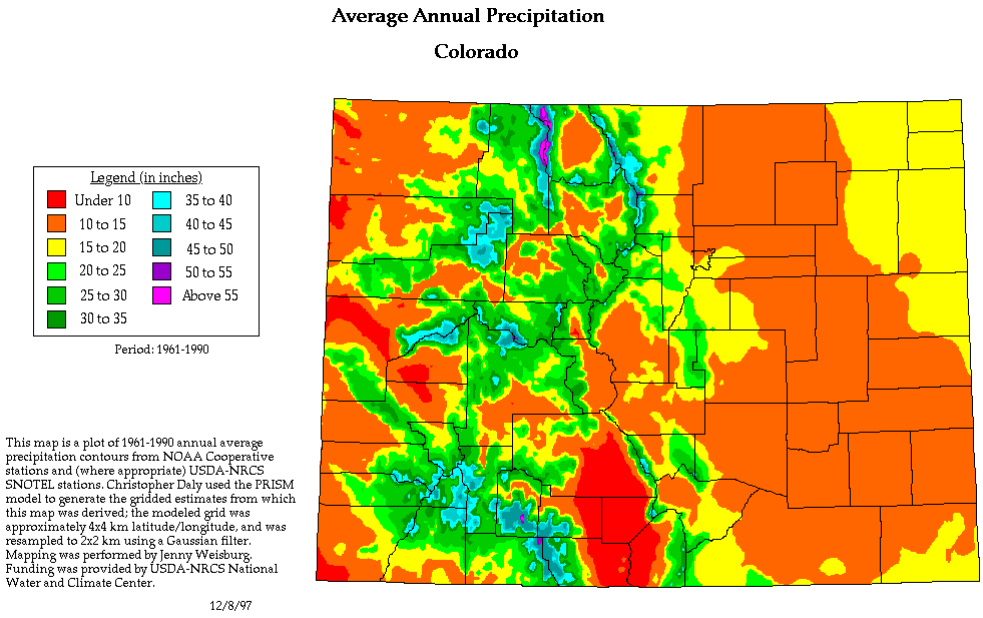
Figure 3: topographic map of Colorado.



Source: Colorado State Geographer.

Colorado patterns of precipitation follow the topography of the State as shown in Figure 4.

Figure 4: Colorado Average Precipitation.

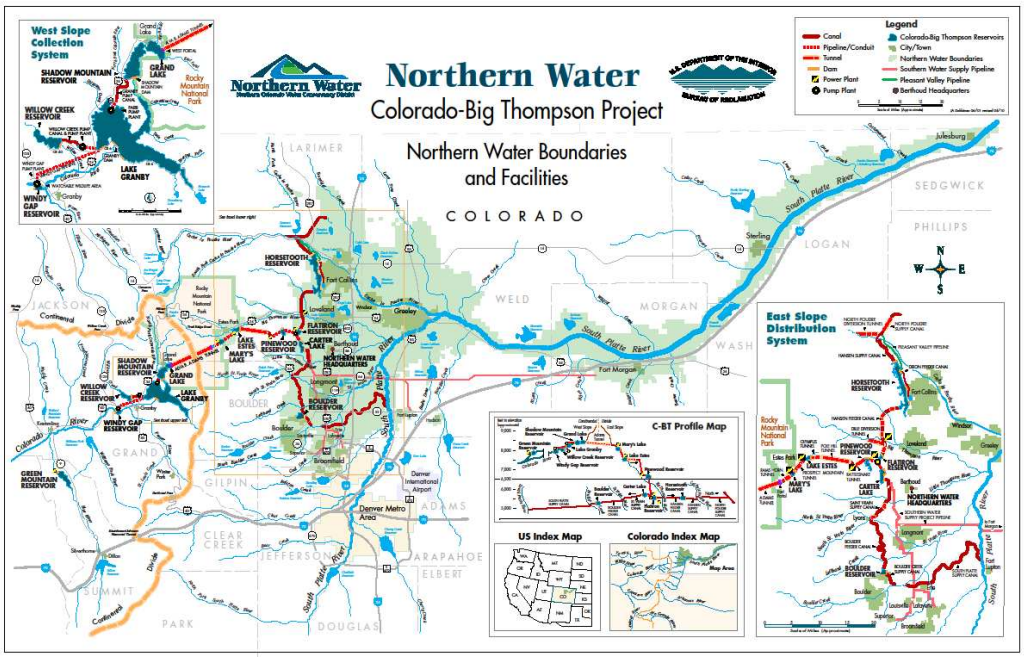


Source: US Geological Survey.

2.1 The Northern Colorado Water Conservancy District.

The NCWCD is located in the northeastern quadrant of Colorado as shown in Figure 5. The District serves Front Range cities from Fort Collins to Broomfield, the richest farmlands of Colorado in Larimer and Weld Counties and agricultural lands bordering the South Platte River to the northeastern corner of the State.

