STATE OF COLORADO

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October 17, 1997

MEMORANDUM

TO: South Platte Water Users

FROM: Hal D. Simpson, State Engineer
Daries C. Lile, Director, Colorado Water Conservation Board

SUBJECT: Senate Bill 96-74, Section 3; Denver Basin and South Platte Basin Technical Study

The draft Denver Basin and South Platte Basin Technical Study is attached for your review and comment. The report contains a substantial amount of technical data and analysis, however, we have provided a summary of the information in Chapters 1 through 14. We suggest an initial review of these chapters will provide an effective overview of the study and allow you to focus your energy in the specific areas of interest.

The Study has been provided to the peer review groups and is available at eight libraries throughout the basin.

Please contact us if we can provide clarification and/or further information regarding the status or content of this study.

Denver Basin and South Platte River Basin Technical Study

Senate Bill 96-074

Draft Report

Prepared for the

Special Water Committee

Prepared By

Hal D. Simpson
State Engineer
and
Chuck Lile
Director, Colorado Water Conservation Board

September 1997

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3. Volume 3 - Study tasks SB 96-74 Section (4) i (I) and i (III) with peer review comments and discussion.

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GLOSSARY

acre-foot (ac-ft) – The quantity of water required to cover one acre to a depth of one foot (equivalent to 43,560 cubic feet or 325,851 gallons).

aquifer – A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield sufficient quantities of water to wells or springs.

beneficial use – Application of water of the State of Colorado which is publici juris by an individual user for human benefit. For statutory specifics, see Section 37-92-103 (4), C.R.S.

cell – A block in a three dimensional mathematical mesh used to subdivide an aquifer system.

conductance – The product of hydraulic conductivity and cross sectional area divided by the length of the flow path.

confined aquifer – An aquifer in which an artesian water body is present. The water level in a well completed in a confined aquifer will be above the top of the artesian water body.

confining unit – A body of "impermeable" material stratigraphically adjacent to one or more aquifers. Although a confining unit may have very small permeability, it may store substantial volumes of water, which may flow to adjacent aquifers under a sufficiently large hydraulic gradient.

compact – A contract between states of the union, entered into with the consent of the National Government, and in water, defining the relative rights of two (2) or more states on an interstate stream to use the waters of that stream.

cubic feet per second (cfs or ft^3/s) – The rate of discharge representing a volume of one cubic foot passing a given point during one second (equivalent to 7.48 gallons per second, 448.8 gallons per minute, or 1.98 acre-feet per day).

deep percolation – The volume of water from precipitation or irrigation that infiltrates the soil and moves by the force of gravity to the water table.

designated ground water basin – An area in which ground water in its natural course would not be available to and required for the fulfillment of decreed surface rights, or ground water in areas not adjacent to a continuously flowing natural stream wherein ground water withdrawals have constituted the principle water usage for at least fifteen years.

drawdown – The difference between the original water level and the water level after a period of pumping.

head – Hydraulic head. Head is used generally to express a water level.

hydraulic conductivity – The volume of water at existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow through a porous material.

hydraulic gradient – The change in static or hydraulic head per unit of distance in a given direction.

infiltration – The downward flow of water under the force of gravity into the soil or rock.

node – The point in the model cell at which the head is calculated.

potentiometric surface – A surface to which water will rise in a well with perforated casing installed below the confining unit of a confined aquifer.

primary storage coefficient – A model term that is equal to specific yield if the aquifer is unconfined or is otherwise equal to the storage coefficient. The term is only used in a transient simulation.

pristine – The original condition of an early period or earliest period; still pure; unspoiled; uncorrupted.

recovery – A rise of the potentiometric surface or water table due to decreased discharge from, or increased recharge to, the ground water reservoir.

saturated thickness – The vertical height of water bearing material under pressure greater than atmospheric.

second foot, cfs or cubic foot per second – A rate of flow of water passing a given point so as to amount to a volume of 1 cubic foot for each second of time.

secondary storage coefficient – A model term that is always equal to specific yield. The term is used instead of the primary storage coefficient when an aquifer converts to unconfined conditions. The term is only used in a transient simulation.

Senate Bill 5 (SB 5) – Enacted in 1985, amongst other things, defined non-tributary (NT) and not-non-tributary (NNT) ground water terms. It provided the requirement to replace 4% of the amount of water withdrawn on an annual basis for wells withdrawing NNT ground water and relinquish 2% of the amount of water withdrawn on an annual basis for wells withdrawing NT ground water. It also provided the requirement to replace actual depletions for wells withdrawing NNT ground water from the Dawson aquifer

specific yield – The ratio of the volume of water which the rocks or soil, after being saturated, will yield by gravity to the volume of the rock of soil.

steady state – Equilibrium conditions when hydraulic heads and the volume of water in storage do not change significantly with time.

storage coefficient – The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

stream-aquifer system – A stream and alluvial aquifer in hydraulic connection such that there may be an interchange of surface and ground water.

stress period – A period of time represented in the model during which stresses input to the model such as pumping and precipitation recharge are held constant.

transient state – Non-equilibrium conditions when hydraulic heads and the volume of water in storage do change significantly with time.

transmissivity – The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

trans-basin -- The removal of the water of a natural stream from its natural basin into the natural basin of another stream.

trans-mountain -- The removal of water from one general stream system to another general stream system, usually from the western slope to the eastern slope.

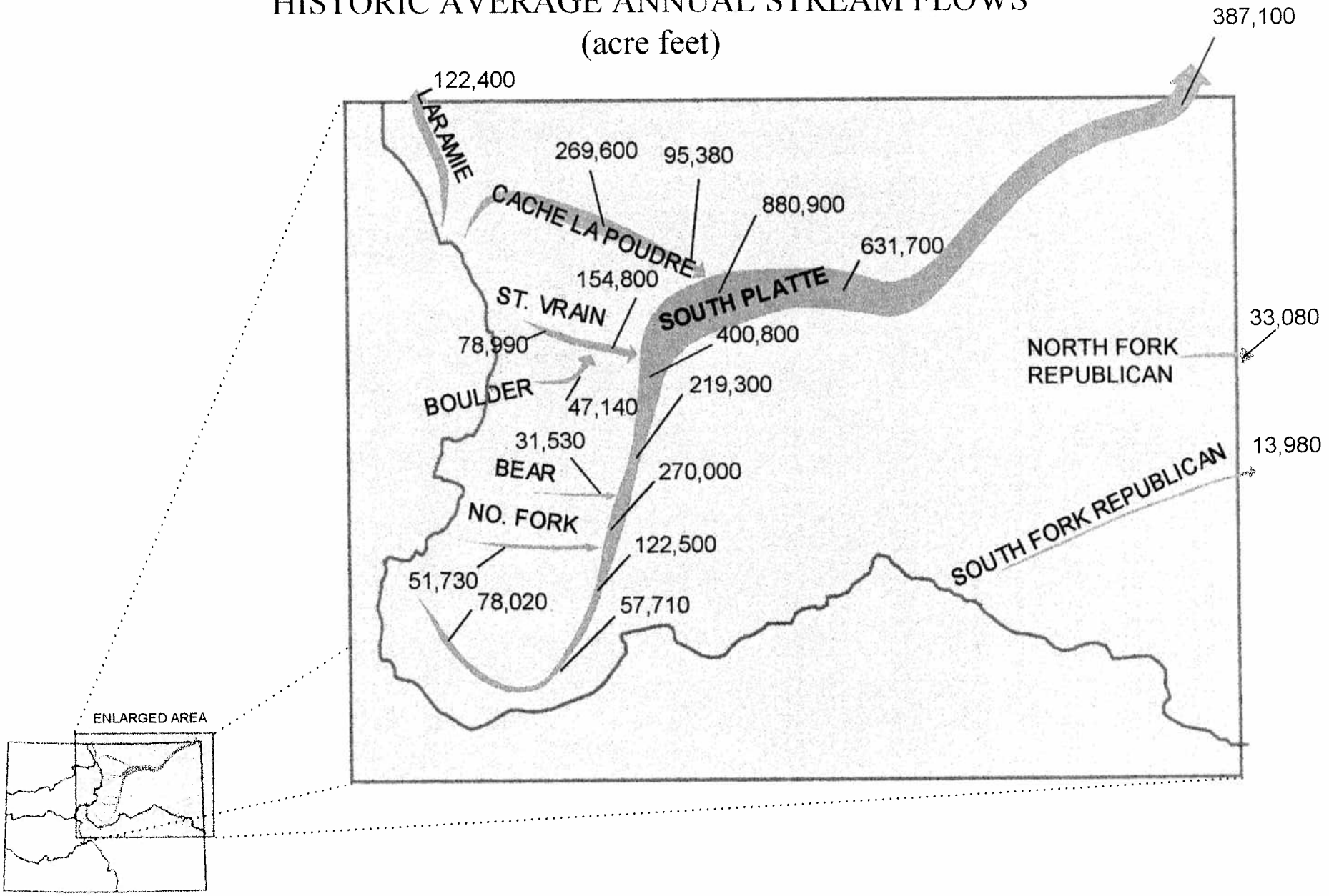
tributary drainage -- The area from which water drains by gravity into a water course.

unconfined aquifer – An aquifer in which a water table body is present.

water table – The surface in an unconfined water body at which the pressure is atmospheric.

water right – A property right to make a beneficial use of a particular amount of water.

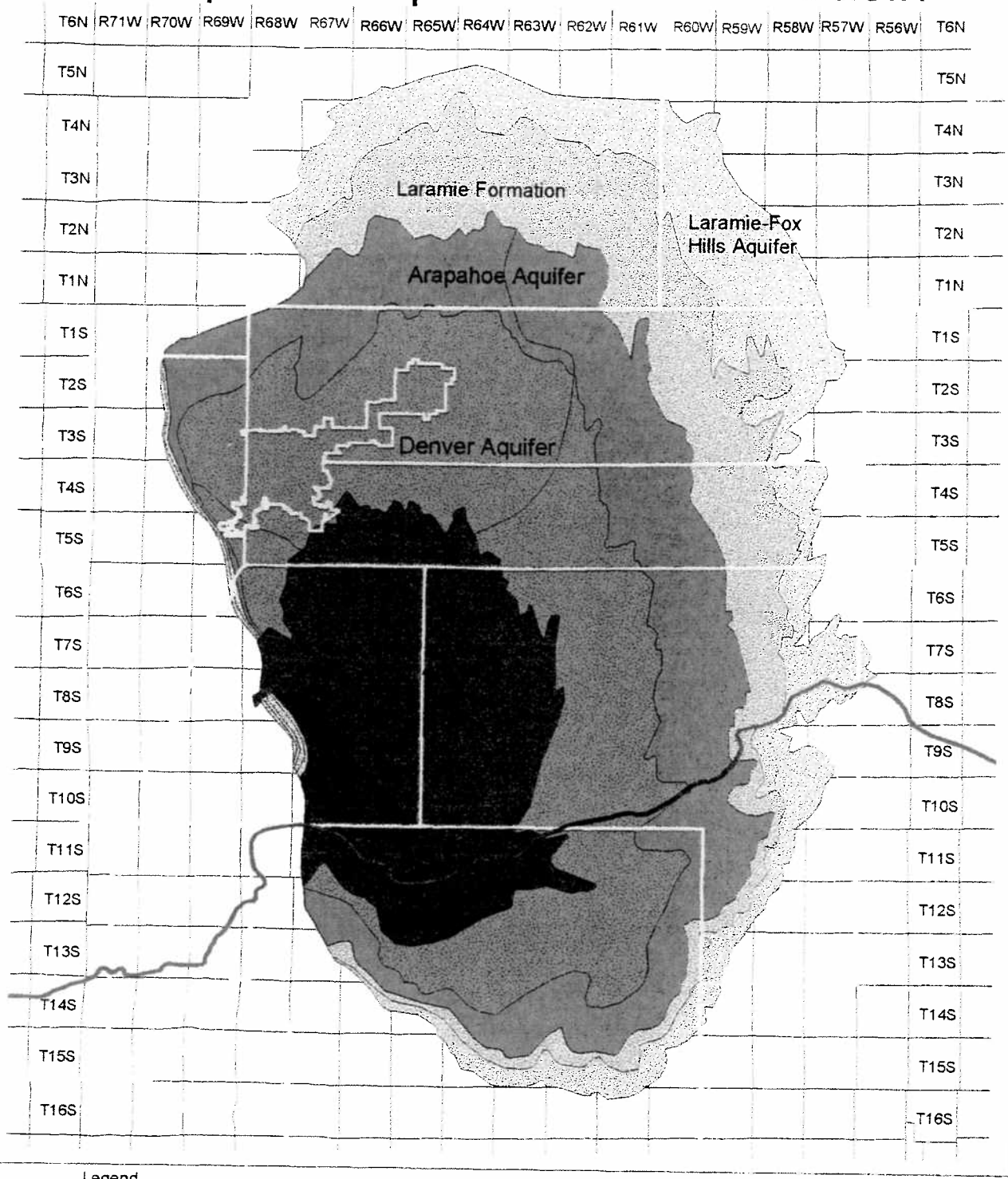
SOUTH PLATTE RIVER BASIN
HISTORIC AVERAGE ANNUAL STREAM FLOWS
(acre feet)



Prepared by the Hydrographic Branch (1995)
Historic averages obtained from USGS Water-Data Report CO-93

OFFICE OF THE STATE ENGINEER
COLORADO DIVISION OF WATER RESOURCES

Aquifer Map of the Denver Basin



Legend

Denver Basin Aquifer
- Arapahoe Aquifer
- Denver Aquifer
- Fault
- Laramie Formation
- Laramie-Fox Hills Aquifer
- Lower Dawson Aquifer
- Upper Dawson Aquifer
- Township/Range

