Denver Journal of International Law & Policy

Volume 6
Number 3 *Special Issue*
Water Needs for the Future

Article 30

January 1976

Denver's Successive Use Program

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Keywords
Water Law, Blood

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The Denver Water Department presently treats and delivers to the metropolitan area about 72 billion gallons of water each year. After serving a variety of purposes, about 40 percent of this water returns to the Platte River system through several sewage treatment plants. Under Colorado's appropriation doctrine, part of this return flow must remain in the river. A substantial part, however, of this now-wasted resource is available to the Department for successive uses.

Recognizing the potential of successive uses, the Denver Water Department began several years ago to investigate profitable possibilities. The Department conducted research into advanced wastewater treatment, investigated the economic and legal feasibility of water reuse, and studied marketing and public acceptance aspects of successive uses. This paper contains a summary of these studies and a description of the program developed as a result.

I. THE DENVER WATER SYSTEM

In order to understand the direction of Denver's successive use program, it is necessary to look at the Department's current water supply situation.

The safe annual yield of the Department's water supply system is approximately 300,000 acre-feet per year. Approximately 40 percent of this is obtained from Eastern Slope tributaries of the South Platte River. The remaining 60 percent of potential supply is derived from tributaries of the Colorado River by transmountain diversion. Recent Colorado Supreme Court decisions hold that return flow derived from the Eastern Slope must be returned to the river, but that the transmountain-diverted portion of Denver's supply is available to the City for successive uses. This situation is shown, in simplified form, in Figure 1. In actuality, the system consists of five major storage reservoirs totaling nearly one-half million acre-feet, four major trans-Continental Divide tunnels, and numerous canals, conduits, and intake facilities. Operation of

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the system not only supplies water for the Denver metropolitan area, but also incorporates water for fish flows, recreation, and joint uses with other public and private agencies.

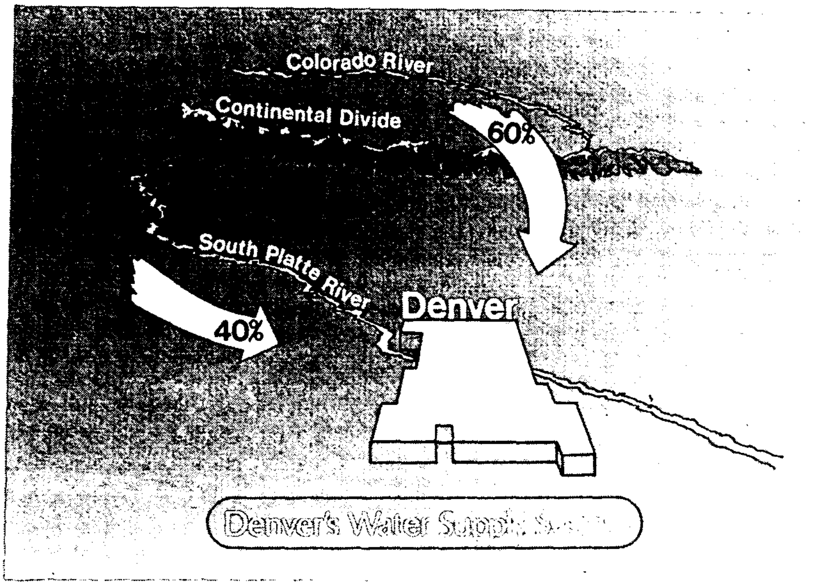


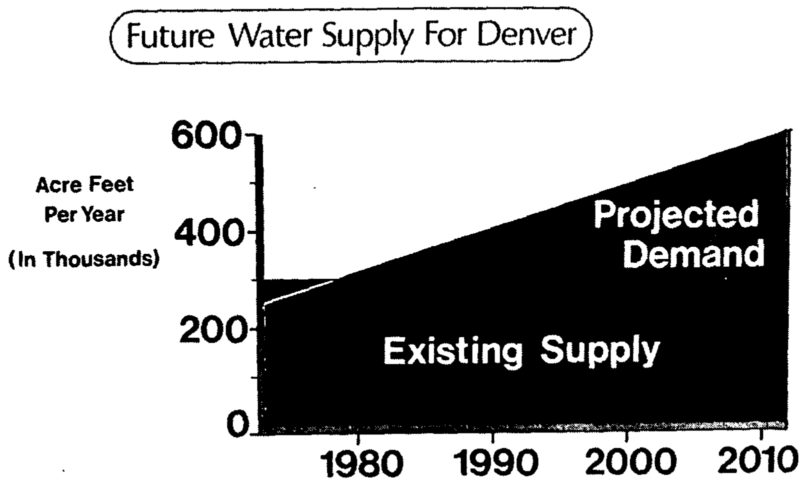
Figure 1.