Figure 5: NCWCD & the Colorado-Big Thompson Project



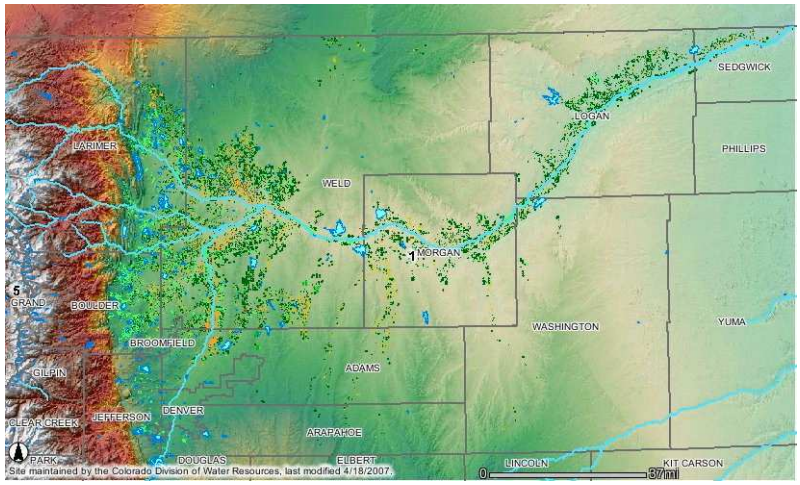
Source: NCWCD website.

NCWCD contains 1.6 million acres in portions of Boulder, Larimer, Weld, Broomfield, Morgan, Logan, Washington and Sedgwick counties. The District was established as the local agency to contract with the federal government to build the Colorado-Big Thompson Project under the federal Reclamation Program. The project stores water from the Colorado River headwaters in a series of reservoirs on Colorado's West Slope that is transported, via the 13-mile Alva B. Adams Tunnel, through the mountains in Rocky Mountain National Park to the District's seven-county service area on the East Slope.

The main rivers of the region are the South Platte River and its major tributaries: the Cache la Poudre; the Big Thompson; the Little Thompson; the Saint Vrain; and Boulder Creek. All these rivers are fed by snowmelt in the spring and early summer and by groundwater discharge in the fall and winter. Before C-BT and the large scale groundwater pumping of the 1950's and 1960's, these streams provided all the available water for the Project region. They still constitute the main channels for distributing both native waters and the C-BT supplemental water.

The long term average annual runoff from the mountain water sheds of the region is about 1.1 million acre-feet. The region is semi-arid with average annual precipitation of 13.7 inches. The natural ground cover was a rich growth of drought resistant blue gramma and buffalo grasses. The irrigated areas of Northeastern Colorado that are served by NCWCD are shown in greater detail in Figure 6.

Figure 6: Irrigated Areas Served by NCWCD/C-BT.



Source: NCWCD website.

2.2 The Colorado-Big Thompson Project.

The Colorado-Big Thompson Project is the largest transmountain water diversion project in Colorado. Built between 1938 and 1957, the C-BT Project provides supplemental water to 30 cities and towns and is used to provide supplemental irrigation to 693,000 acres of northeastern Colorado farmland. The complex collection, distribution and power system is comprised of twelve reservoirs, 35 miles of tunnels, 95 miles of canals and 700 miles of transmission lines. The C-BT system spans roughly 150 miles east to west and 65 from north to south.

West of the Continental Divide, a system of reservoirs at increasing altitude collect and store the water of the upper Colorado River. The water is pumped into Shadow Mountain Reservoir where it flows by gravity into Grand Lake. From there, the 13.1 mile Alva B. Adams Tunnel transports the water under the divide to the East Slope.

Once the water reaches the East Slope, it is used to generate electricity as it falls almost half a mile through five power plants on its way to Colorado's Front Range where three major reservoir store the water. C-BT water is released as needed to supplement native water supplies in the South Platte River basin.

An interesting feature of the C-BT Project is the Green Mountain Reservoir on the western side of the mountains that provides replacement water for the basin-of-origin, the Colorado River Basin. Green Mountain Reservoir is considered to be part of the project, even though separated physically from the main project. It was required to be completed before C-BT began operation in deference to Western Slope interests who had objected to C-BT. This was an innovative form of compensation to

the basin of origin. Compensation to the basin-of-origin is now required for all out-of-basin diversions in Colorado.

The C-BT Project annually delivers an average of 213,000 acre feet of water to northeastern Colorado for agricultural, municipal and industrial uses. Descriptive data are summarized in Table 1 below.

Table 1: C-BT by the Numbers

30	cities and towns served by the Colorado-Big Thompson Project
693,000	**a**cres irrigated by C-BT water in northeastern Colorado
12	reservoirs in the system
35	miles of tunnels in the system
95	miles of canals in the C-BT system
700	miles of transmission lines
310,000	acre-feet the intended annual delivery capacity of the Project.
213,000	acre feet actually delivered annually on average.
1.6 million	The number of acres in the Project's service area
13.1	miles of the Trans-Mountain Tunnel
$1.50 The original price, per acre-foot charged to users for C-BT water in 1937-38.	

Source: Homepage of NCWCD: www.ncwcd.org

2.3 Conditions Leading to the Establishment of NCWCD and C-BT

The 1927-37 period was a dry period with severe drought from 1931 through 1935, part of the infamous "dust bowl" of the Great Plains. Flows in the Colorado River (from which C-BT water is diverted) were high from1896-1929, followed by a 38 year dry period from 1930 -1968, illustrating the decadal variation in climate conditions. The lowest flow on record of only 5.6 million acre-feet occurred in 1934. The U.S. Bureau of Reclamation estimated that 75% of the 615,000 acres potentially served by C-BT had inadequate (for full yield) water supplies.