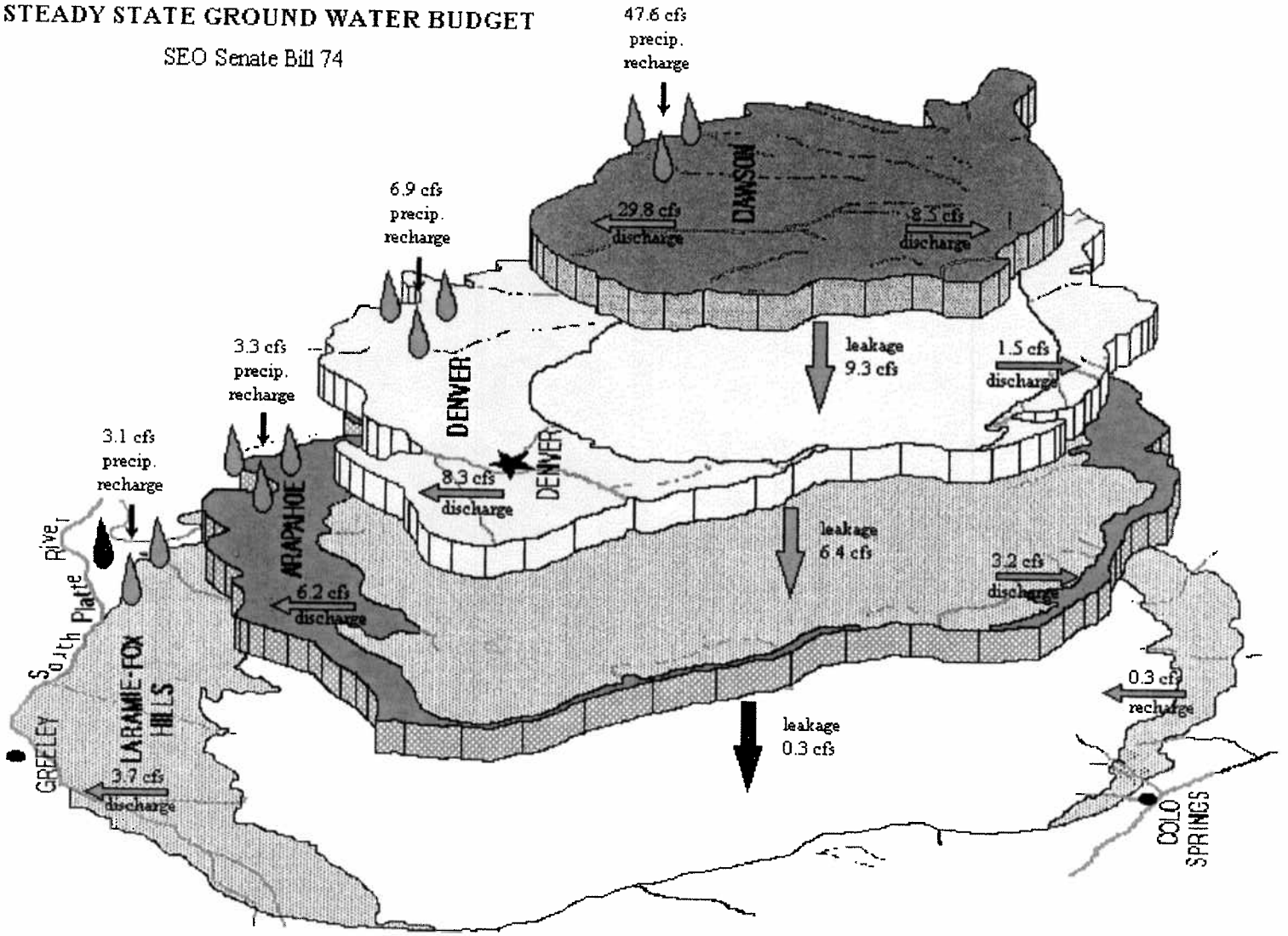
Division Boundary
County Boundary

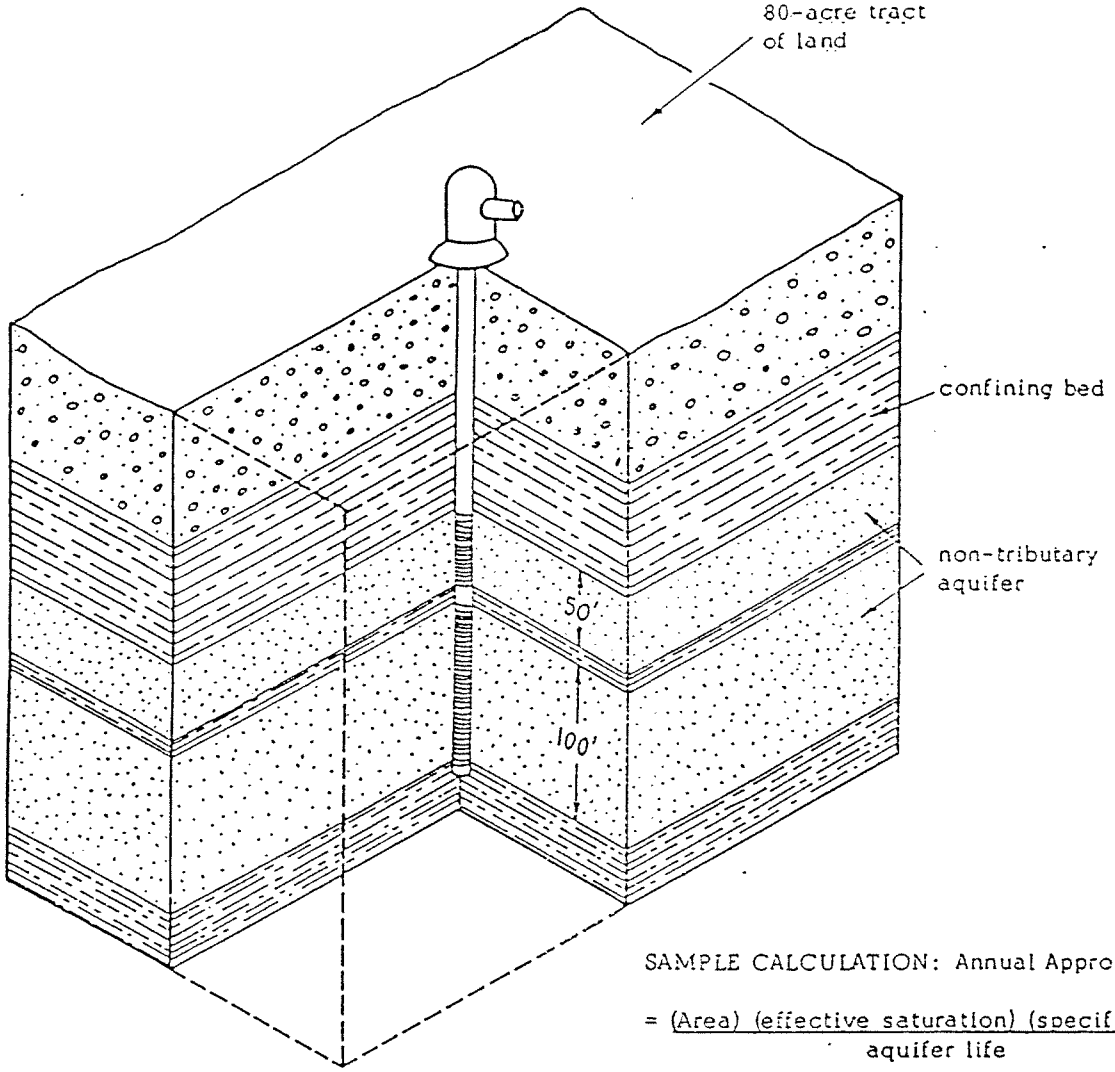
WATER RESOURCES

DENVER BASIN

STEADY STATE GROUND WATER BUDGET

SEO Senate Bill 74





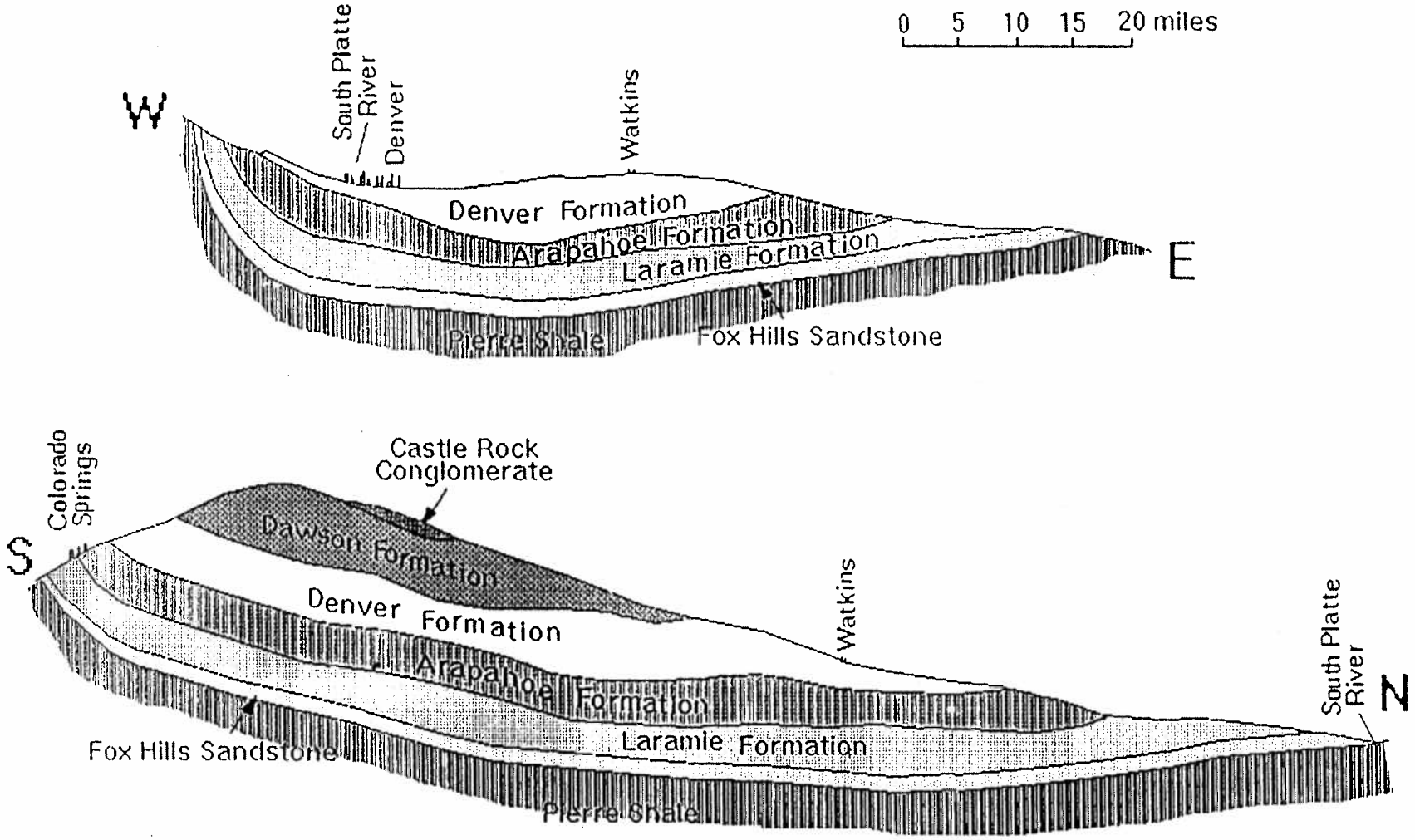
SAMPLE CALCULATION: Annual Appropriation

$$= \frac{\text{(Area) (effective saturation) (specific yield)}}{\text{aquifer life}}$$

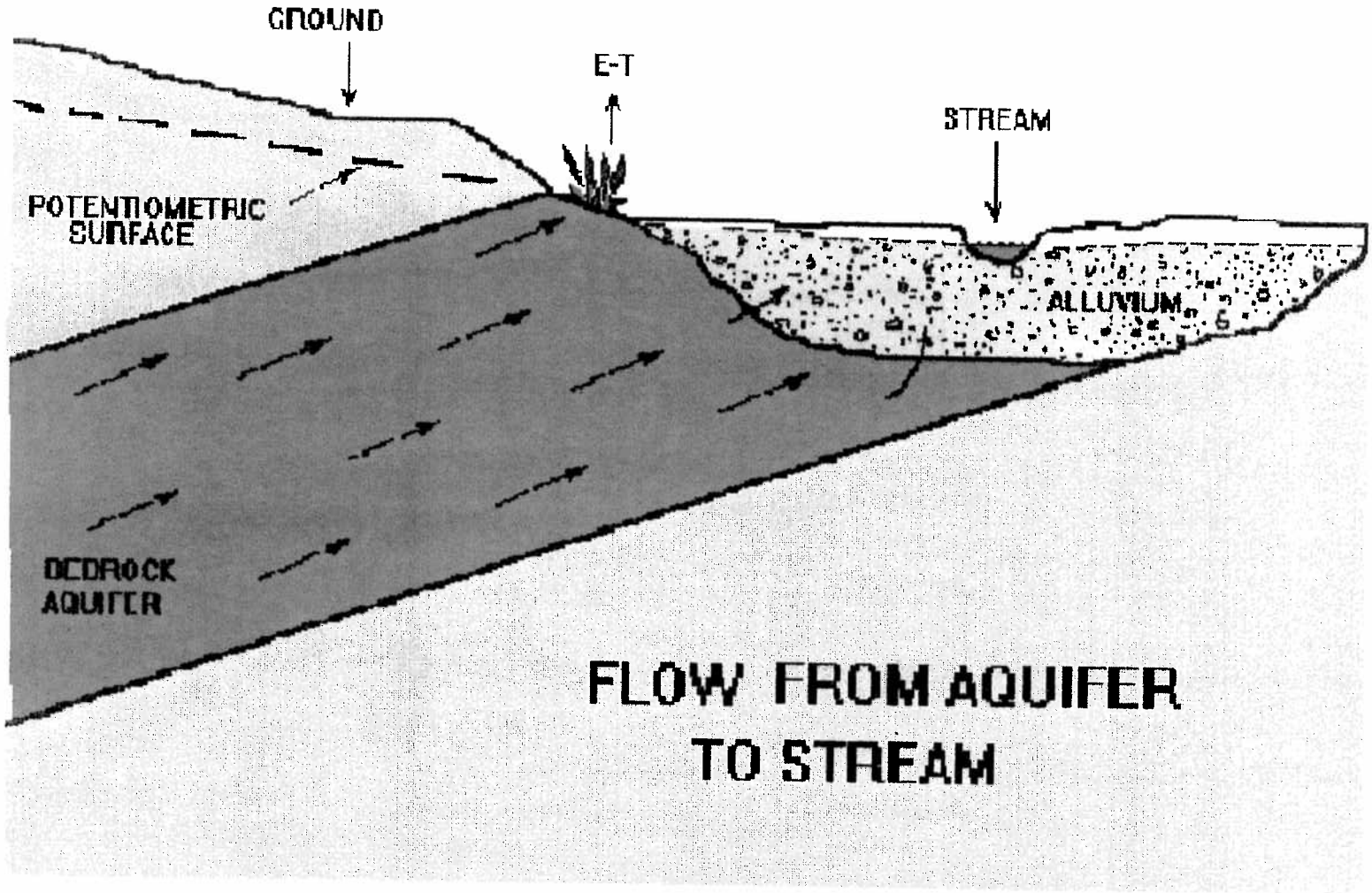
$$= \frac{\text{(80 acres) (150 feet) (.20)}}{\text{100 years}}$$