Denver began operation of transmountain diversion projects in the 1930s in order to augment the Eastern Slope supply system. The most recent transmountain diversion consists of Dillon Reservoir and the 23-mile long Roberts Tunnel along with other facilities planned for development. As part of the court action granting Denver rights to build this project, the "Blue River Decree" effectively required that Denver investigate the possibilities of successive uses of Western Slope water.[1]

Figure 2 shows Denver's supply and demand situation. Supplies are presently adequate. The currently available 300,000 acre-feet will not meet demands beyond about 1980, however. Additional supplies will be needed, eventually doubling the Department's present capabilities. This water is available to the metropolitan area, but the costs of supplying

1. *In re* the Adjudication of Priorities of Water Rights in Water Dist. 36 for the Purposes of Irrigation, Civ. No. 5016 (D. Colo., Oct. 12, 1955); *In re* the Adjudication of Priorities of Water Rights in Water Dist. 36 for Purposes Other than Irrigation, Civ. No. 5016 (D. Colo., Oct. 12, 1955).

it will increase dramatically because of market factors, increasing distances from the City, lower elevations requiring pumping, and, most recently, various governmental constraints on development.



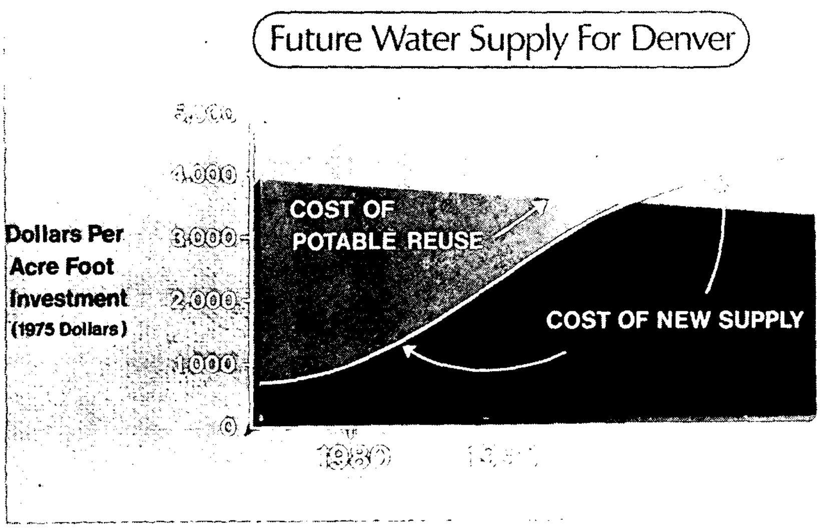


Figure 2

At some point in the future, the cost of treating sewage effluent, even to potable quality, will be competitive with the cost of developing new supplies. The exact date is uncertain, because potable reuse has never been tried in this country, but appears to be some time in the 1990s.