Because of persistent drought conditions, an application was made in August, 1933 to the Federal Government for the planning and construction of a supplemental water supply project that would bring water through the mountains. The Bureau of Reclamation had the expertise and carried out a project survey in 1935. An officially recognized organization to represent the water users of the region having broad legal powers was needed. There were no provisions under Colorado law for such an

Entity, so the Colorado Conservancy District Act was passed in 1937- innovative legislation that has been copied by all western states. Conservancy districts could be established by State District Courts and had broad legal powers, including power to place a tax on all property in the district-a financing arrangement that would be relied on heavily in place of heavier user charges. NCWCD was established in 1938.

The contract with the Federal Government contained the following features for NCWCD:

1. An intended delivery of 310,000 acre-feet annually;
2. A highly subsidized repayment of construction costs;
3. A minimum tax rate on property in the District plus (minimal) annual payments by the water users;
4. Ownership of and arrangements for managing return flows from diversions of project water-a key issue.

2.4 The Economic Efficiency of NCWCD Market Arrangements

The importance of the special provisions governing return flows was not appreciated at the time. Under western U.S. water law, return flows "belong to the stream" and cannot be claimed by the water right holder who made the diversion. Because the Bureau of Reclamation had obtained the needed water rights on the Colorado River and because the water would be new to the South Platte Basin, the contract allowed NCWCD to claim ownership of all return flows for recapture and reuse-a feature critical to the subsequent evolution of the NCWCD efficient water market.

The Bureau of Reclamation initially insisted that NCWCD sell the return flows to guarantee further revenues that would help repayment of the construction costs[1]. The District resisted this because (1) it would be impossible to estimate the volume and timing of the return flows with sufficient accuracy to establish clear property rights and (2) such an arrangement would be inconsistent with State law concerning return flows.

The most profound effect of the District's refusal to sell return flows (which it owned) was that it left the District free to approve proposed transfers anywhere in the District without recourse to the Water Court procedures typically required of transfers to guarantee "no injury" to other water users-a basic requirement of the appropriations doctrine of water law. Thus only the District Board had to approve transfers, an expeditious and cost-minimizing procedure.

This does not mean there are no hydrologic third party impacts from transfers. If the change in point of diversion reduces streamflows below the original diversion point, water users downstream will lose the benefits of higher flows while water users downstream from the new diversion point will experience higher flows. These effects have been overlooked in Colorado water administration and imply that some inefficiencies might occur if the benefits to new downstream gainers were less than losses to old downstream losers.

[1] This insistence on obtaining further revenues to help repay construction costs is something of a joke since the arrangements for repayment contained huge subsidies including a 50 year repayment period with no interest on the unpaid balance, no adjustments for inflation and 50% of the costs being repaid in the last 10 years of the repayment period.

The issue of loses or gains to activities economically linked to Project water users, e.g. suppliers of agricultural inputs or users of agricultural products (i.e. "community effects" or externalities) is complicated and has been treated in an extensive literature (Howe & Goemans, 2003; R. Young, various; others). While such effects are frequently dismissed as "pecuniary externalities" that are fully accounted for in market transactions, the consensus of that literature is that an expansion or contraction of a primary water-using activity (e.g. irrigated acreage) in a depressed region where there is unemployment of resources and capacities, "real" (national) economic gains or losses can be generated in the linked activities. However, in the case of NCWCD, the regional economy is quite prosperous with both highly productive irrigated agriculture and expanding urban, industrial and commercial activities. Many water transfers are initiated by changes in land use as urban and commercial activities expand into farm land. Thus third party externalities are not a serious issue.

Where does this leave us regarding the overall efficiency of the transfer process in NCWCD? The question is whether the advantages of an easy, low cost transfer process offset any net adverse third party effects. If the transfers are within the agricultural sector, it seems likely that net third party effects will be positive since the initial transfer is from a lower productivity use to a higher productivity use. If the transfer is from agriculture to urban use, the net third party effects are surely positive since urban uses are typically higher-valued than most agricultural uses. Towns are also increasingly reusing wastewater attributable to interbasin sources (Binney, various) thus increasing the net value of ag-to-urban transfers.

3. Evolution and Operation of the Allotment Market

The area to be served by NCWCD included areas of quite different native (natural) water supplies relative to the arable land. Some areas were served by ditches with senior rights while others had unreliable native supplies. This lead to diverse opinions about the values of C-BT and about how C-BT water might be distributed among users. Farmers did not want a mandatory, uniform assignment of water to land.

It was clear that the relative water needs would change among different types of users and different areas. Thus all potential users were allowed to subscribe voluntarily for shares in the District (which are called allotments) at nominal prices starting in 1939. The 310,000 allotments available [2] were not fully subscribed until 1955. Finally, in 1957 an allotment was legally defined as a freely transferable

[2] The anticipated yield of the Project was 310,000 acre-feet, so 310,000 shares (allotments) were made available with the expectation that each allotment would represent on acre-foot of water.

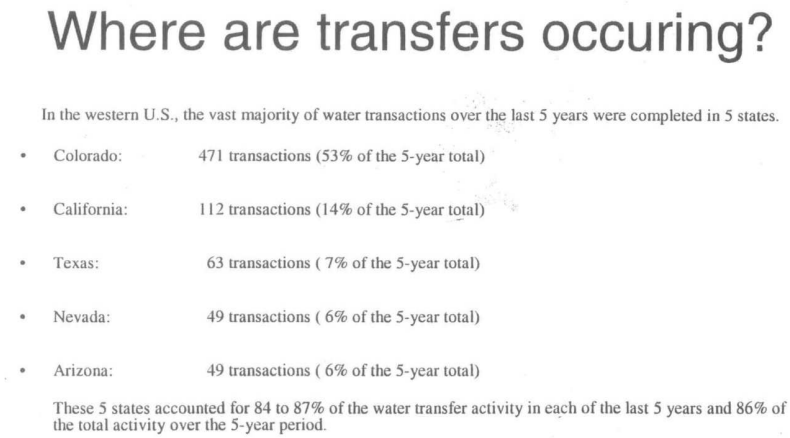
contract between the District and the holder, subject to demonstrated beneficial use within the District.