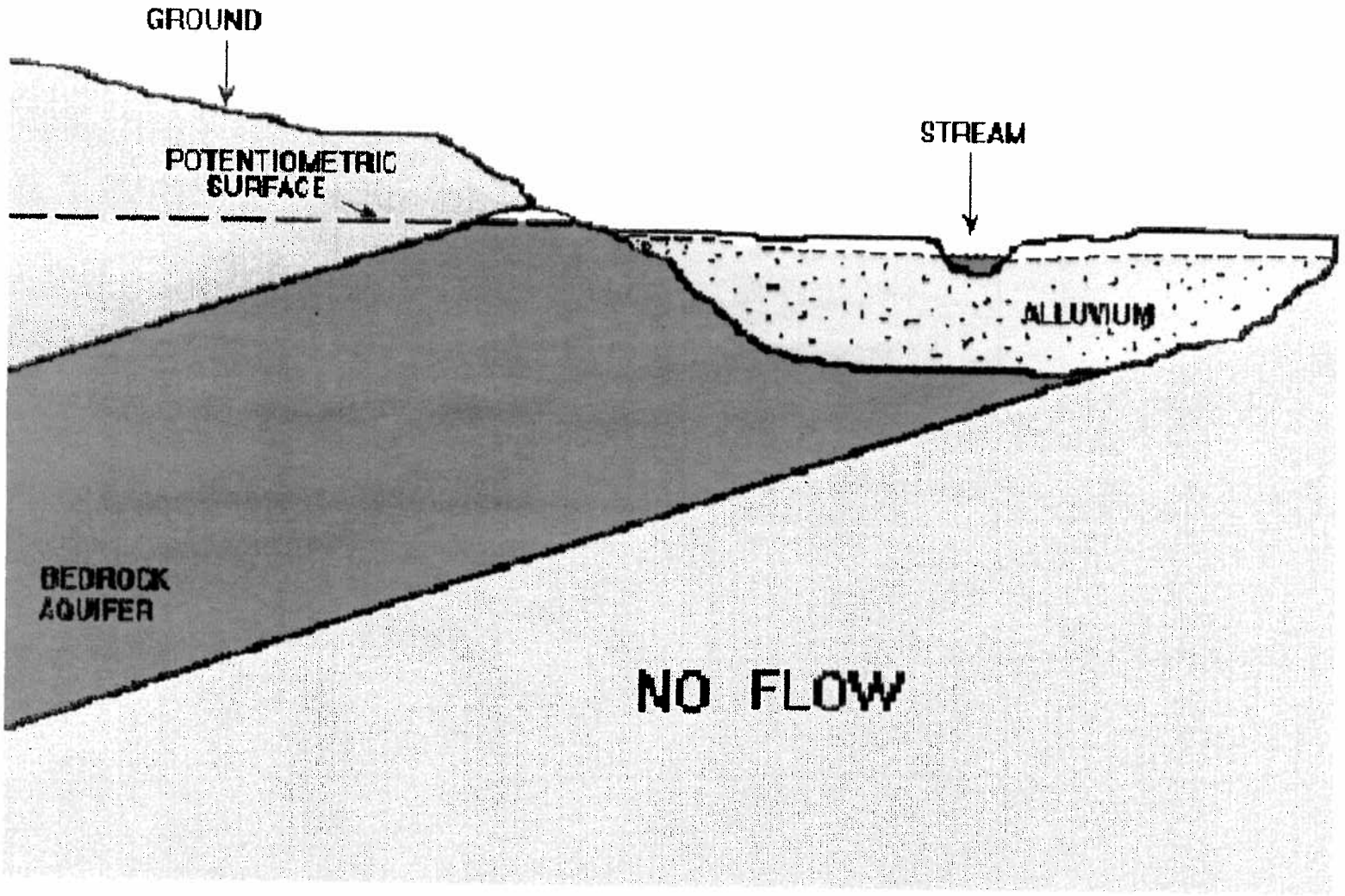
$$= 24 \ \frac{\text{acre-feet}}{\text{year}}$$

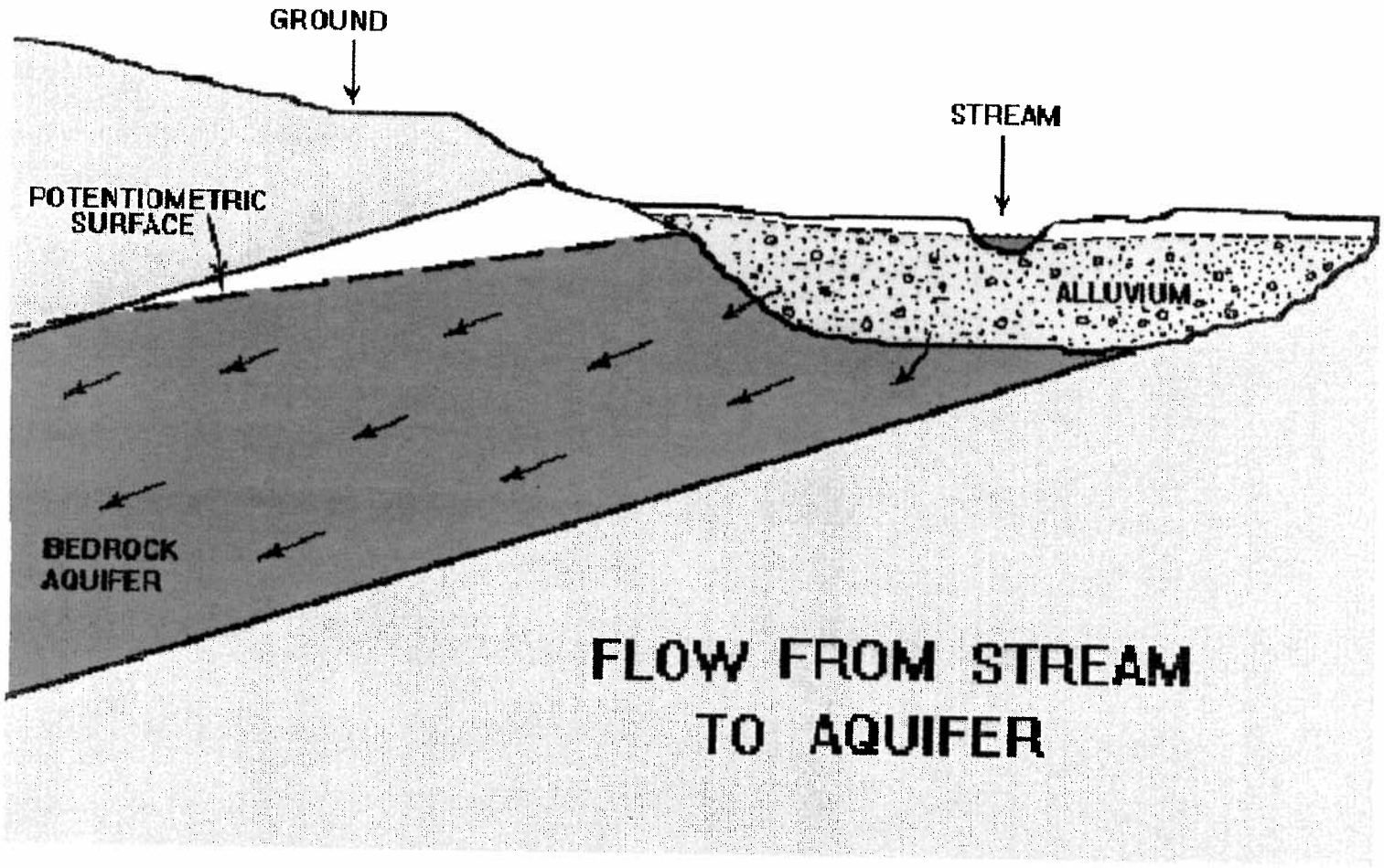
DETERMINATION OF APPROPRIATION
IN NON-TRIBUTARY AQUIFERS

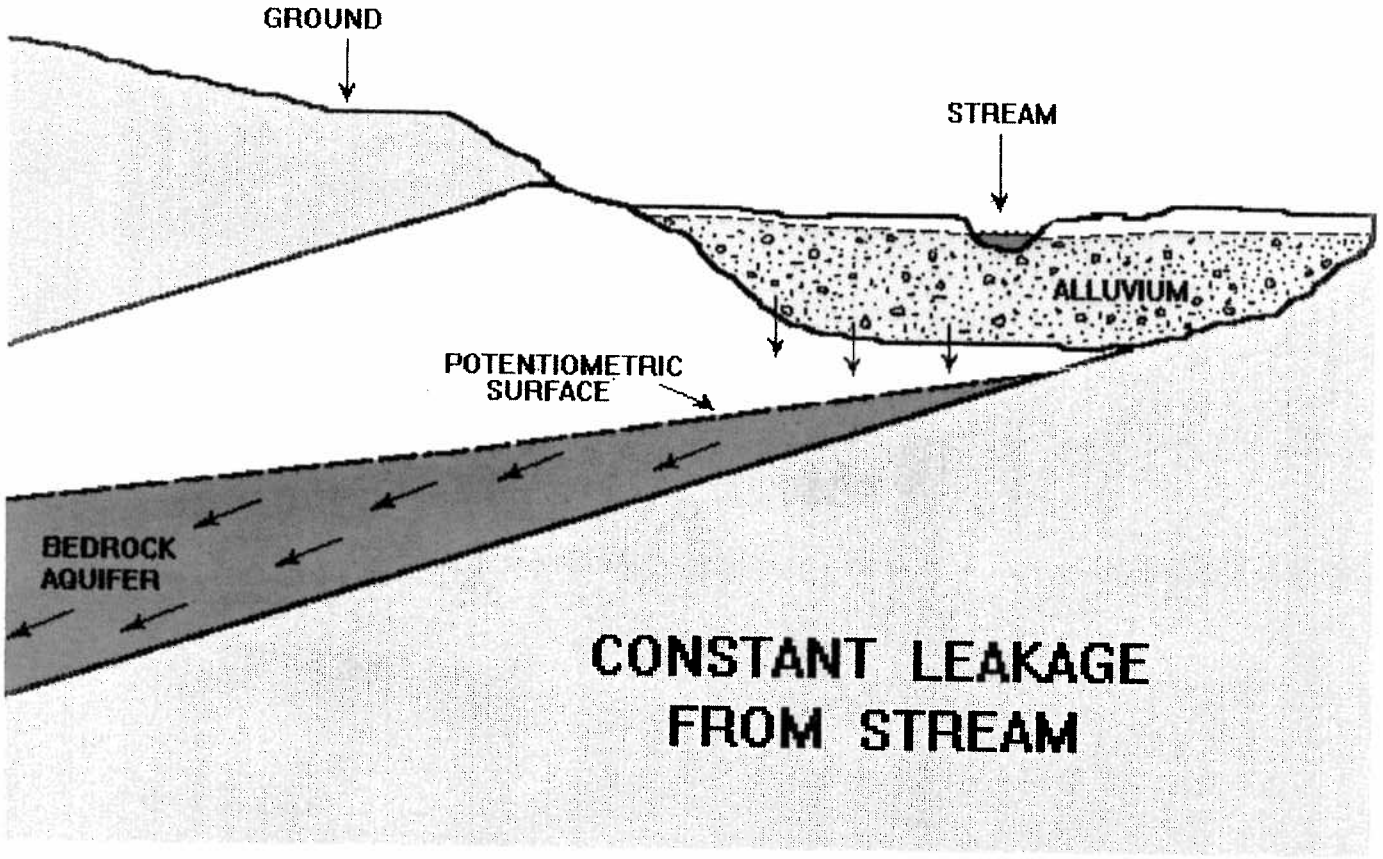


GENERALIZED GEOLOGIC SECTIONS THROUGH THE DENVER BASIN


GROUND
E-T
STREAM
POTENTIOMETRIC SURFACE
ALLUVIUM
BEDROCK AQUIFER
FLOW FROM AQUIFER TO STREAM


GROUND
POTENTIOMETRIC SURFACE
STREAM
ALLUVIUM
BEDROCK AQUIFER
NO FLOW


GROUND
STREAM
POTENTIOMETRIC SURFACE
ALLUVIUM
BEDROCK AQUIFER
FLOW FROM STREAM TO AQUIFER


GROUND
STREAM
ALLUVIUM
POTENTIOMETRIC
SURFACE
BEDROCK
AQUIFER
CONSTANT LEAKAGE
FROM STREAM

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1.0 INTRODUCTION AND STUDY BACKGROUND

The 1996 General Assembly in Senate Bill 96-74 authorized establishment of a Special Water Committee (SWC) of nine legislators to investigate Denver Basin ground water management and South Platte River Basin issues. The Committee's consideration of these issues will be assisted by this technical study which was administered by the State Engineer and the Director of the Colorado Water Conservation Board (CWCB Director) which was also authorized in SB 96-74.

1.1. SPECIAL WATER COMMITTEE

The Special Water Committee consists of:

Representative Jeanne Adkins
Representative Ken Gordon
Representative Marilyn Musgrave
Representative Jack Taylor
Representative Brad Young

Senator Don Ament, Chairman
Senator Joan Johnson
Senator Richard Mutzebaugh
Senator Ed Perlmutter

The specific responsibilities of the Committee as set forth in the legislation include:

1. Define the scope of a technical study of issues to be administered by the State Engineer and the CWCB Director prior to the commencement of the study.

2. Hold public hearings on the draft report submitted by the State Engineer and CWCB Director.

3. Review and comment on the draft report.

4. Review and comment on the evidence and comments received at public hearings prior to issuance of the final report.

5. Make recommendations, if deemed necessary, for legislation based on the final report and public hearings.

1.2 RESPONSIBILITIES OF THE STATE ENGINEER AND CWCB DIRECTOR

The State Engineer and CWCB Director are directed to administer a study of issues enumerated in subsection (4) of section (3) of the statute. The progression of specific responsibilities of the State Engineer and the CWCB Director is as follows:

1. Submit the scope and methodology of the study to the Committee before commencement of the study.

2. Consult with affected interests and consider existing information throughout the study.

3. Subject each phase of the study to peer review and written comments by the members of several professional disciplines.

4. Begin the study no later than August 1, 1996.

5. Use data and information from previous and existing studies.

6. Use latest methodologies, including hydrologic modeling, to develop the information for the report.

7. Report the results to the Committee no later than June 1, 1997.

Because the statute states the specific items to be studied in very broad terms, it is the judgment of the State Engineer and the CWCB Director that the technical study will be most useful to the Special Committee if the scope and methodologies are the product of a consultative process among the Committee members, state agency personnel, and interested members of the public. This Draft Preliminary Scope of Work and Workplan therefore proposes a procedure that is intended to promote such a consultative process.

1.3 PRELIMINARY SCOPE OF WORK AND WORKPLAN

The issues to be studied are set forth in SB 96-74, subsection (4) of section (3) in subparagraphs (a) through (i). These subparagraphs are excerpted from the statute and repeated below for the reader's convenience:

(a) *An inventory of surface water and groundwater resources in the South Platte River Basin;*

(b) *The effect of existing efficiencies and conjunctive management of surface water and groundwater resources on future supply and on local and regional existing water rights above the Henderson gauge;*

(c) *The effect of existing water reuse on future supply and on existing water rights;*

(d) *A review of distribution system infrastructure in the Denver metro area to identify ways to promote maximum utilization of the water resources available to the South Platte Basin above the Henderson gauge;*

(e) The effect on existing water rights of current recharge technology and practices in Denver Basin aquifers;

(f) The impact of de minimis standards for injury based upon an annual depletion standard;

(g) The effect of the four percent replacement and the two percent relinquishment requirements of current law on future water supplies and on existing water rights and the need for placement of post pumping depletions resulting from withdrawal of Denver Basin groundwater.

(h) Use of nontributary groundwater and its long-term impact on water rights; and

(i) An assessment of:

(I) The need for and scope of participation, including financial participation, by the State of Colorado in processes associated with the implementation of the federal "Endangered Species Act of 1973" 16 U.S.C. Sec. 1531, et seq., as amended, with respect to the exercise of water rights associated with water resources and the South Platte River Basin and the Denver Basin;

(II) Opportunities for the application of local and regional water use efficiency and reuse technologies and methods, in conjunction with additional water supply sources, to enhance the reliability and yield of water rights associated with the water resources of the South Platte River Basin and Denver Basin;

(III) Surface and groundwater development in the Lower South Platte River in accordance with the South Platte River Compact.

The issues to be analyzed are broadly stated and could be approached analytically in many different ways. Since fiscal and human resources are very limited, the Committee held an initial "scoping" meeting at which the State Engineer and the CWCB Director presented options for accomplishing the study.

The State Engineer and CWCB Director developed a final scope of work and workplan, considering the guidance provided by the Committee, as well as an assessment of the time and resources available to complete the specified work.

1.4 STUDY METHODOLOGY

The methodologies employed in the study reflect the legislative direction embodied in SB 96-74, while taking into account available fiscal and human resources and time limitations. SB 96-74 contained no appropriations for conducting the technical study. Therefore, as recognized in the text of SB 96-74, it was very important to use data and information from past and existing studies and information sources to minimize study costs and reduce the time necessary to complete certain tasks.