II. ALTERNATIVES FOR SUCCESSIVE USES

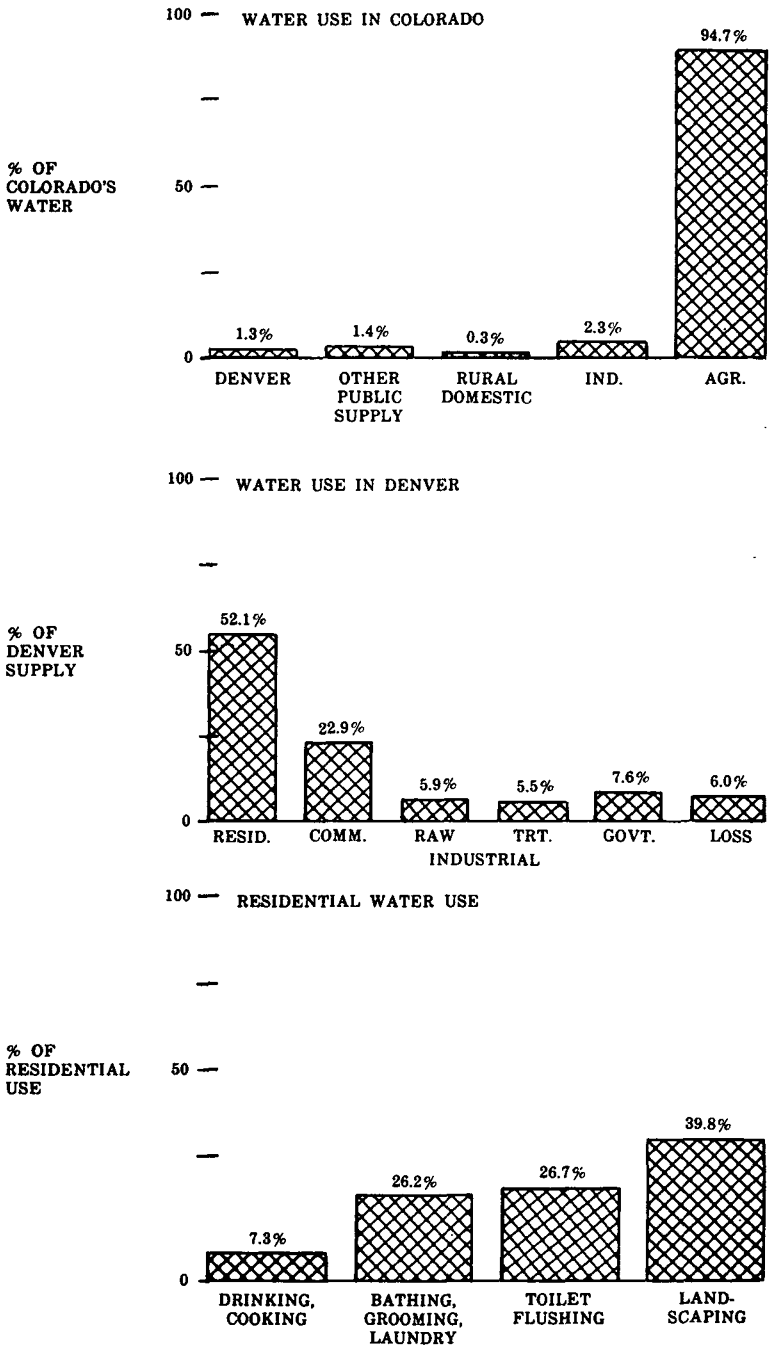
Potable reuse is not the only form of successive use available to Denver; it is simply the most demanding and expensive alternative. In order to place the various possible successive uses in perspective, Figure 3 illustrates the present use of water in the Denver system. The top figures indicate that Denver uses about 1.3 percent of the State's water. Agriculture uses about 94.7 percent. Unfortunately, the Blue River Decree has been interpreted as preventing Denver from utilizing its return flow for agricultural uses.[2] The middle portion of Figure 3 illustrates water use within the Denver Water Department's system. The majority of water (52.1 percent) goes to residential customers. Industry takes 5.5 percent of the system's water, and 7.6 percent goes to various governmental agencies for their use, including park and lawn irrigation. These latter uses of relatively small amounts of water are spread throughout the metropolitan area, making a second distribution system to serve less-than-potable-quality water economically infeasible. Within the home, only about 7.3 percent of Denver's residential water goes toward human consumption, while 39.8 percent is used in landscaping. This latter figure correlates to 21 percent of Denver's water or 27/100ths of one percent of the State's water.