Proposed buyers and sellers make a transfer application to the District Board. Beneficial use must be demonstrated except for municipal users who are allowed to hold "conditional water rights" in anticipation of future growth. Some brokers act as "speculators" (in spite of State law to the contrary) by buying allotments at favorable prices, applying the water temporarily to some agricultural land until a favorable buyer is located. This "packaging" of allotments is probably beneficial (Howe, 2008).

3.1 Current Operations of the Allotment Market

As water scarcity increases everywhere, flexibility in the allocation of existing supplies becomes increasingly important.. In the U.S., there is a long history of water marketing, especially in the states of Texas, California, Arizona, Nevada and Colorado. Table 2 shows recent evidence of market transfer activity.

Table 2.



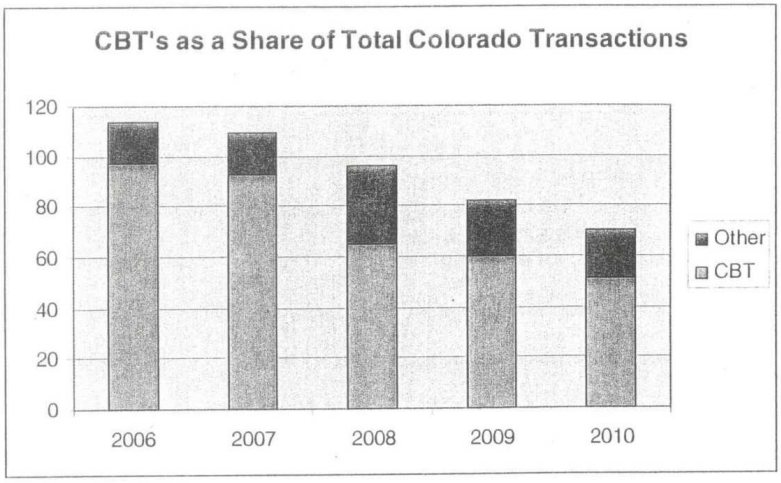
Source: Rod Smith …

It's clear that Colorado ranks first among the western states. Further, NCWCD's allotment market dominates Colorado transactions as shown in Figure 7.

As a result of the active NCWCD market and rapid urban growth, ownership of the District allotments has shifted steadily toward urban users as shown in the first panel of Figure 8. While ownership has shifted, changes in actual use has been less dramatic. Cities typically buy water rights in excess of average needs to protect against drought. In average years, they then rent substantial amounts of water back to agriculture as shown in the second panel of Figure 8.

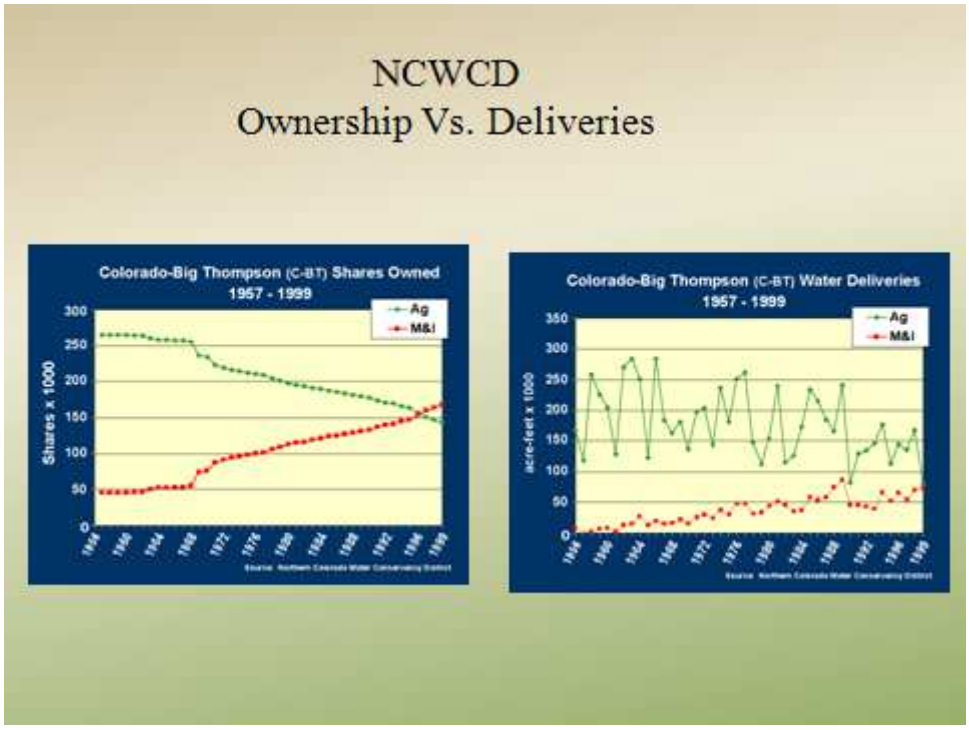
Figure 7.

Colorado's dominance of the market is driven heavily by activity on the Front Range, especially in the market for Colorado–Big Thompson units.