During the discussions on the final language in SB 96-74, it was indicated that a portion of unused funds appropriated in the CWCB's Construction Fund in 1994 for acquisition of data and information in the South Platte River Basin may be available for this related study of issues affecting water rights and water resources management in the South Platte River Basin. The State Engineer and the CWCB Director used these funds to leverage existing investments by the State of Colorado in the Metropolitan Water Supply Investigation (MWSI), which developed extensive information and modeling capability that relates very closely to the issues defined in subsections 4(a) through (e), and (I) (II).

With respect to issue (4) (f), the State Engineer and CWCB Director invited interests to present their perspectives at a public meeting concerning *de minimis* standards for an annual depletion. Staff reviewed case law and related policy to offer a possible *de minimis* standard for consideration by interested members of the public and the Committee. A recommendation and rationale concerning an appropriate *de minimus* standard will be provided to the Committee in the draft report.

With respect to issue (4) (g), the State Engineer and the CWCB Director reviewed current law concerning the four percent replacement and two percent relinquishment requirements at public meetings where affected interests were encouraged to present their views. In particular, parties involved in the negotiations resulting in the current law (SB 85-5) present their understanding for the basis of the current law. Staff of the State Engineer developed an improved ground water model and reviewed previous studies to evaluate the assumptions in the current law with respect to assumed aquifer conditions. The intent is to determine if the four percent replacement requirement for not non-tributary ground water pumping is appropriate.

With respect to issue (4) (h), determinations regarding the long-term impacts on water rights of Denver Basin ground water pumping likely will require the use of current ground water models and existing information to look at impacts several hundred years into the future. Considerable input from affected interests is desired with opportunities for discussion of model data and results of the models along with review of comments provided in the peer review process. It is expected that the results of a related ongoing study, known as the Economic Life of the Denver Basin Aquifers will be used to assist with completing this portion of the overall study.

The assessment required under subsection (4) (i) (I), which deals with appropriate responses to the Endangered Species Act of 1973 and its impact on current and future water resources management, will be accomplished by the various water suppliers that make up the Platte River Project.

The assessment required under subsection (4) (i) (III), which considers additional water resources development in the Lower South Platte River, will be accomplished by the Lower South Platte River Group, Inc. This organization has received a grant of $75,000 from the CWCB Construction Fund for FY 97 to evaluate water development opportunities in the Lower South Platte River. This evaluation is to be completed by July of 1997.

2.0. INVENTORY OF SURFACE WATER AND GROUNDWATER RESOURCES IN THE SOUTH PLATTE RIVER BASIN

This chapter provides an inventory of the surface water and nontributary groundwater resources of the South Platte River Basin in Colorado. The purpose of this inventory is to provide a framework for understanding the "big picture" interrelationships between South Platte surface water and groundwater resources and various conservation, reuse, groundwater development and conjunctive use options being considered by Denver area water providers.

2.1 SURFACE WATER RESOURCES

As part of the surface water resources inventory for the Denver Basin and South Platte River Basin Technical Study, flow data has been developed for five key gage locations in the South Platte River basin. These locations include:

- South Platte at South Platte
- South Platte Below Chatfield
- South Platte At Denver
- South Platte at Henderson and
- South Platte at Kersey

For most of these locations preliminary estimates of the following have been developed:

- Natural flows
- Historical flows
- Future flows
- Reusable return flow portions of historical and future flows
- Undeveloped (free water) portions of historical and future flows

Based on the availability of data, Hydrosphere have developed these estimates for the 1950 through 1980 period of hydrologic record.

Natural Flows

For the purposes of this study, natural flows are defined as the surface water flows that would occur without the influence of human activities.

Future Flows

For the purposes of this study, future flows are defined as those flows which reflect "reasonably certain" future conditions with respect to municipal and industrial water supply system development and associated water demands within the South Platte River basin.

2.2 SOUTH PLATTE, CHATFIELD, DENVER AND HENDERSON GAGES

For the South Platte, Chatfield, Denver and Henderson gage locations Hydrosphere relied on output data from Denver Water's PACSM model reflecting Denver's Baseline Near Term (Baseline NT) modeling scenario. This scenario reflects the operation of Denver's water supply system at an annual raw water demand of 390,000 acre feet. This is the demand level that Denver's system will be capable of reliably meeting with the addition of several near term future measures including additional effluent exchanges, water conservation programs, nonpotable reuse projects and other minor supply-side additions. Denver expects that its service area demands will take at least 30 years to reach this level. By comparison, Denver's current raw water demand is approximately 275,000 acre feet per year. Denver's Baseline NT scenario also generally reflects future water demands and water supply system operations for Aurora, Thornton, Englewood and Centennial Water & Sanitation District. Increased levels of municipal return flows as well as diversions are reflected in this scenario.

Denver's Baseline NT modeled stream flows do not reflect three potentially significant factors: 1) runoff from impervious surfaces and lawn irrigation return flows derived from increased urbanization of the metro Denver area beyond levels that existed during 1947 through 1991; 2) increased future wastewater flows from Cherry Creek, Plum Creek and Clear Creek; and 3) exercise of certain junior water rights on the South Platte between Metro and Strontia Springs. Each of these factors were considered in the context of Denver's Baseline NT model scenario.

2.3 RUNOFF FROM IMPERVIOUS SURFACES AND LAWN IRRIGATION RETURN FLOW

As a region urbanizes, much of the land is covered with impervious surfaces (streets, buildings, parking lots, etc.), which increase the amount of precipitation that runs off to surface streams. Also, as previously dry land becomes urbanized and regularly irrigated by municipal water supplies, return flow from those irrigated areas contributes to stream flows. This is further discussed in the next chapter.

Denver's Baseline NT flow data for the Denver and Henderson gages were adjusted upward accordingly using the average monthly distribution of runoff from imperveous surfaces (RIS) and lawn irrigation return flow (LIRF). For the purposes of this study it

was assumed that estimated future flow increases due to metro area RIS and LIRF would be fully included in the Denver and Henderson gage flows.

2.4 INCREASED FUTURE WASTEWATER FLOWS FROM TRIBUTARIES

Denver's PACSM model uses historical gage data to simulate inflows from Plum Creek, Cherry Creek, Bear Creek and Clear Creek to the South Platte. However, it likely that future flows from some of these tributaries will increase due to increases in wastewater discharges.

At Baseline NT demand levels, Douglas County water demands will probably exceed 100,000 acre feet per year, with most of this supply coming from nontributary groundwater. As a result wastewater flows in the Cherry Creek and Plum Creek basins will increase significantly. While some of this wastewater is likely to be reused through augmentation plans and direct reuse, a net increase in wastewater flows is projected, primarily in the Cherry Creek basin. To estimate this net increase in wastewater flow, future Douglas County water demands met by nontributary groundwater, resulting wastewater flows and associated augmentation/reuse plans were estimated based on current County projections (Mulhern, 1995). The net increase in wastewater flows derived from nontributary groundwater sources was calculated taking into account average monthly municipal delivery and wastewater production patterns, augmentation plans and direct reuse plans. The resulting net increase in wastewater ranged from 1 cfs to 20 cfs and averaged 5,700 acre feet per year. These flows were added to Denver's modeled flows at the Denver and Henderson gages.

Flows from Clear Creek into the South Platte have increased since 1990 by approximately 15 cfs due to wastewater discharges from the Coors/Golden plant no longer being diverted by the Croke Canal. These flow increases are not reflected in Denver's modeled Henderson gage flows. This increased Clear Creek inflow generally affects flows at the Henderson gage during all months except August through October, when intervening irrigation rights on lower Clear Creek divert most of this water. It was assumed for the purposes of this study that these wastewater flows would increase average flows at the Henderson gage by 15 cfs during November though July. Denver's modeled flows at Henderson were adjusted accordingly.
Increased flows from Bear Creek and Plum Creek compared to historical gage records were assumed to be negligible.

2.5 JUNIOR SOUTH PLATTE WATER RIGHTS

Denver's model does not include several junior water rights which could affect South Platte flows at the Chatfield, Denver and Henderson gages. These include: 1) Thornton's junior water rights at the Burlington Ditch and its conditional exchange rights from Metro to the Burlington Ditch and to various locations on Clear Creek; 2) Aurora's

exchange rights from Metro to Strontia Springs and to Spinney Mountain Reservoir; and 3) Englewood's exchange rights from the St. Vrain and from Clear Creek to Chatfield Reservoir. These rights were not included in Denver's model because they are junior to Denver's water rights and would not affect Denver's system yield. They would, however, affect stream flows primarily at the Henderson gage and to lesser degrees at the Denver and Chatfield gages. These water rights would reduce future flows primarily during the months of May through August when stream flows are relatively high. However, the future exercise of these water rights will be highly variable due to constraints of stream flows, call conditions, water quality and water demands. It is therefore unlikely that these water rights would be fully utilized every year. A full analysis of the effects of these rights was beyond the scope of this study. Based on a review of the water rights and flow conditions involved it was assumed for the purposes of this study that these rights would reduce average flows at the Henderson gage by 100 cfs during May though August. Denver's modeled flows at Henderson were adjusted accordingly.

2.6 KERSEY GAGE

To develop estimated future flows for the Kersey gage, Hydrosphere adjusted the historical Kersey gage flows to reflect the following: 1) changes in flows at the Henderson gage due to future operations of metro Denver area water supply systems as modeled by Denver Water and adjusted, described above; 2) changes in historical flows from the St. Vrain, Big Thompson and Cache La Poudre basins due to increased municipal and industrial water use in these basins, future Windy Gap project water deliveries, and to account for the fact that Colorado-Big Thompson project deliveries did not reach full levels until 1953; and 3) changes in diversions by District 2 irrigation ditches in response to future changes in supplies.

2.7 REUSABLE FLOWS

Reusable flows from the metro Denver area were estimated only for the Henderson gage since most reusable return flows are generated at the Metro Wastewater Reclamation District plant or at downstream locations. All metro Denver area reusable flows are assumed to accrue to the river at the Henderson gage even though a small portion of these reusable flows would actually occur slightly downstream. Reusable return flows were estimated for both existing and future conditions. Estimates were generated as part of the MWSI project through review of existing and future water supply system operations for Denver Water, Aurora, Westminster, Arvada, Thornton, major Douglas and Arapaho County water districts, Broomfield, Northglenn, Englewood and South Adams County Water & Sanitation District. In the future the gross amount of reusable return flows from these sources is estimated to be approximately 40,000 acre feet per year. Current plans for reuse of these future reusable flows amount to approximately 15,000 acre feet per year.

2.8 UNDEVELOPED FLOWS

Undeveloped flows were estimated for the South Platte, Chatfield and Henderson gages using output data from Denver's Baseline Near Term PACSM model scenario. These flows reflect excess flows at these gage locations under future demand conditions based on modeled water rights and demands. The criteria for excess flows for the South Platte and Chatfield gages were meeting a 550 cfs flow target at the Henderson gage from April through September and no shortage to water rights above the Henderson gage. The criteria for excess flows for the Henderson gage were meeting a 550 cfs flow target at the Henderson gage from April through September and a 200 cfs target from October through March.

The subject of undeveloped flows at the Kersey gage has been previously addressed in the South Platte River Basin Assessment Report (Woodward Clyde, 1982). That study reported annual historical and anticipated future undeveloped stream flows at Kersey as averaging 186,000 acre feet per year and 233,000 acre feet per year, respectively, for the 1953-1978 hydrologic period. This previous analysis was reviewed and found to be a reasonably accurate estimate of undeveloped steam flows for this location.

2.9 GROUNDWATER PRODUCTION ESTIMATES FROM THE DENVER BASIN AQUIFERS

The purpose of this sub task as described in the scope of work is to develop a 1995 groundwater production estimate from the Denver Basin aquifers, estimate groundwater return flows to the surface water system, and identify and quantify groundwater reuse. Personnel from the State Engineer's Office (SEO), as part of their S.B. 96-74 groundwater flow modeling work, assembled 1996 municipal groundwater production information from the Denver Basin aquifers. Additionally, the SEO totaled well permit records by beneficial use category. The well permit work reflects the number of well permits in 1996. As more data is available for 1996 than 1995, 1996 production estimates from the Denver Basin aquifers were assembled instead of 1995.

2.10 GROUNDWATER SUMMARY

Total groundwater use from the Denver Basin aquifers for 1996 is summarized on Table 2-20. Total production in 1996 is estimated to be 58,474 acre feet. On a continuous annual production basis this volume represents 80.8 cubic feet per second. Information on the bottom portion of the table includes: the number of wells, average use estimate per well, total production by category, and the percentage of each use compared to the total use estimate. The data shows that municipal production from the Denver Basin aquifers is 42.6 percent of the total use, irrigation is 21.5 percent, commercial and industrial use is 10.1 percent, domestic and livestock is 24.6 percent, and household use only is 1.1 percent of the total.

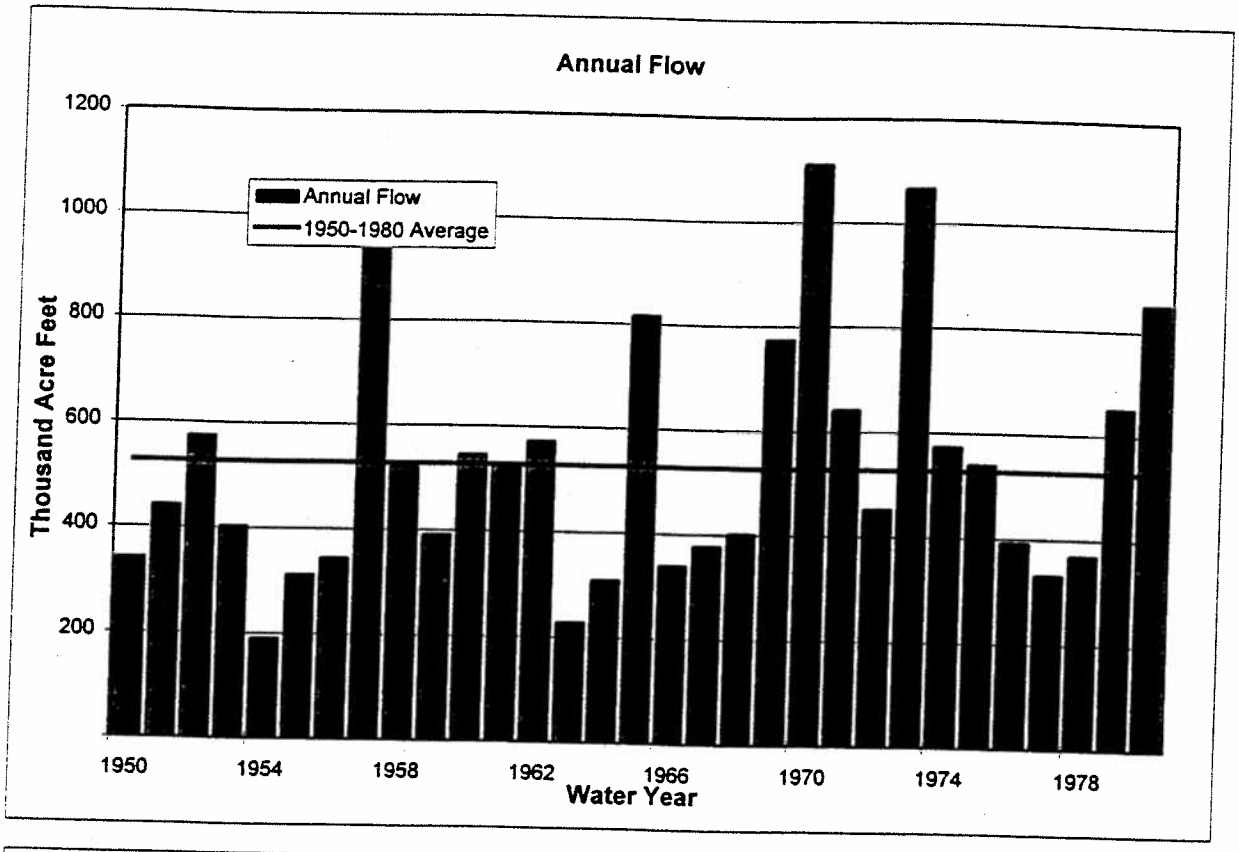
A with an average accuracy of plus or minus 30 percent on the commercial-industrial, irrigation, domestic use, and household use only production estimates, total production from the Denver Basin aquifers is estimated to range from 48,406 to 68,542 acre feet in 1996. On a continuous annual production basis these volumes convert to 66.9 and 94.7 cfs, respectively.