With this background, it is possible to make some choices regarding the direction of Denver's successive use program. The various alternatives are shown in Figure 4. Exchange, the simplest successive use, involving no treatment and relatively low cost, is the most attractive. Denver intends to implement exchange, or the trading of used water at the sewage treatment plant outfall for less polluted water at the existing intakes, in the immediate future. Unfortunately the amount of relatively unpolluted water available in the South Platte River is severely limited, and exchange will not utilize all of the return flow

2. Note 1 *supra*.

FIGURE 3

TYPICAL WATER USE



resource available. Agricultural reuse may require some minimal treatment beyond that now applied depending upon the crop to be irrigated. Unfortunately this practice appears to be prohibited by the Blue River Decree. Industrial reuse and lawn and golf course watering with return flows require additional treatment and are uneconomical with the low, scattered demands found in the Denver area. Only the location of large, water-using industries in Denver would change this situation. Potable reuse is capable of utilizing the amounts of sewage effluent available and, as mentioned before, may be economically competitive with more conventional supplies some time in the future.

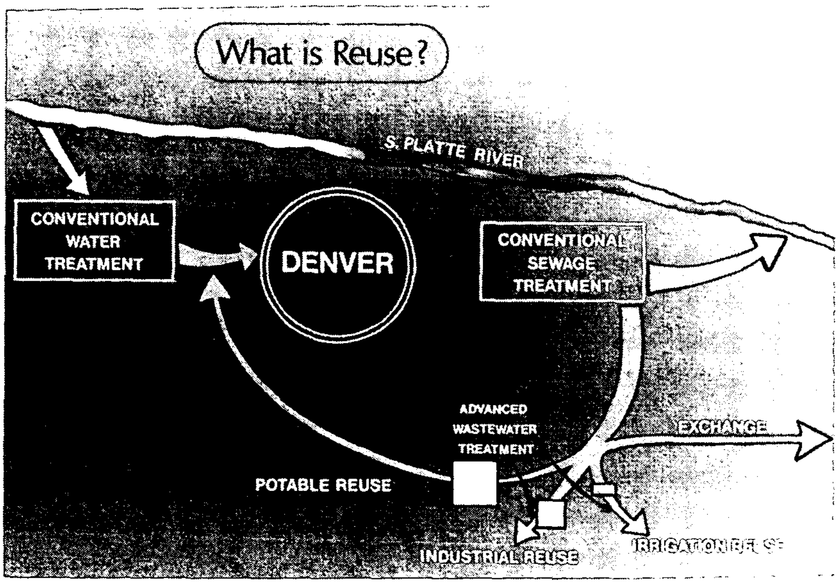


Figure 4.

Planned, conscientious potable reuse has never been practiced in this country. There exist many questions regarding the safety, acceptability, and legal and economic feasibility. Recognizing this, the Denver Water Department began investigating various aspects of potable reuse in the late 1960s. An advanced wastewater treatment pilot plant was constructed by a grant from the Federal Water Quality Administration (now EPA) through cooperative agreements with the University of Colorado. Since that time, the plant's processes have been upgraded, and it has served continuously as a laboratory for graduate student research operated jointly by the civil engineering department at C.U. and the Denver Water Department.

Recognizing the importance of an informed and approving public, the Denver Water Department has conducted an extensive public information program. In order to determine the success of this program, several surveys have been undertaken. The results of one survey, performed by contract in 1974, are shown in Figure 5. As with other surveys, the results indicate that Denver residents would accept potable reuse if the quality of the water were identical with that which they now receive.

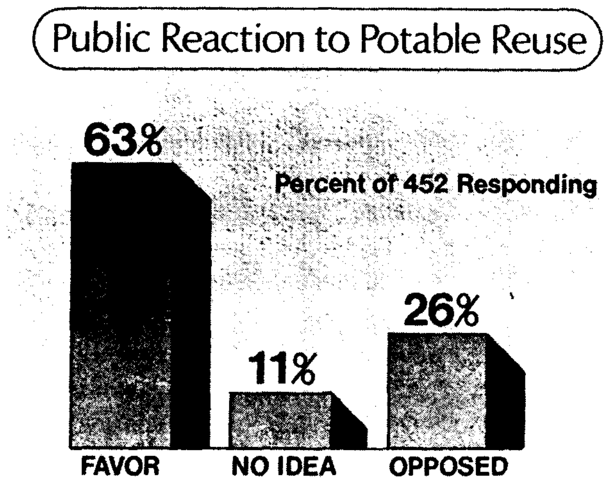


Figure 5.