Source: Smith.

Figure 8.



Source: Howe & Goemans, 2003.

The long term effect of increases in urban and industrial demand has been to drive up the prices of C-BT allotments as shown in Figure 9, with data through 2000.

Figure 9.

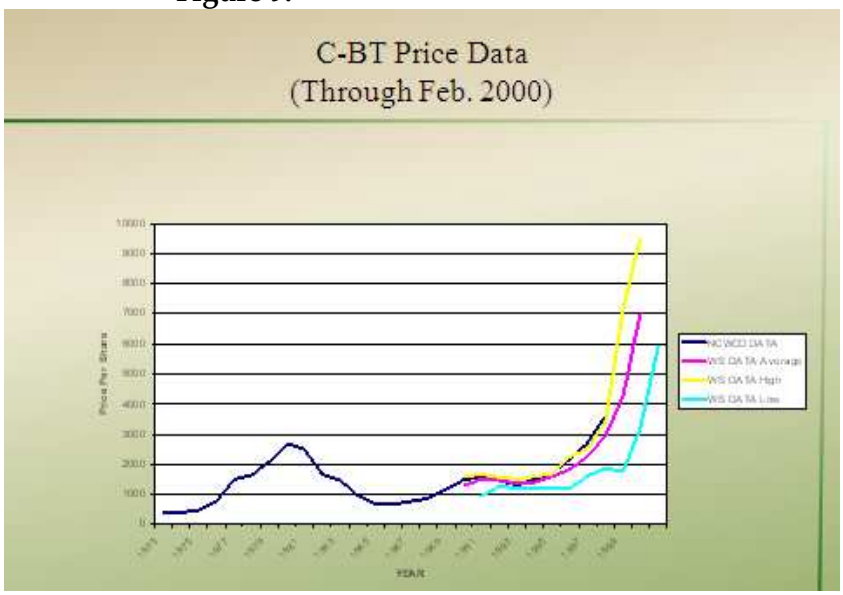
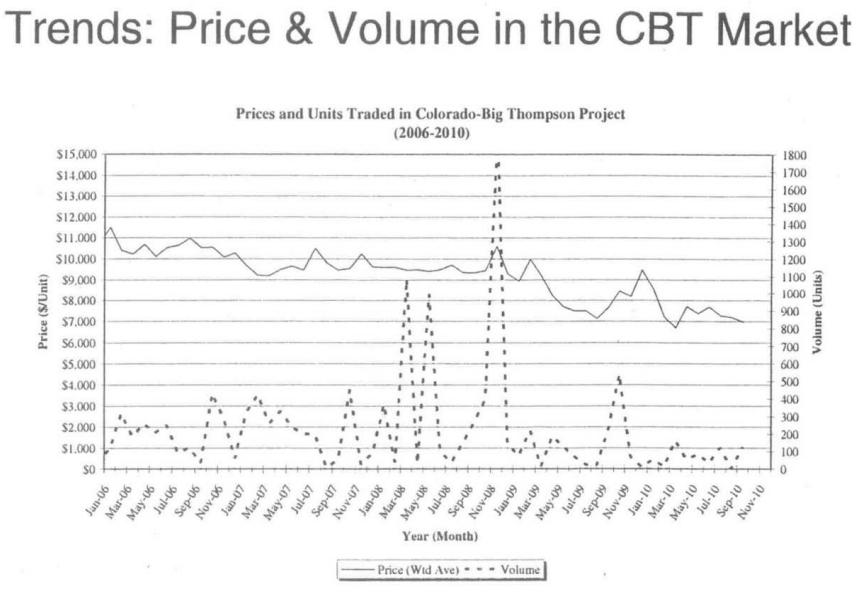


Figure 10 shows the trends in volume of transfers and prices of those transfers since 2006. Volumes and prices are in terms of C-BT allotments. Historically, an allotment has delivered 0.7 acre-feet rather than the originally intended 1.0 acre-feet. For example, the volume traded in November of 2009 was roughly 500 units or 350 acre-feet while prices in that month were in the neighborhood of $ 8000 per unit or roughly $ $11,500 per acre-foot in perpetuity.

Figure 10.



Source: Smith.

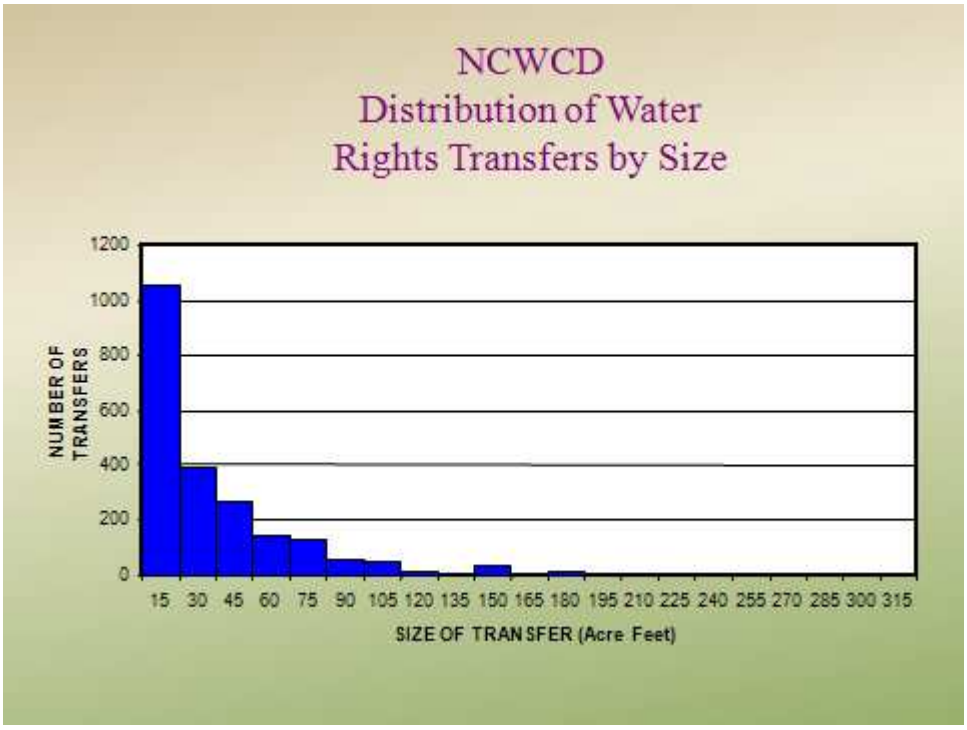
The large changes in volumes are due to weather conditions and spurts of urban growth. Curiously there has been a downward trend in prices since 2006. This is largely attributable to very effective programs of urban conservation that appear to have permanently reduced urban water use in spite of continued population growth.