2.11 SURFACE WATER RETURN FLOW AND REUSE ESTIMATES FROM THE DENVER BASIN AQUIFERS

A portion of the groundwater pumped from the Denver Basin aquifers for each beneficial use is returned to the surface water system. Return flow percentages are high, (90 percent), for household use only and commercial and industrial uses, and low, (20 percent), for irrigation use. The municipal and domestic and livestock return flow percentage, 50 percent, reflects a combination of in-house and irrigation use. From the estimated 1996 production from the Denver Basin aquifers of 58,474 acre feet, 28,522 acre feet is estimated to return to the surface water system. This volume of production and gross return flow represents a gross return flow percentage of 49 percent (28,522 af/58,474 af).

Return flows generated from municipal use of Denver basin groundwater are legally reusable. Some groundwater suppliers are currently reusing a portion of their groundwater return flows for augmenting alluvial well pumping and for direct irrigation purposes. Estimates of current levels of reuse of groundwater return flows were obtained from groundwater suppliers in Douglas and Arapahoe Counties. Approximately 2,200 acre feet per year of Denver Basin groundwater return flows are currently being consumed through augmentation and direct use.

Figure 2-1
Natural Flow
South Platte River at Henderson Gage



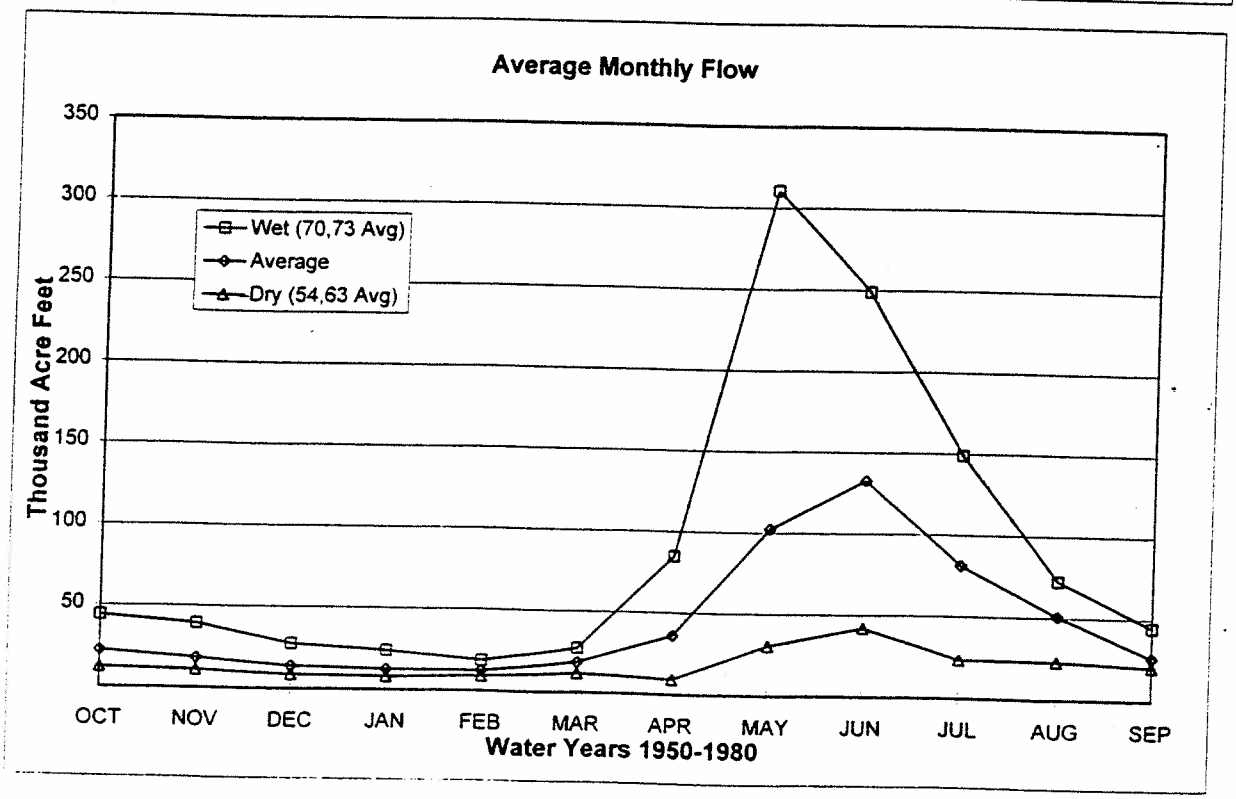
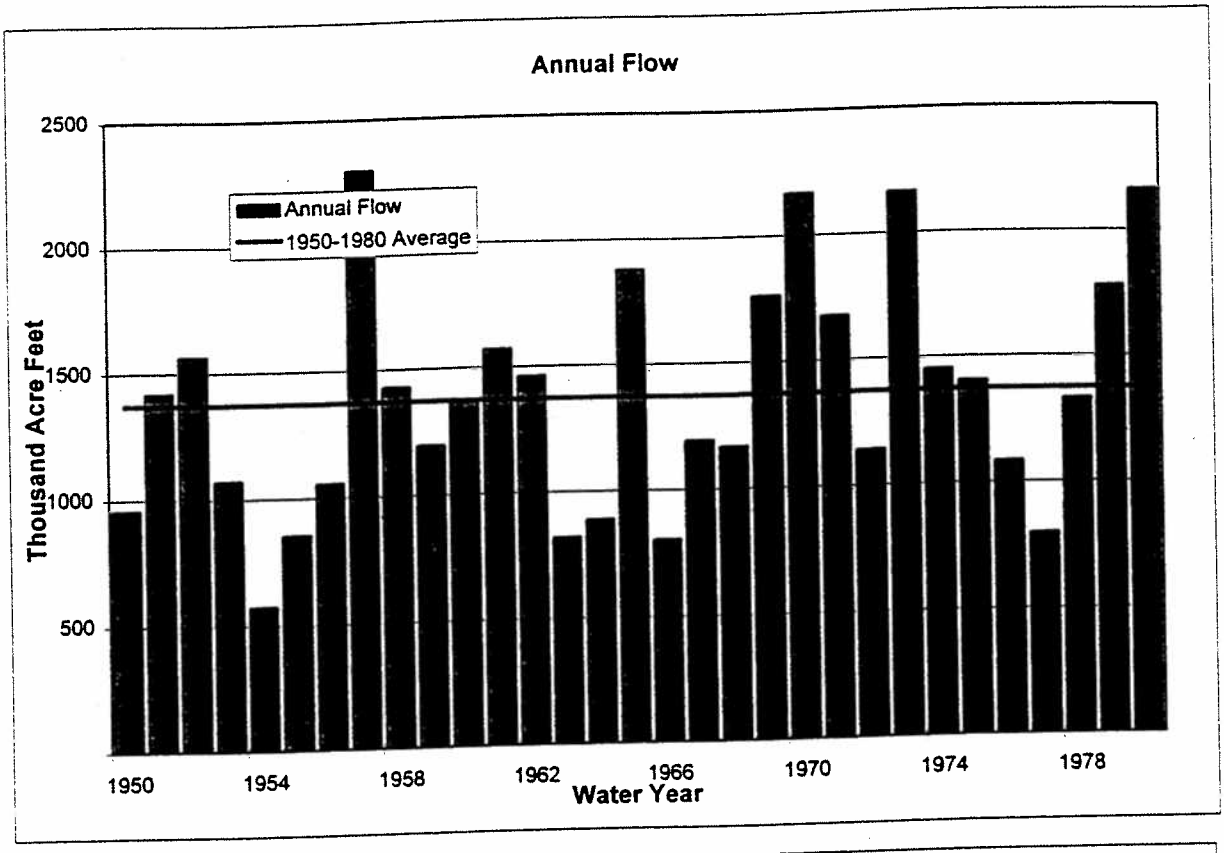


Figure 2-2
Natural Flow
South Platte River near Kersey Gage



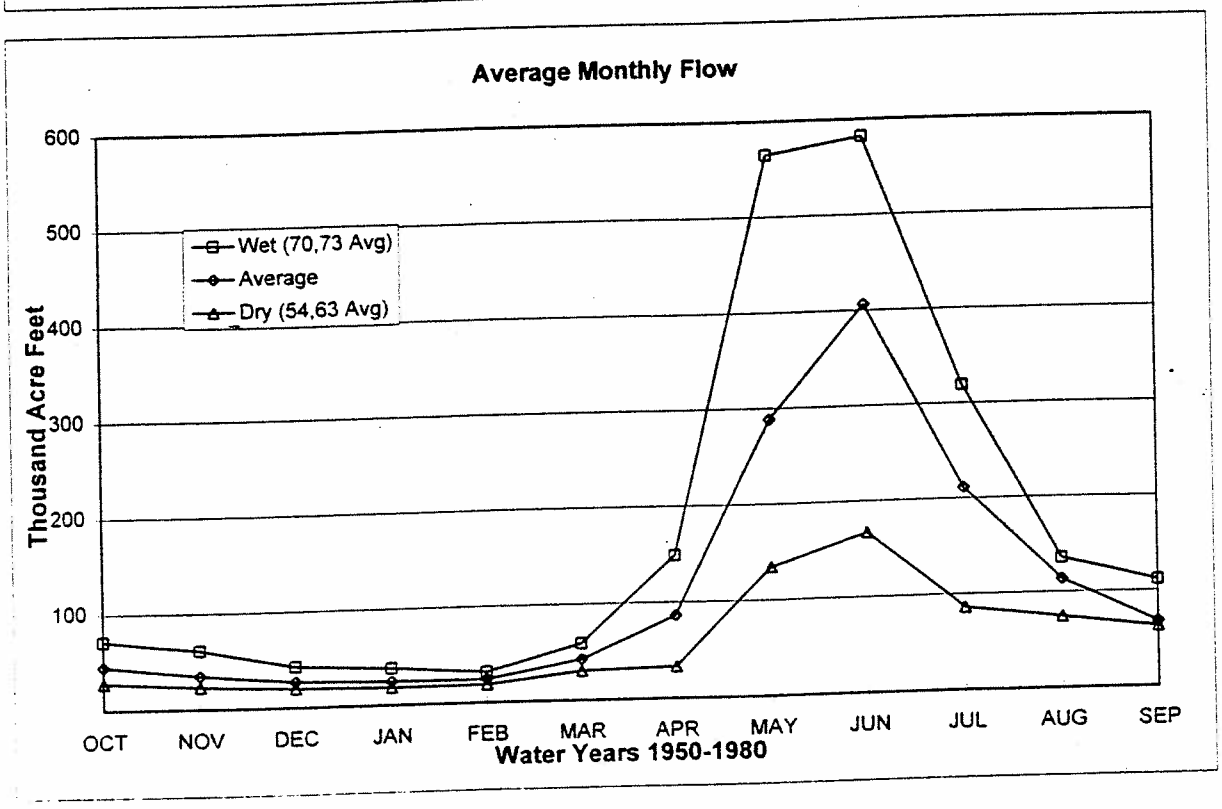
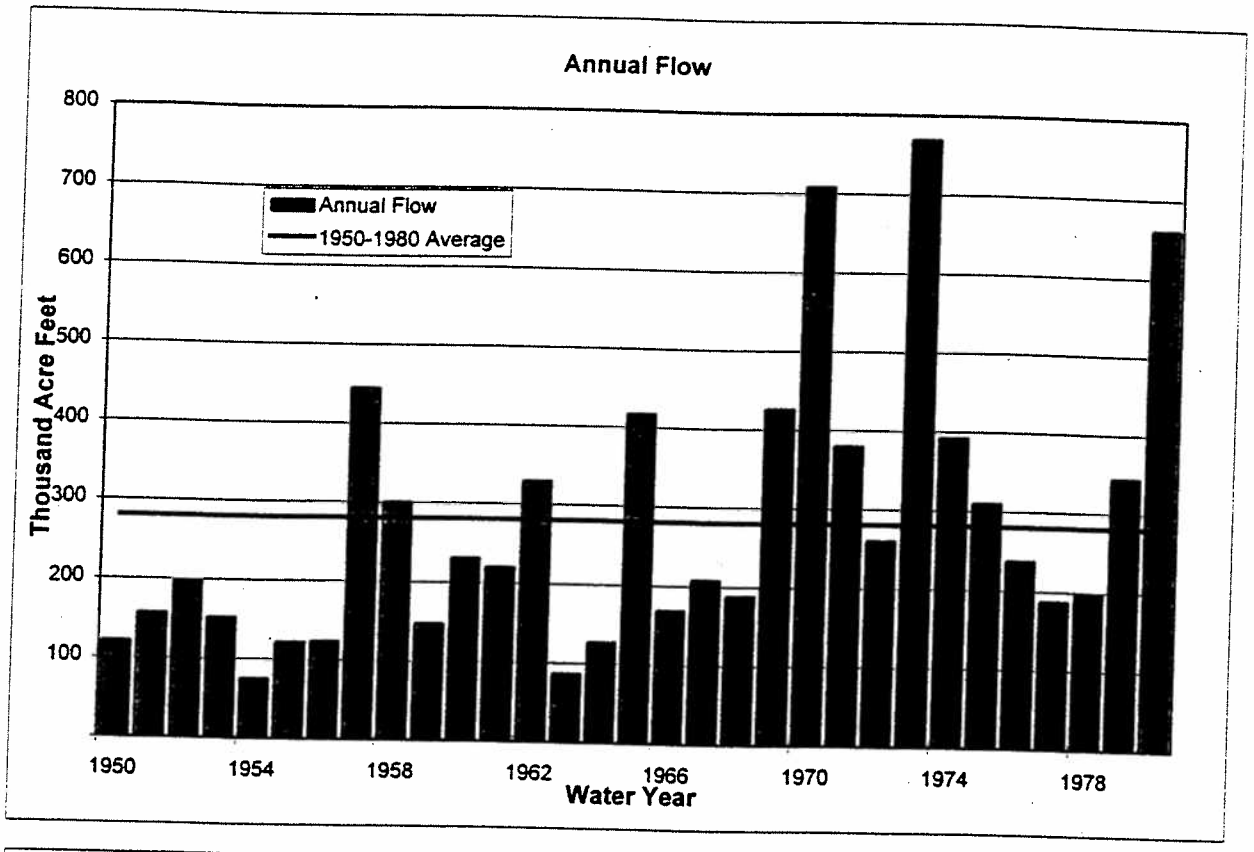