III. DENVER'S DEMONSTRATION PLANS

Recognizing the importance of water quality in the public's mind, and noting a lack of national quality standards for water reuse, the Department has adopted a quality goal of equivalency with existing potable water. Advanced wastewater treatment will have to remove the "use increment," or the amount of each pollutant added between water supply intake and wastewater discharge, in order to meet this goal, as shown in Figure 6. Since no precedent exists for direct potable reuse and since many questions remain unanswered, a 5- to -10-year demonstration of appropriate treatment processes is planned. Interim recreational use and extensive health and quality testing will accompany this demonstration.

POTABLE REUSE DEMONSTRATION PLANT
QUALITY GOALS

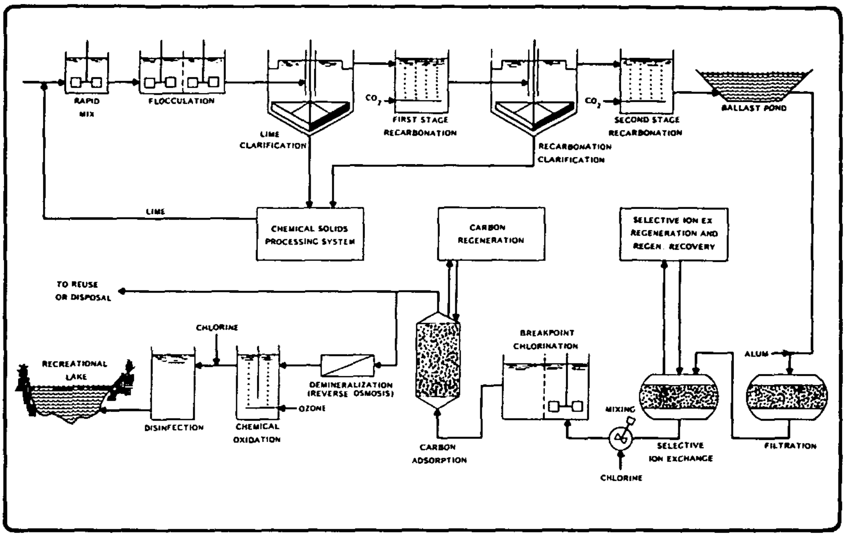
VIRUS, PATHOGENIC BACTERIA, HARMFUL ORGANICS	NONE PRESENT
TRACE METALS, INORGANICS, ORGANICS, NUTRIENTS, BACTERIA	AT OR BELOW EXISTING POTABLE WATER QUALITY

EXAMPLE

TDS	157
Hardness	88
Suspended Solids	0.0
COD	<5.0
Turbidity	0.6 units

Figure 6.

In December 1975, the Department hosted a one-day design seminar at which national experts of advanced wastewater treatment and reuse health effects advised Denver and its engineering consultants on a proper process train for the demonstration project. This information was turned over to the design firm of CH_2M-Hill Engineers who prepared a conceptual design of the plant in August of 1975. As shown in Figure 7, the treatment train will link several processes in series to accomplish the quality goal. Lime will be added to raise the pH, precipitate phosphorus and heavy metals, and reduce suspended solids. Following two-stage recarbonation to remove the flocculated material and lower the pH, the water will enter a holding pond followed by conventional multimedia filtration to finish suspended-solids removals. Selective ion exchange and breakpoint chlorination will be utilized to reduce ammonia-nitrogen concentrations and disinfect the water. The flow will then enter carbon adsorption columns for organic removal. Lime, the ion exchange regenerant, and activated carbon will all be regenerated and reused in the processes. For economic reasons, only part of the flow stream will proceed to the remainder of the treatment processes. Reverse osmosis, a desalting process, will be used to reduce dissolved solids; ozonation will be utilized to disinfect the water and polish organic removals; and chlorination will serve to provide a residual disinfectant. Extensive quality and health tests will then be performed with the effluent flowing to a recreational lake and eventual industrial use.



Process Flow Diagram

Figure 7.

IV. PROGRAM

As shown in Figure 8, the Department's current plans call for designing the demonstration plant in 1977 with construction to be complete by 1980. Operation of the plant will progress for perhaps 10 years, accompanied by extensive quality and health testing. If all goes well, a full-scale plant could be on line in the early 1990s.