3.2 Comparative Characteristics of NCWCD Transfers

Figure 11 below presents a comparison of the types of transfers occurring in 3 Colorado water markets, including the NCWCD market. The other markets are markets in traditional water rights, the first in the South Platte Basin (of which NCWCD is part) and the Arkansas River Basin in southern Colorado.It is clear that transfers out of agriculture are the predominant type of transfer, but an important feature in the NCWCD market is the higher percentage of agriculture-to-agriculture transfers that occur as a result of the fast, low cost transfers. This is critical for irrigated agriculture in semi-arid areas.

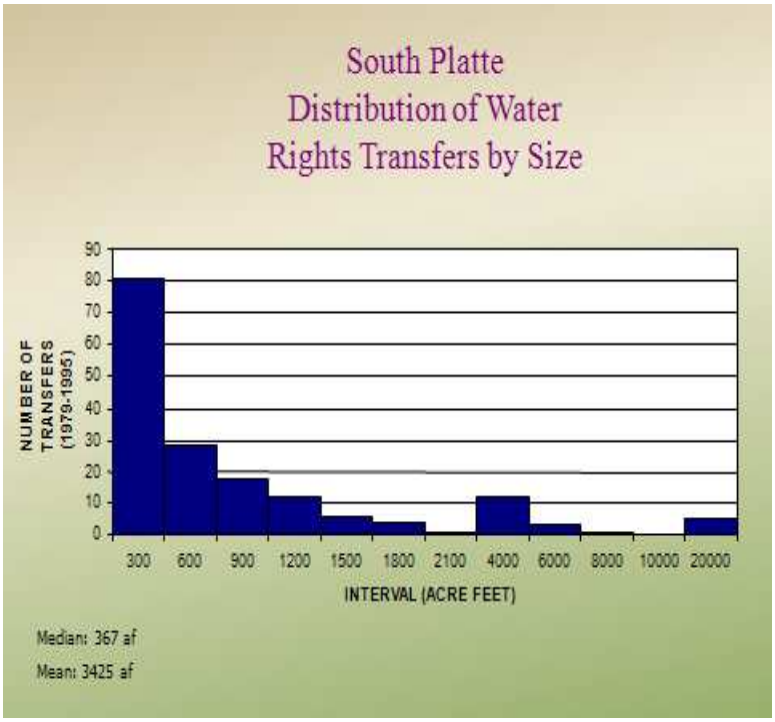
Comparisons can also be made of the size distributions of transfers in NCWCD compared to the size distribution of transfers occurring in the regional South Platte market for traditional water rights. This is shown in Figures 12 and 13below. The striking thing is that, while the median size of transfer in the South Platte traditional market is 367 acre-feet with a mean of 3425, in the NCWCD market over the same period, the median is only 16.8 acre-feet with a mean of 34 acre-feet.

Figure 12.



Median: 16.8 acre-feet, Mean 34.0 acre-feet.

Figure 13.



The differences are attributable to the low cost and continuity of the NCWCD market. Cities operating in traditional water markets typically prefer to buy large

quantities of agricultural rights in a single transaction because a large part of transaction costs is fixed. In the NCWCD market, however, there is a continuous market in which allotments (0.7 acre-feet) can always be purchased at largely predictable prices. There is no need to engage in large transfers in anticipation of future needs. This clearly illustrates the efficiency of the low cost NCWCD market.

3.3 The NCWCD Rental Market

A continuous listing of seasonal offers by parties "wanting to rent" and those "willing to rent" is maintained in the District office and online.. This is illustrated by the District on-line table below.

Wanting to Rent Water

Contact (s)	Phone Number (s)	Email	Acre Feet	Price in wet Acre Feet
John File	303-570-9798		24	Negotiable
Frank Brothers	970-587-5125		1000	Negotiable
Brady Neumann	970-663-1187		6	Negotiable
Butch Sekich	970-535-4643		300	Negotiable

Willing to Rent Water

Contact (s)	Phone Number (s)	Email	Acre Feet	Price in wet Acre Feet
C - Quin Enterprise (John)	(303) 861 - 8008		120 A.F.	negotiable
Art Knoonenberg	303-220-1796		88	Negotiable
Brad Bischoff	970-227-9400		50	Negotiable
David Jessup	(970) 667 - 3915		100	20$

Northern Colorado Water Conservancy District • 220 Water Ave. Berthoud, CO 80513 • 970-532-7700

Source: NCWCD Records.