Figure 2-3
Historical Flow
South Platte River at Henderson*



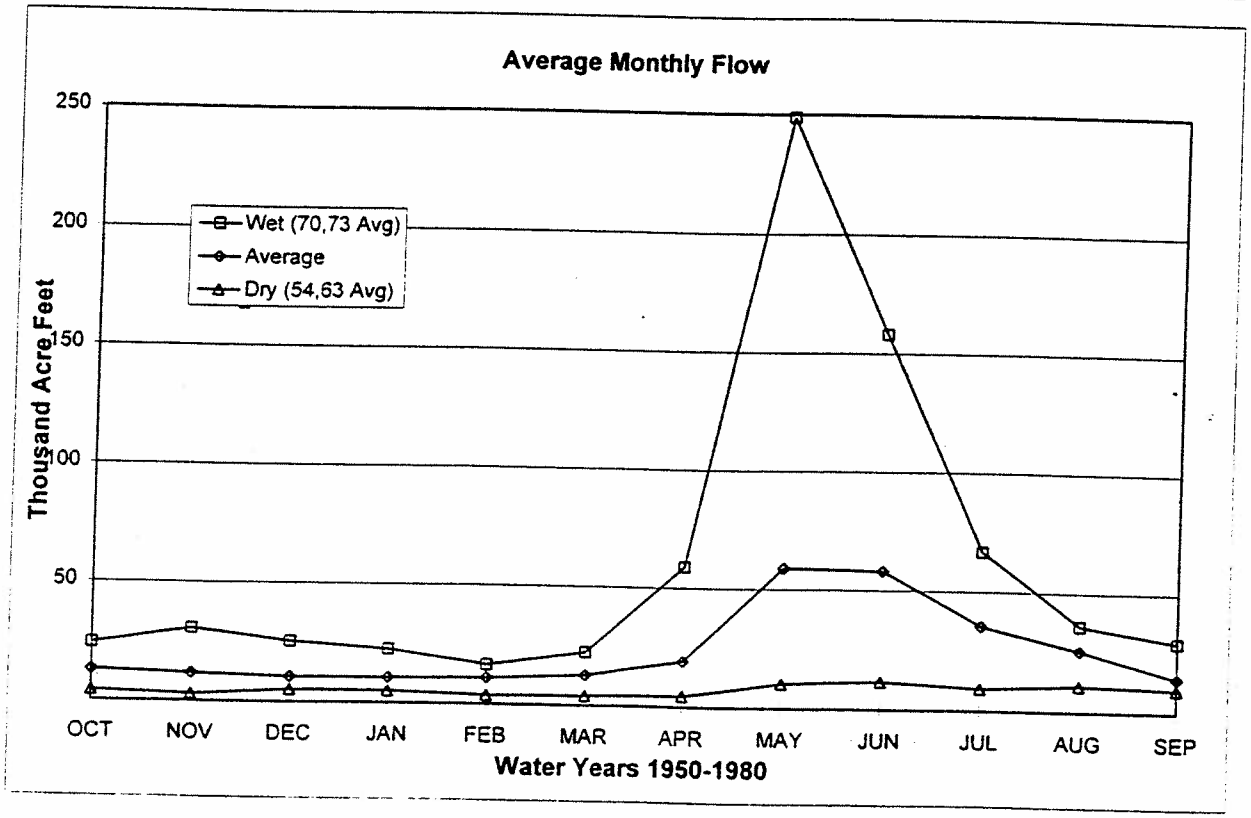
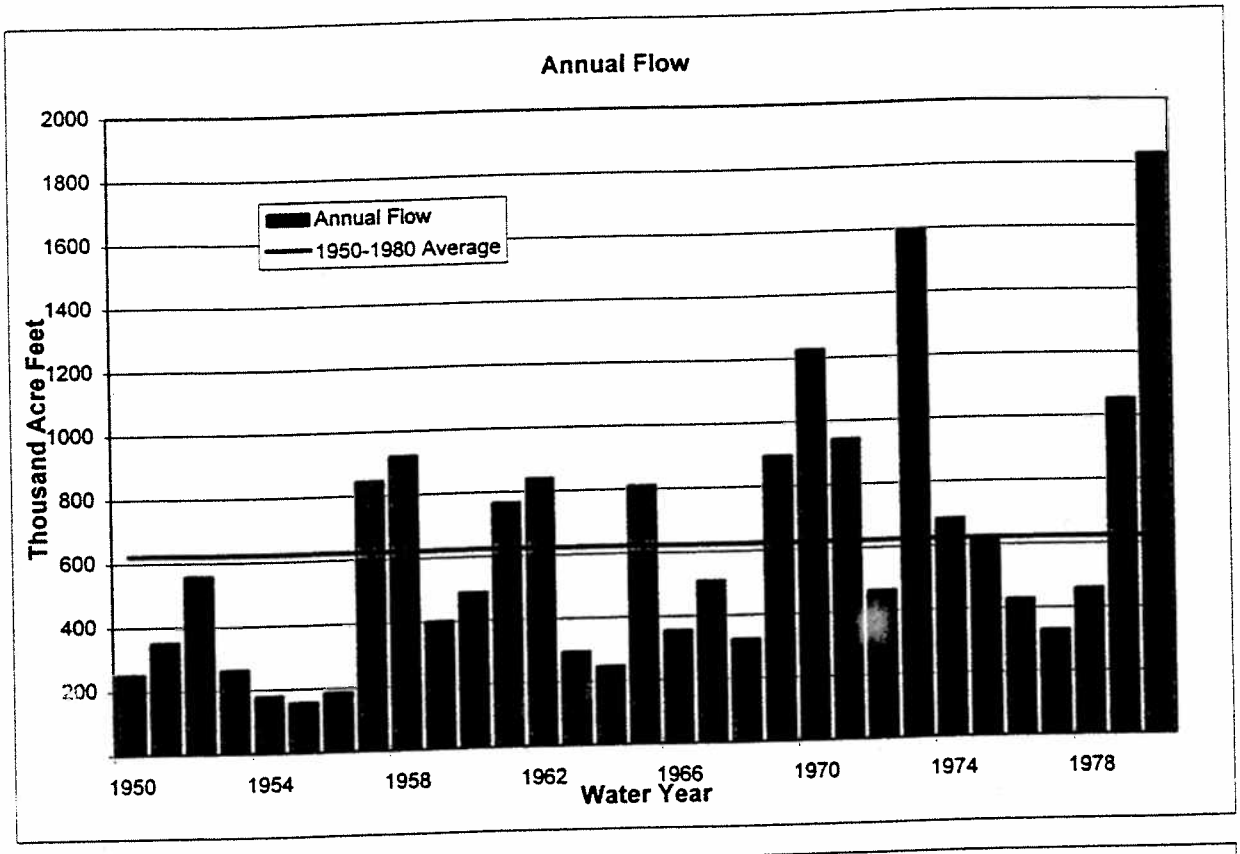
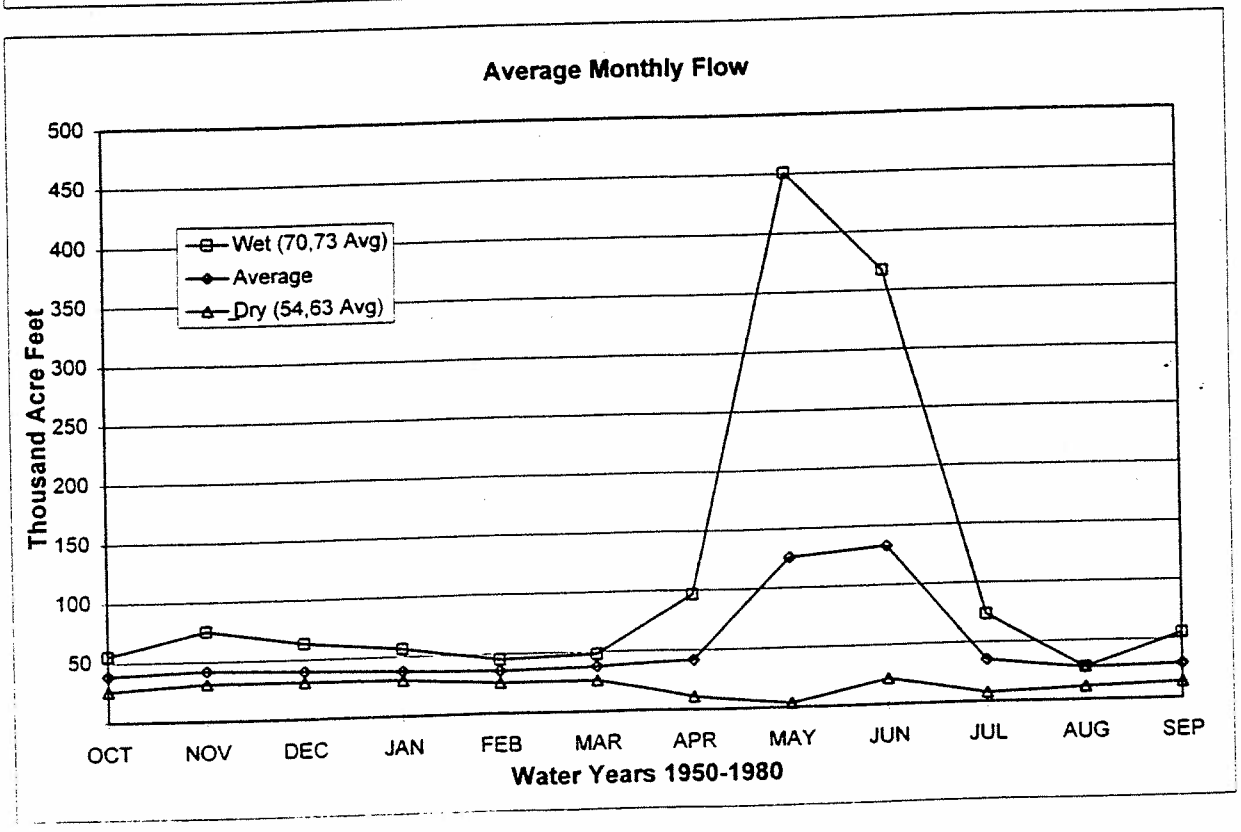


Figure 2-4
Historical Flow
South Platte River near Kersey*





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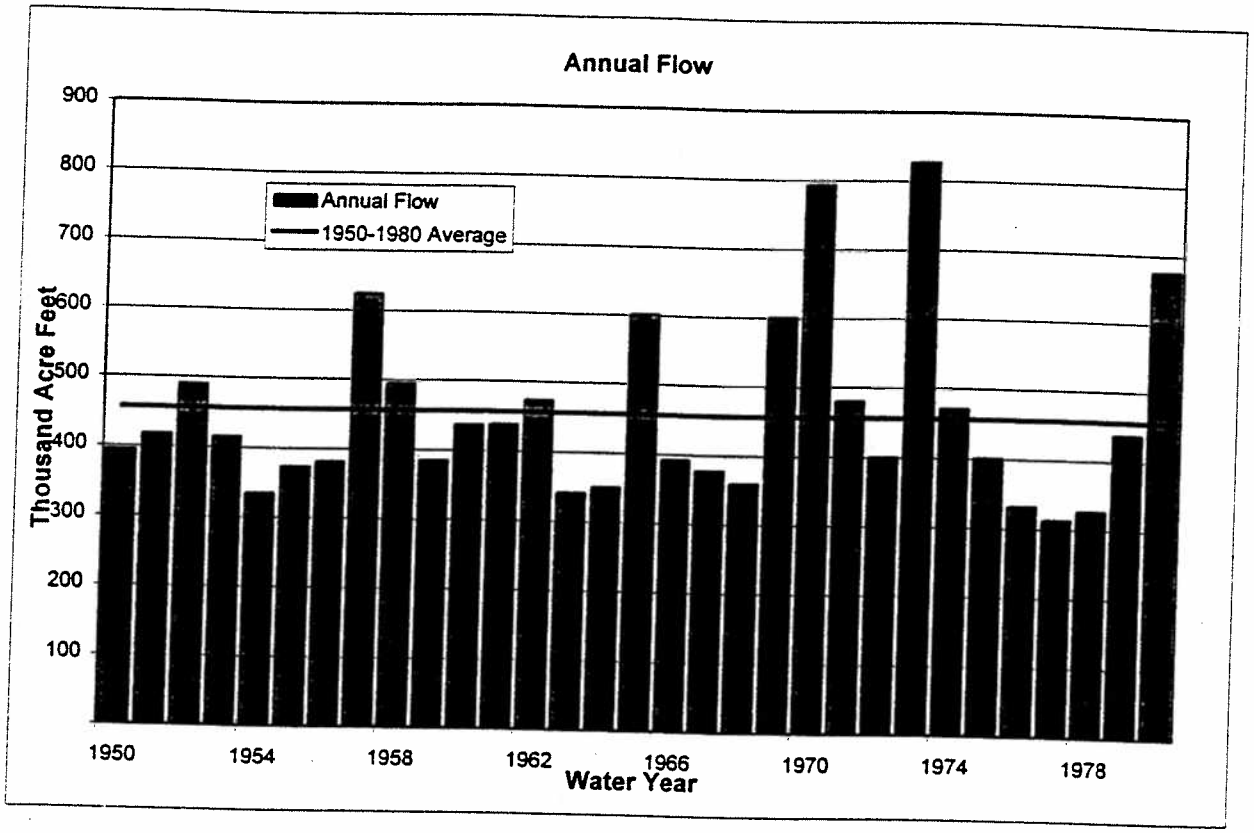
Historic.xls