The consultants estimate that the plant will cost 8.39 million dollars. This capital expenditure, coupled with other parts of the successive use program will cost in excess of 100 million dollars over the next 20 years. As shown in Figure 9, in addition to the demonstration plant capital cost, 6.48 million dollars will be spent on its operation and 1.1 million dollars on parts of the program common to both reuse and exchange, such as legal work, a quantity accounting system, and public relations. A reservoir to facilitate exchange operations will cost about 8.7 million dollars. Depending upon the results of the demonstration, a full-scale plant of approximately 100 MGD capacity will cost somewhere between 95 and 150 million dollars.

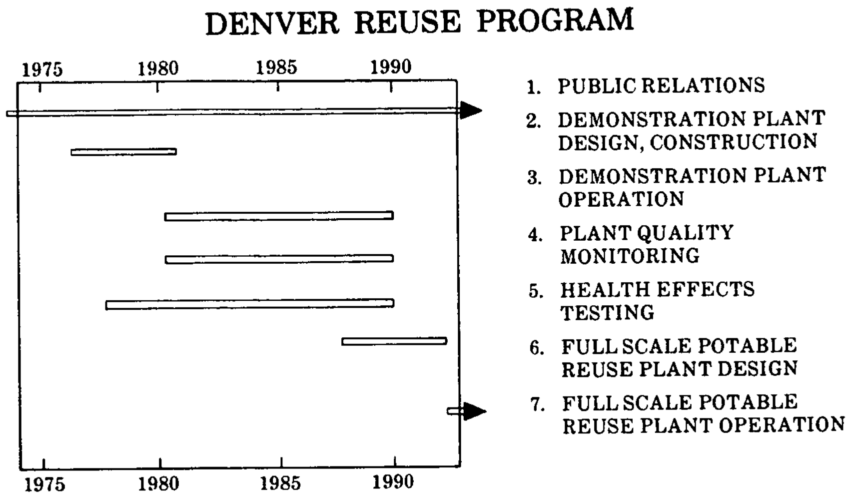


Figure 8.

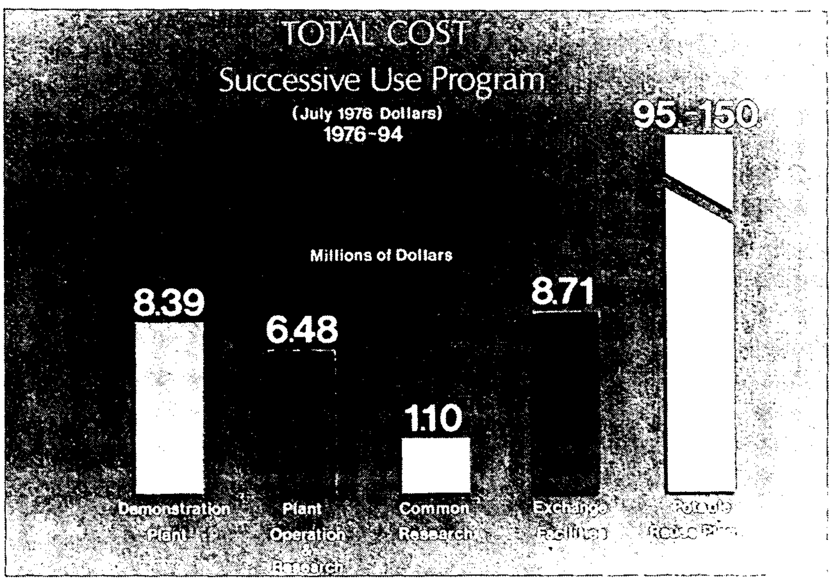


Figure 9.

V. SUMMARY

In summary, the Denver Water Department has been investigating the possibility of utilizing a once wasted resource. Extensive marketing, legal, economic, and technical investigations have led to a program which could add significant quantities of water to the Denver metropolitan area before the end of this century. The potential of successive use is limited, however, because only return flows derived from transmountain diversions are available for exchange or reuse. Successive use, therefore, must be considered as part of an overall program of water supply development including conservation and conventional supply alternatives.