Records of lease transactions and prices are limited to special studies at several times in the past. These studies have shown that, on the average over time, nearly 50% of the C-BT water available to allotment owners is rented, most consisting of rentals from cities to agriculture. The volume and direction of rentals are sensitive to weather conditions, with cities withholding water from agriculture and charging

somewhat higher prices during drought. Prices tend to increase in the late season when farmers often need added water to "finish" a crop and when traditional surface supplies are low.

It has been the policy of the District to keep rental prices low, to exert pressure on cities not to "gouge" agriculture. While low rental prices help the farmers who manage to find rental water, it also restricts the supplies that farmers (if not cities) are willing to rent.

4. Assessment Criteria

The EPI in this case study is the efficient water market that has evolved within the administration of the Northern Colorado Conservancy District. The District and the market have evolved together so it is not possible to identify or isolate the environmental, economic or distributional effects of each totally separately. Important lessons would be lost if the institutional lessons from the evolution of the NCWCD were to be omitted.

4.1 Environmental Outcomes

The NCWCD and its later market were not started with environmental objectives in mind other than overcoming the effects of serious drought in the 1930's. Nonetheless, the environmental dimensions of importance to the NCWCD and the surrounding counties and towns can be identified as:

1. Preservation of the long term productivity of agricultural lands in terms of crops, broader soil and ecosystem maintenance and aesthetic values;
2. Protection of water quality in the soil, in the aquifers and in surface streams;
3. Maintenance of healthy seasonal streamflows for the preservation of riparian ecosystems, sports fisheries and other forms of water based recreation, especially rafting and kayaking;

Agricultural water use constitutes over 80% of total use in Colorado and in the NCWCD, both in terms of withdrawals and consumption. As seen in the earlier graphs, while agricultural water use has been declining (urban use expanding), agriculture remains the largest user of NCWCD water. The District has pursued educational and demonstration projects to assist farmers in achieving economic water conservation. These programs are carried out in cooperation with the Agricultural Extension Service and Experiment Stations of the U.S. Department of Agriculture. A major step has been the stimulation of efficient irrigation techniques like the drop line sprinkler pictured below. This technology also permits accurate

application of fertilizers and pesticides thus reducing nutrient and chemical loadings in ground and surface waters. Adoption of such techniques is stimulated by the active water market that "puts a price on water".

Figure 14. Efficient Low Dropline Sprinkler Techniques.

As urban use of C-BT water expands, it is increasingly important to establish economic conservation in the urban setting. Roughly 50% of urban water use is for the irrigation of lawns, gardens and trees. The major conservation steps encouraged by NCWCD and followed by towns in the District include:

1. Establishment of monthly "water budgets" for residential, commercial industrial and institutional customers;
2. Establishment of increasing block rate structures in conjunction with the water budgets;
3. Issuance of "smart readers" to customers so that the customer can determine current rates of use & cumulative use compared with the budget;
4. Subsidies to installation of water-saving appliances: toilets, washing machines, shower and bath fittings, etc.
5. Educational programs for urban users that center on efficient outdoor use, including demonstration gardens like that shown b

Figure 15 *Demonstration Gardens at the NCWCD Headquarters.*

These urban conservation programs have resulted in a permanent 30% reduction in per capita water use in the District's service area. The saved water results in higher streamflows with positive impacts on riparian ecosystems, water related recreation and irrigation water supplies.

The efficient, continuous market means that urban areas can acquire water as needed rather than buying large volumes of agricultural water rights that results in drying up large areas. The environmental and aesthetic values of agriculture are increasingly recognized in all areas of public decision-making.

4.2 Economic Assessment Criteria

An ex post benefit/cost analysis of the Colorado-Big Thompson Project was carried out by Howe et al (Natural Resources Journal, Winter, 1987). That analysis estimated the economic benefits and costs of the project from both a national accounting stance and from the C-BT regional accounting stance. It must be kept in mind that the C-BT Project, its administration by the NCWCD and the water market imbedded in the District have evolved together. Thus it isn't possible to isolate the impacts of the water market itself from the effects of the institutional evolution of the District . While the ex-post study is dated, it serves to bring out several important points, among them:

1. A benefit/cost assessment depends completely on the "accounting stance" adopted by the study, i.e. whose benefits and costs are to be counted. The accounting stance, in turn, is likely to depend on the political boundaries of the agency making the policy change or project being assessed;

2. The economic impacts of water transfers on the area from which the water is being transferred depend on the nature of the regional economy, in particular whether the region is economically strong with dynamic changes taking place or whether it is a depressed (often agricultural) region with few alternatives to the use being phased out.

It is interesting to note that no benefit-cost analysis for CBT was conducted. The Bureau of Reclamation survey report concluded that, with its estimated construction cost for the project, the sale of power and the sale of water at $2 per acre-foot made the project financially feasible." Estimates were presented of the water "shortage" in the intended project area575,000 acre-feet which would largely be covered by C-BT deliveries of 310,000 acre-feet plus associated multiple return flows. Average annual losses in gross crop value due to water shortage were estimated to be $4.7 million, and it was observed by the Bureau that water rental prices in the area averaged about $4.50 per acre-foot. No attempt was made to draw any formal conclusions from this. The Secretary of Interior voiced doubt about the "feasibility" of the project, but he seemed to be referring to repayment, rather than to economic feasibility.