Figure 2-5
Future Flow
South Platte River At Henderson



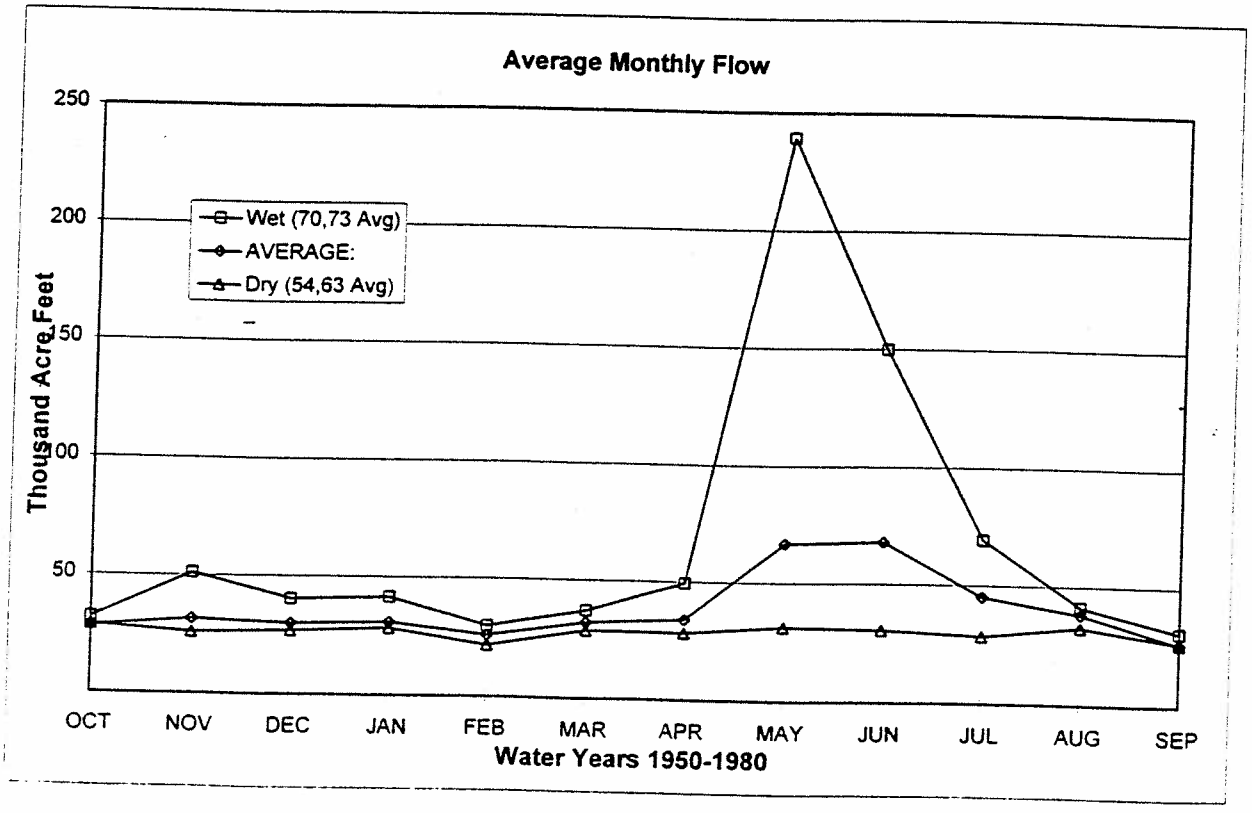
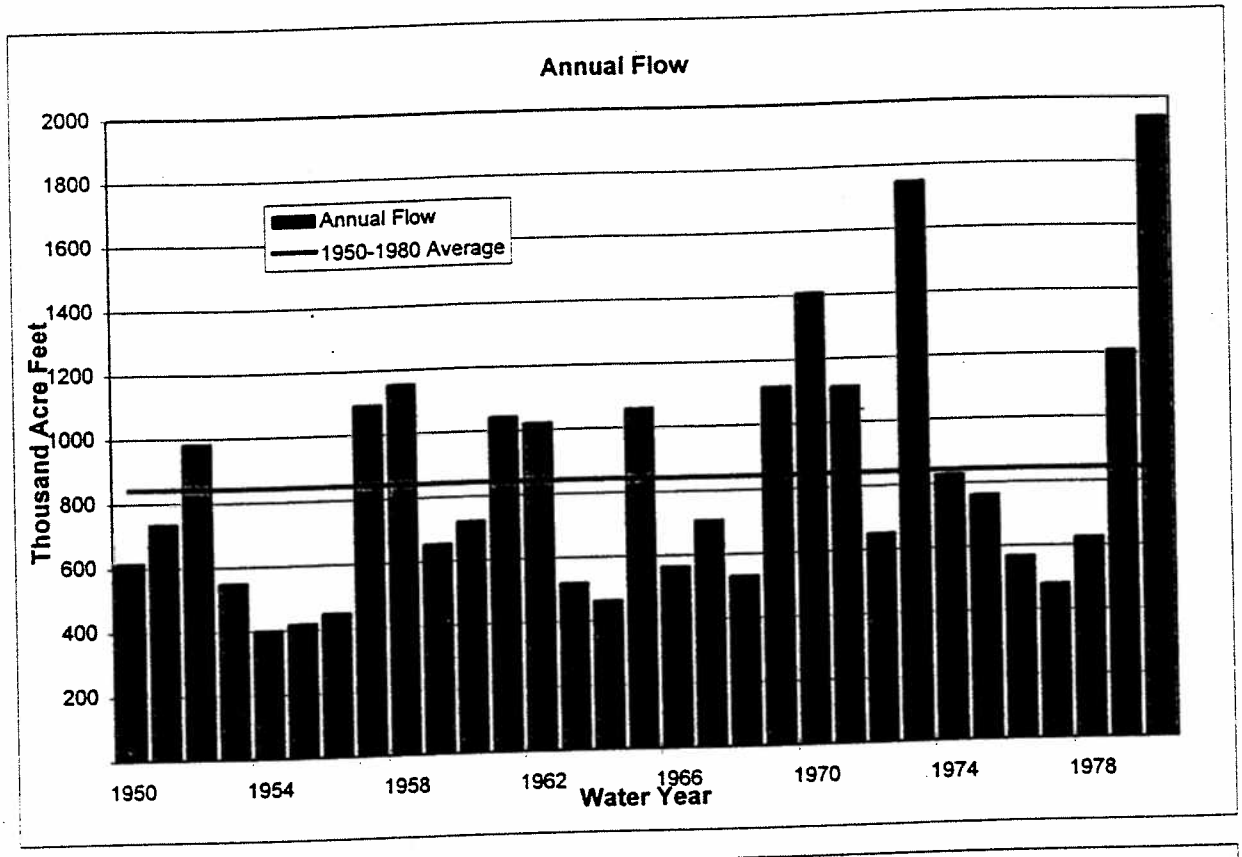


Figure 2-6
Future Flow
South Platte River At Kersey



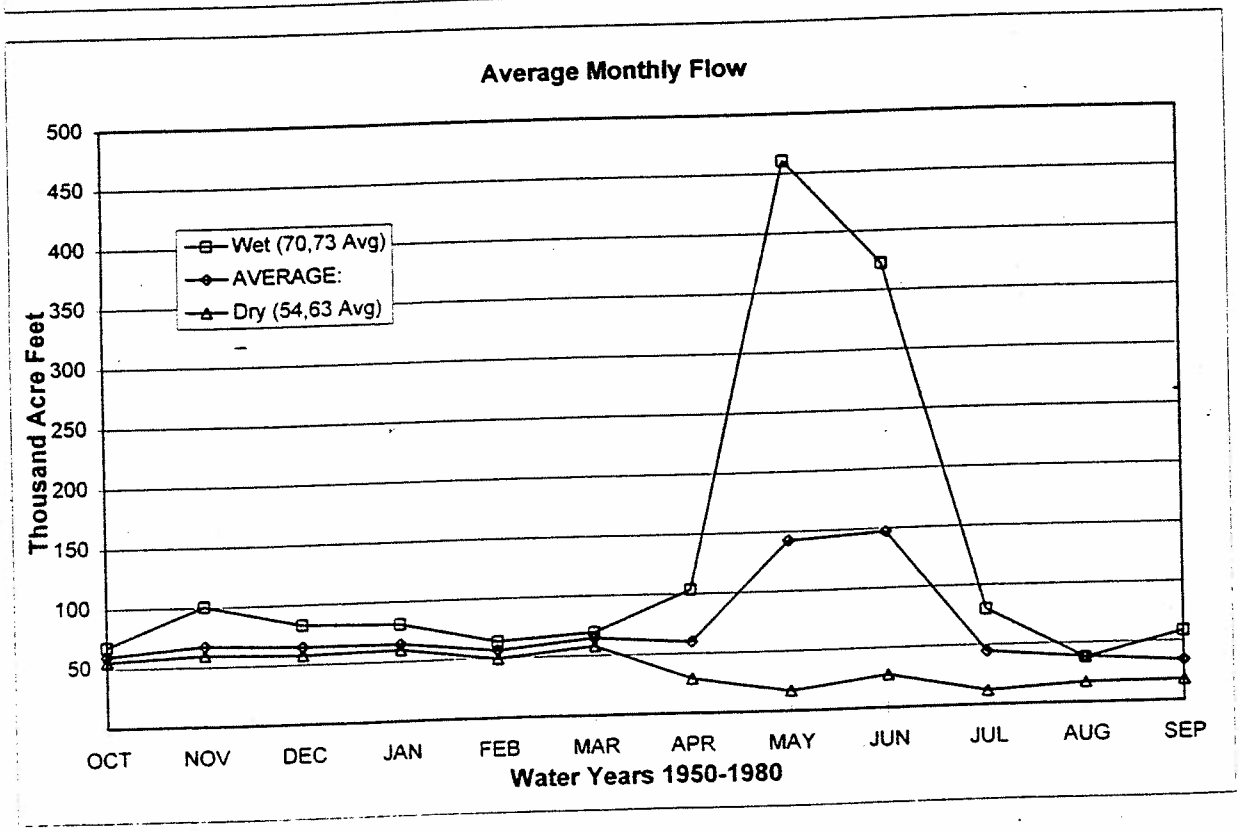


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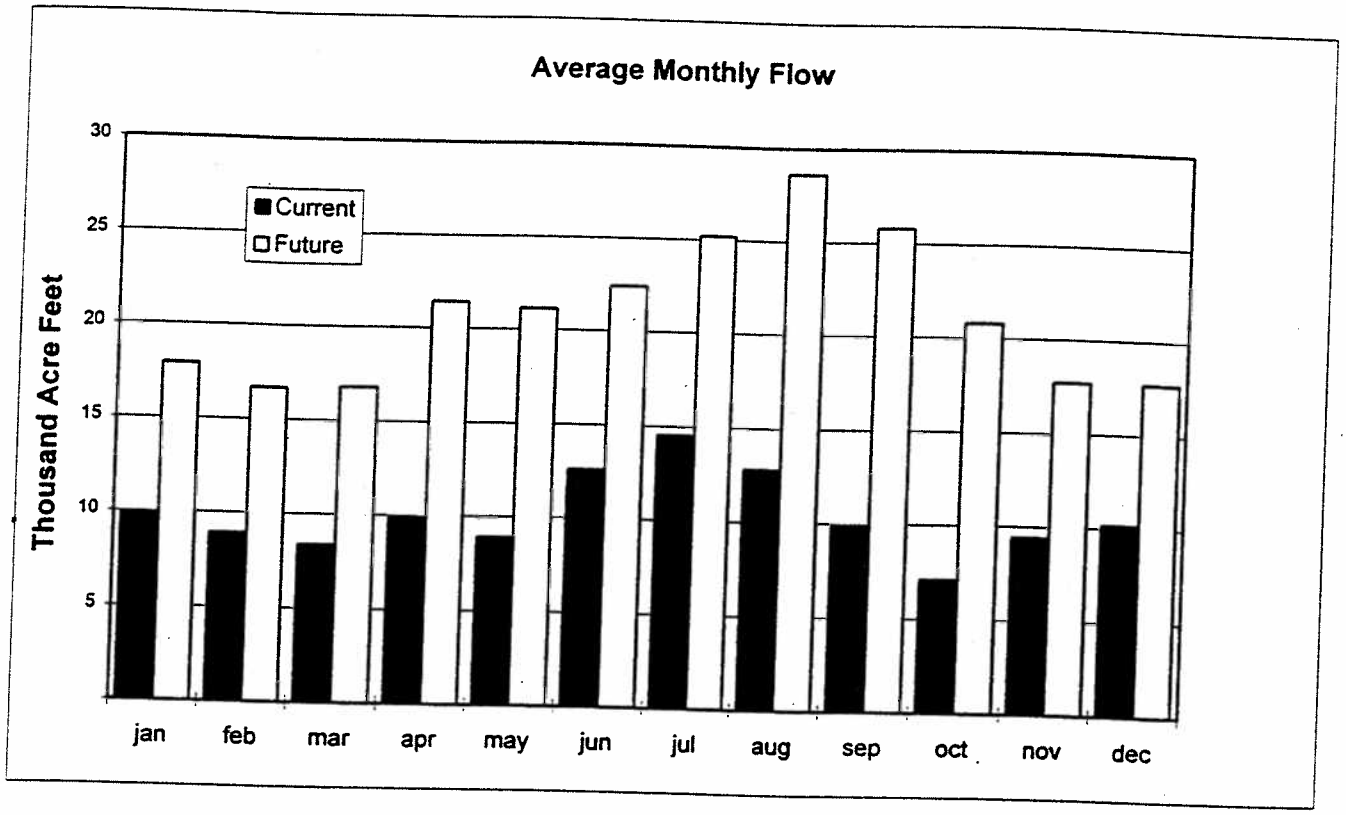
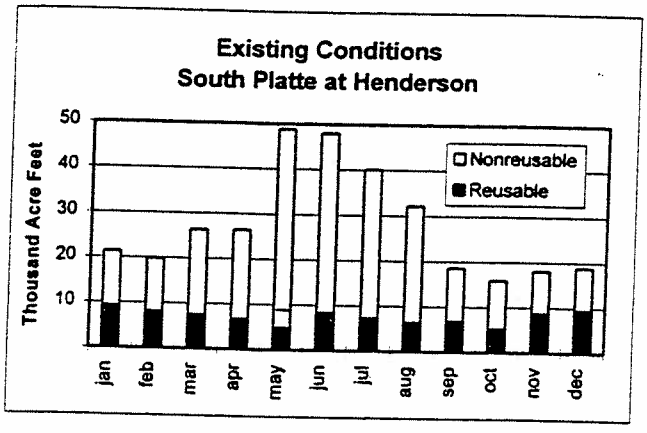
Figure 2-7
Metro Denver Area Reusable Return Flow





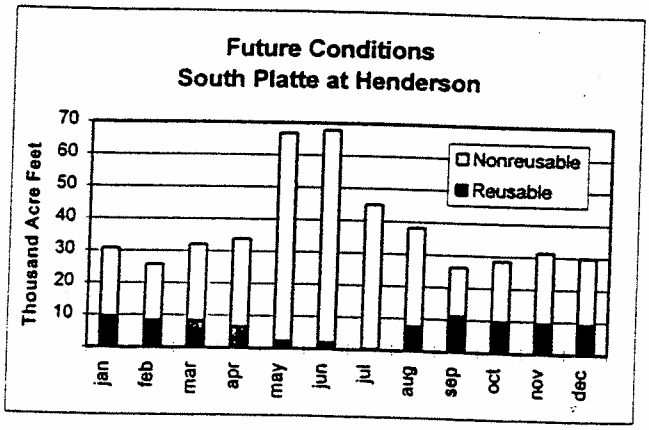
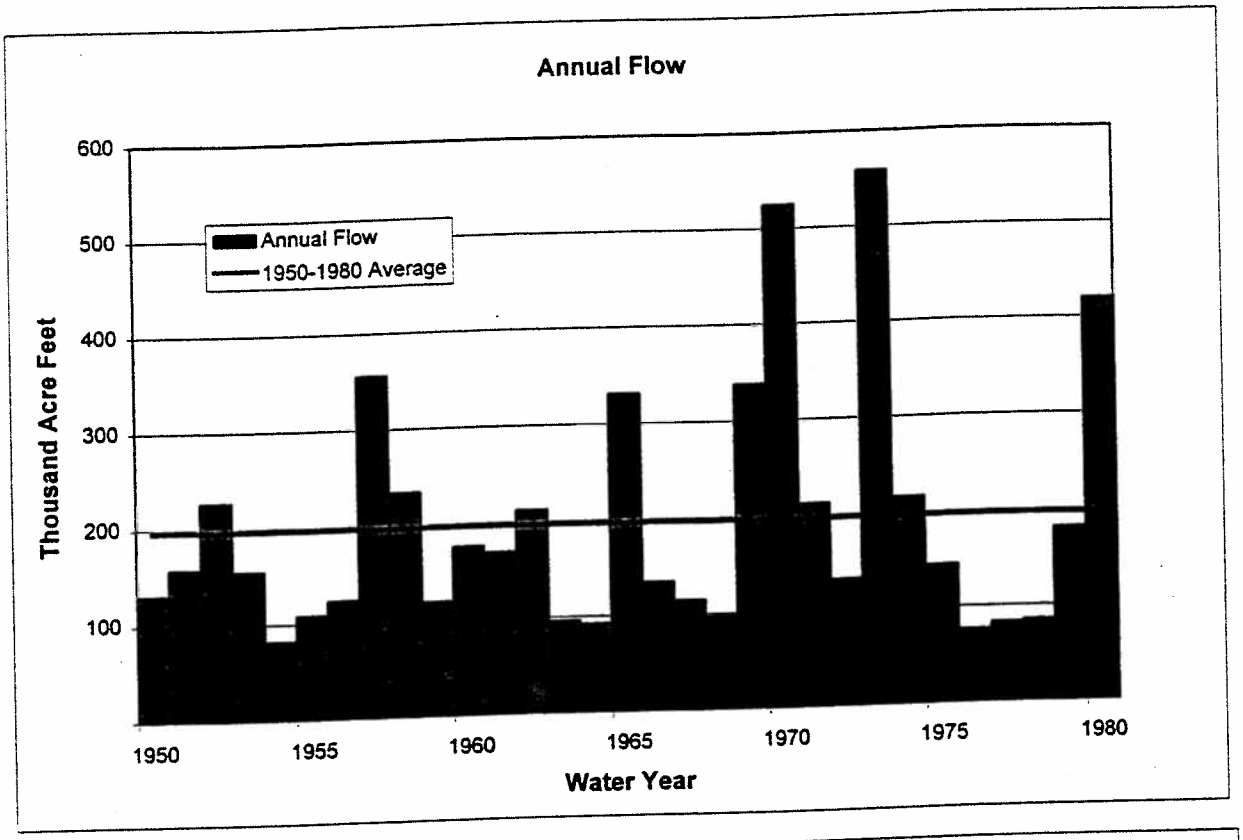