Construction of the C-BT began in 1938, but was interrupted in 1942 by World War]] priorities. The first deliveries of water into natural streams on the Eastern Slope were made in 1947, and full water deliveries commenced in 1957.

The realized net benefits of CBT/NCWCD are conceptualized as the difference between the actual state of the national or regional economy as it grew with C-BT/NCWCD in place and as it might have been had the project not been built. The ex-post with-without comparison is simple in principle but difficult to carry out.

The "project region" first needs to be clearly defined. It could be confined to the boundaries of NCWCD itself, but the District is part of a larger, highly-integrated multi-county region of northeastern Colorado. Data availability is also on a county basis, so the project region was defined as a six county region. This region encompasses the areas in Colorado that benefit from Project return flows.

The distinction between a regional and national accounting stance are exhibited in the estimates presented in Table 6 below.

Table 6 .
Summary Table: 1960 Present Value of C-BT/NCWCD Benefits and Costs from National and Regional Accounting Stances (mlllions of 1960 dollars through 1980) .

	Benefits	Costs	Net Benefits	B/C Ratio
National:	209.3	550.7	-341.4	0.38
Regional	874.8	107.9	766.9	8.11

Source: Howe 1987.

The lessons learned from Table 6 are that : (1) the financial arrangements (including subsidies of various forms) made for the construction of a project can create large differences between regionally borne costs and the true national costs.; (2) due to the mobility of economic activities over time, many of the apparent benefits to the region are really benefits transferred from other regions and, thus, not fully a net gain from the national accounting stance.

4.3 Distributional Effects and Social Equity

The existence of the flexible, efficient market through which small amounts of water could be purchased at any time at predictable prices helped to maintain small-scale agriculture and related businesses. In other regions where high transaction costs result only in large water transfers, agriculture tends to be dominated by very large agricultural operators.

4.4 Institutions

The evolution of the NCWCD has been covered in earlier sections. The institutional framework of NCWCD has been vital to the evolution of the efficient market.

4.5 Policy Implementability

This remains an issue. First, the establishment of an efficient market is limited to legal regimes in which water rights are clearly defined and considered to be tradable property, properties of regimes adopting some version of the appropriations doctrine. In the U.S. and Canada, regions that have used other legal frameworks like the old English riparian doctrine are increasingly changing to more flexible rules, e.g. tradable water extraction permits in the eastern U.S..

The other issue is the level of transaction costs. In the present case, transaction costs have been kept low because of the return flow arrangements described earlier, i.e. that the C-BT water was imported and NCWCD thus owned the return flows. This relieved NCWCD of "no injury" obligations related to transfers and thus avoided formal court review.

However, there are other designs that could lower transaction costs, e.g. establishing sealed bid double auction markets where the volume of trades warranted.

4.6 Transaction Costs

This has been treated in detail in previous sections. Indeed, it is the key to effective, efficient market arrangements.

4.7 Uncertainty

The uncertainty (more likely, risk) involved in establishing and operating almost any water market stems from climate and hydrology. Most watersheds have long records of streamflow and climate data, these days extended to hundreds of years through dendrochronology. Thus the density functions for historic annual and monthly streamflows are available. A major question facing water planning is the relevance of these historic traces to possible future conditions under likely climate change.

The main mechanism for dealing with hydrologic risk is storage. There are limits to the effectiveness of storage in providing reliable supplies. In the case of NCWCD, there are large reservoirs in both West Slope and Eastern Slope regions. This largely eliminates hydrologic variability but weather continues to create some uncertainty on the demand side: if there is an extended dry period, demands will increase and the reverse will happen during wet periods. This causes problems of balancing the supply system, i.e. having the water where and when needed.

The conjunctive management of surface and ground waters can be effective in regions with large groundwater stocks in tributary aquifers. During dry periods, the groundwater can be called on to replace surface supplies. While this strategy should be obvious, in some jurisdictions the surface and groundwaters are administered by different agencies and covered by different sets of law (see Howe 2008).

4. Conclusions

4.1 Lessons Learned

1. The existence of a flexible water market motivates water conservation by all users by confronting the user with the real opportunity cost of the water. It can thus overcome the distorting effects of inappropriate pricing policies that are often in place;

2. The economic impacts of water transfers out of agriculture depend on (1) whether the new uses are in the same economic region and on (2) the economic vitality of the economy of the area or origin. If water transfers are being induced by the growth of new, more valuable economic activity, the transfers reinforce growth. In depressed areas of origin, transfers out of the area reduce activity with little hope for replacement activities.

3. In the case of transfers out of a depressed region, extra-market compensation may be warranted. When C-BT was built, additional reservoir storage on the

West Slope (Green Mountain Reservoir) was included in the design to compensate for reduced streamflows ("compensatory storage"). When out-of-basin transfers occur from economically depressed areas, the buyers frequently negotiate cash payments to local governments to compensate for reduced tax bases.

4. Cumulative impacts of transfers out of agriculture cause increasingly negative impacts, sometimes approaching a "tipping point" at which agriculturally-related businesses begin to fail.

5. Recent experimental research on water markets (Goemans, DiNataly et al) shows that the markets for permanent transfers (water rights) and water rental markets interact. Where efficient , expeditious leasing arrangements are available, water rights prices are likely to be reduced since permanent transfers and leases are, to some extent, substitutes.