Figure 2-8
Developable Flow, Future Conditions
South Platte River at Henderson



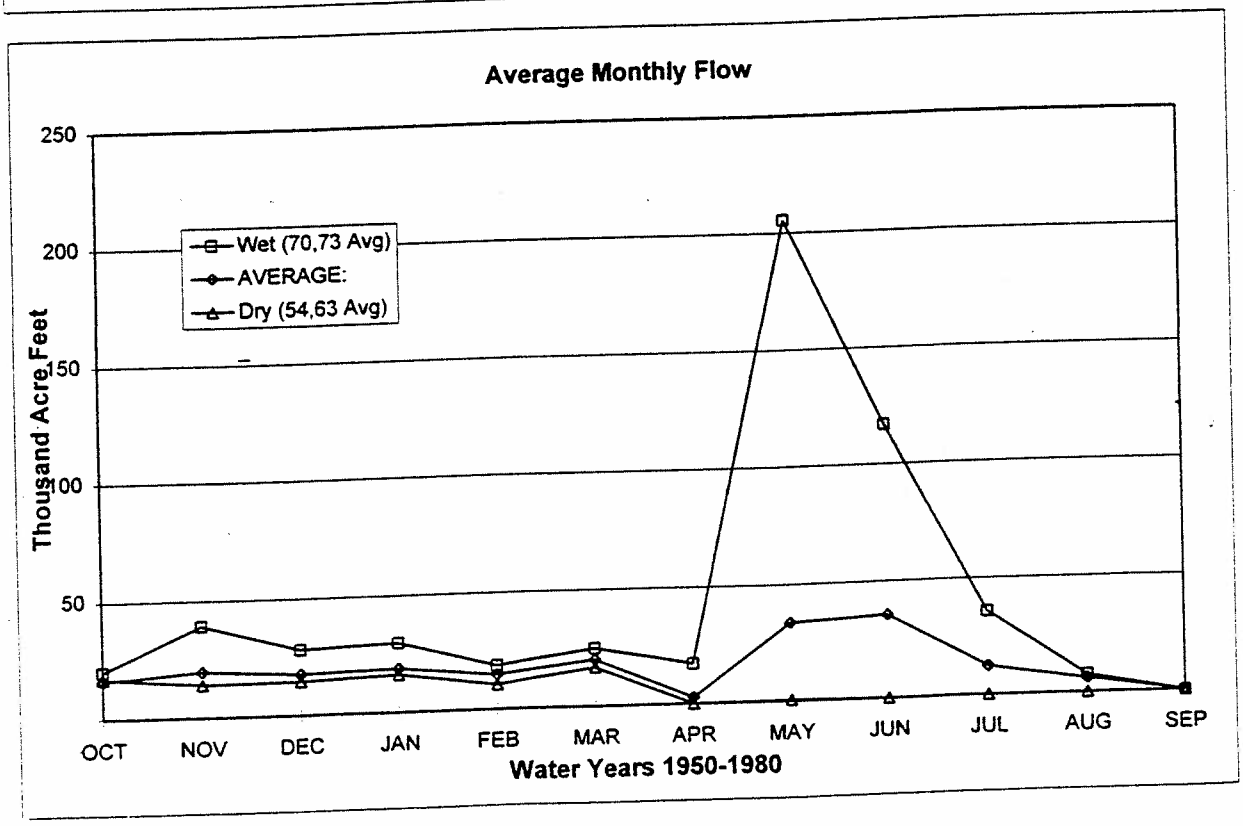


Table 22-1
Metro Denver Area Reusable Supplies and Return Flows
(Acre Feet Per Year)

provider	reusable supply present	reusable supply future	reusable wastewater present	reusable wastewater future
Denver Water	85,000	145,000	46,000	77,000
Aurora	49,000	70,000	26,000	38,000
Douglas County (1)	24,000	116,000	10,000	46,000
Thornton	9,000	45,000	5,000	24,000
Westminster	6,000	8,000	4,000	5,000
Arvada	4,000	5,000	1,000	2,000
Other (2)	24,000	43,000	12,000	19,000
Subtotal	201,000	432,000	104,000	211,000
Reusable LIRF's (3)			20,000	41,000
Total	201,000	432,000	124,000	252,000

(1) Includes all Douglas County Water Resource Authority providers
(2) Includes Brighton, Broomfield, Englewood, Golden/Coors, Northglenn, SACWSD and miscellaneous providers
(3) Lawn irrigation return flows

Table 1-20: Estimates of Municipal Use from the Denver Basin Aquifers in 1996 (Preliminary and Subject to Change)

Water User	1996 Production (acre feet)
Arapahoe	493
Bennett	286
Byers	195
Castle Pines	532
Castle Pines North	573
Castle Rock	3,078
Centennial	1,561
Colorado Springs	422
Cottonwood	492
Deer Trail	55
Donalla	858
East Cherry Creek Valley	4,738
Elizabeth	168
Englewood	17
Federal Heights	194
Forest View Acres	24
Hazeltine Heights	52
Highland Acres	86
Inverness	729
Keenesburg	111
Meridian	1,010
Mid-Colorado	61
Monument	212
Northgate	8
Paint Brush	91
Parker	2,498
Park Forest	75
Perry Park	92
Peyton Pines	9
Pinery	303
Ramah	13
Schubert Ranches	300
Shannon	56
Shaw Heights	26
Silver Heights	107
South Adams County	885
Stonegate Village	1,021
Sunnyslope Mutual	19
Thunderbird	57
Walden Corporation	9
Westlake	58
Willows	2,561
Woodmoor Corp.	85
Woodmoor W & S	694
Subtotal	24,914

Denver Basin Aquifers - Groundwater Production Estimates by Beneficial Use, Number of Permits and Annual Production per Permit

Beneficial Use	Number of Permits	Annual Production Per Permit (af)	Annual Production Acre Feet	Percentage of Total Use
Irrigation	307	41	12,587	21.5%
Commercial & Industrial	657	9	5,913	10.1%
Domestic & Livestock	24,000	0.6	14,400	24.6%
Household Use Only	2,000	0.33	660	1.1%
Subtotal			**33,560**	
Municipal			**24,914**	
Basin Total (acre feet)			**58,474**	
Basin Total (cfs)			**80.8**	

Table 2-2
Estimate of Return Flows to Surface Streams
Due to Production from the Denver Basin Aquifers in 1996
(Preliminary and Subject to Change)

Beneficial Use	1996 Groundwater Production Estimates from the Denver Basin Aquifers (acre feet)	Return Flow Percentage	Gross Return Flow Volume (acre feet)
Municipal	24,914	50%	12,457
Irrigation	12,587	20%	2,517
Commercial & Industrial	5,913	90%	5,322
Domestic & Livestock	14,400	53%	7,632
Household Use Only	660	90%	594
Total	58,474		28,522

3.0 ESTIMATE OF THE IMPACT ON RUNOFF TO THE SOUTH PLATTE RIVER FROM CONSTRUCTION OF IMPERVIOUS SURFACES IN THE DENVER METROPOLITAN AREA FOR THE PERIOD 1950-1995

This chapter describes an analysis of the increase in South Platte River gains through the Denver metropolitan area over the past several decades as a result of urbanization. The approach used to estimate the increased stream flow gains assumes the gains have resulted primarily from (1) runoff from impervious surfaces (RIS), and (2) lawn irrigation return flows (LIRF).

3.1 BACKGROUND

The analysis relies on previous studies which have indicated that stream flow gains have increased as the Denver area has urbanized, and that the gains are not explained by increases in precipitation.

Denver Water, as a part of its PACSM modeling studies, developed estimates of the total increase in gains through the Denver metropolitan area since 1947. The MWSI study included estimates of the current LIRF in the Denver area. The difference between the total urban gains and the LIRF is assumed to approximate the increase in RIS. The urban gain estimates were disaggregated into four reaches of the South Platte River defined by the following locations: Chatfield Reservoir, the Denver gage, the Burlington Ditch headgate and the Henderson gage. Finally, historical daily stream flow records for Cherry Creek were reviewed to characterize daily gain variations.

3.2 TOTAL GAINS

The total gains between the Waterton and Henderson gages were estimated from 1947 through 1991 based on virgin flow estimates. The virgin inflows to the Denver area were subtracted from the virgin outflow at the Henderson gage.

The period from 1949-1969 represents the pre-development period with an average gain of about 20,000 acre-feet per year (af/yr), The period from 1974-1991 represented the post-development period. There appears to be a generally increasing trend in the gains from the mid-1950's through the end of the study period in 1991. Therefore, it was assumed that the average gain during the last five years of the study period represented the current level of total gains through the Denver area. The average annual gain from 1987 through 1991 was 111,000 af.

3.3 PRE-DEVELOPMENT GAINS

Although Denver Water defined the 1949-1969 average gain as representative of pre-development conditions, Denver was obviously urbanized to some extent prior to and during this period. Therefore, an estimate of the runoff that would occur absent development was made to assess whether any portion of the pre-1970 gain could be considered to be due to urbanization.

Information published by the U.S. Geological Survey (USGS, 1970) indicates the average runoff from the Denver area is about 1.5 inches per year which equates to a volume of 45,000 af/yr. This exceeds the 20,000 af/yr gain for the 1949-1969 period. The results appear to indicate that the gain estimate during the 1949-1969 period would be largely comprised of gain that was present prior to urbanization. As a result, the 20,000 af/yr gain for the 1949-1969 period was assumed to represent the pre-development gain.

3.4 URBAN GAIN

The gain from urbanization of the Denver area was computed as the difference between the average 1987-1991 total gain (111,000 af/yr) and the average pre-development gain (20,000 af/yr). The result is an annual urban gain volume of 91,000 af/yr.

The data was analyzed to determine a representative monthly distribution of the post-development gain. The distribution exhibits a winter base flow component that is comprised of lawn irrigation return flows, direct snowmelt runoff and lagged underground return of runoff from impervious surfaces.[1] During the summer months the distribution exhibits a bi-modal characteristic with peaks in May and August.

Stream depletions resulting from alluvial wells would reduce the gain from what would occur in the absence of the wells. To the extent the well effects are present in both the post and pre-development gains, the effect would be compensating and would not affect the magnitude of the increase in the gain between these periods.

---

[1] Runoff from impervious surfaces to permeable areas which then infiltrates to the ground water system.

Location	Incremental Urbanized Area (square miles)	Incremental Urbanized Area (%)
Chatfield Reservoir	0	0%
Denver Gage	246	66%
Burlington Ditch	21	6%
Henderson Gage	106	28%
Total	373	100%

3.5 LAWN IRRIGATION RETURN FLOWS

The current annual LIRF for the Denver metropolitan area are estimated at about 39,000 af/yr. It was assumed that these return flows accrue to the South Platte River and its tributaries at an approximately constant year-around rate. This is due to the relatively low transmissivity of the surface formations underlying the metro area and the relatively long return flow distances.

The reusable portion of the LIRF for the entire metro Denver area was estimated to be about 47% of the total LIRF, or 18,000 af/yr, based on the current mix of water sources used by Denver metropolitan water providers. Most of this amount, including the LIRF of Denver and Aurora, has not been adjudicated by the water court.

3.6 RUNOFF FROM IMPERVIOUS SURFACES (RIS)

The RIS was estimated as the difference between the total urban gain (91,000 af/yr) and the portion estimated to result from LIRF's (39,000 af/yr). The result is an estimated annual RIS of about 52,000 af/yr.

Unlike LIRF, RIS is assumed to be non-reusable by the water provider from whose service area the RIS originated. Instead, these gains become part of the natural river flow available for priority allocation.

3.7 NON-REUSABLE URBAN GAIN

The overall non-reusable urban gain is comprised of the RIS (52,000 af/yr) and non-reusable LIRF (21,000 af/yr), totaling about 73,000 af/yr.

3.8 URBAN GAIN USABILITY

The LIRF accrue on a relatively constant basis. However, most of the RIS occurs within a matter of days following precipitation events. In order to evaluate the gain hydrograph, it was assumed that timing of the gain in the Cherry Creek basin is representative of the timing of the urban gain across the entire Denver area. Based on this assumption, the normalized frequency distribution was applied to the average urban gain above the Henderson gage (125 cfs) in order to compute a typical annual frequency distribution for the total urban gains upstream of Henderson as summarized below.

Urban Gain Upstream of Henderson (cfs)	Percent of Annual Days with Greater Gain (%)
50	84%
100	37%
150	20%
200	14%
300	7%
400	4%
500	3%
1000	0.5%

3.9 SUMMARY OF RESULTS

The following is a summary of the increase in gains resulting from urbanization of the Denver metropolitan area:

1. The estimated stream flow gain resulting from urbanization is summarized as follows:

Description	Estimated Annual Gain at Henderson (af/yr)	Estimated Average Gain at Henderson (cfs)
Runoff from Impervious Surfaces	52,000	71
Lawn Irrigation Return Flows	39,000	54
Total Urban Gain	91,000	125
Reusable Urban Gain	18,000	25
Non-Reusable Urban Gain	72,000	100

The reusable portion of the urban gain represents the estimated return flows derived from initial irrigation use of totally consumable water sources. These return flows are assumed to be reusable by the water providers which are the source of the gain. The reusable gain was estimated as 47 percent of the lawn irrigation return flows. The non-reusable gain belongs to the stream and is subject to allocation under the priority system.

2. Between 1950 and 1990, the population of the Denver metropolitan area increased by 1,273,000 persons. Based on this increase, the total stream flow gain from urbanization equates to approximately 0.10 cfs, per 1,000 persons.

3. The timing of the urban gain varies depending on the gain component. Lawn irrigation return flows are assumed to accrue to the stream at a generally constant rate year-around. The runoff from impervious surfaces is highly influenced by the timing of precipitation events.

4. The usability of the urban gain by downstream water users is influenced by the rate at which the gain occurs. Much of the runoff from impervious surfaces occurs as storm runoff over a two to three day period following the precipitation event. Peak runoff flows may be partially unusable because the gain rate may exceed the capacity of the downstream diversion structures.

5. The analysis described provides estimates of urban gains at several locations in the Denver metropolitan area. These estimates should not be interpreted as water which is physically available at the various locations. Portions of the estimated gains are undoubtedly diverted and consumed within the Denver area.

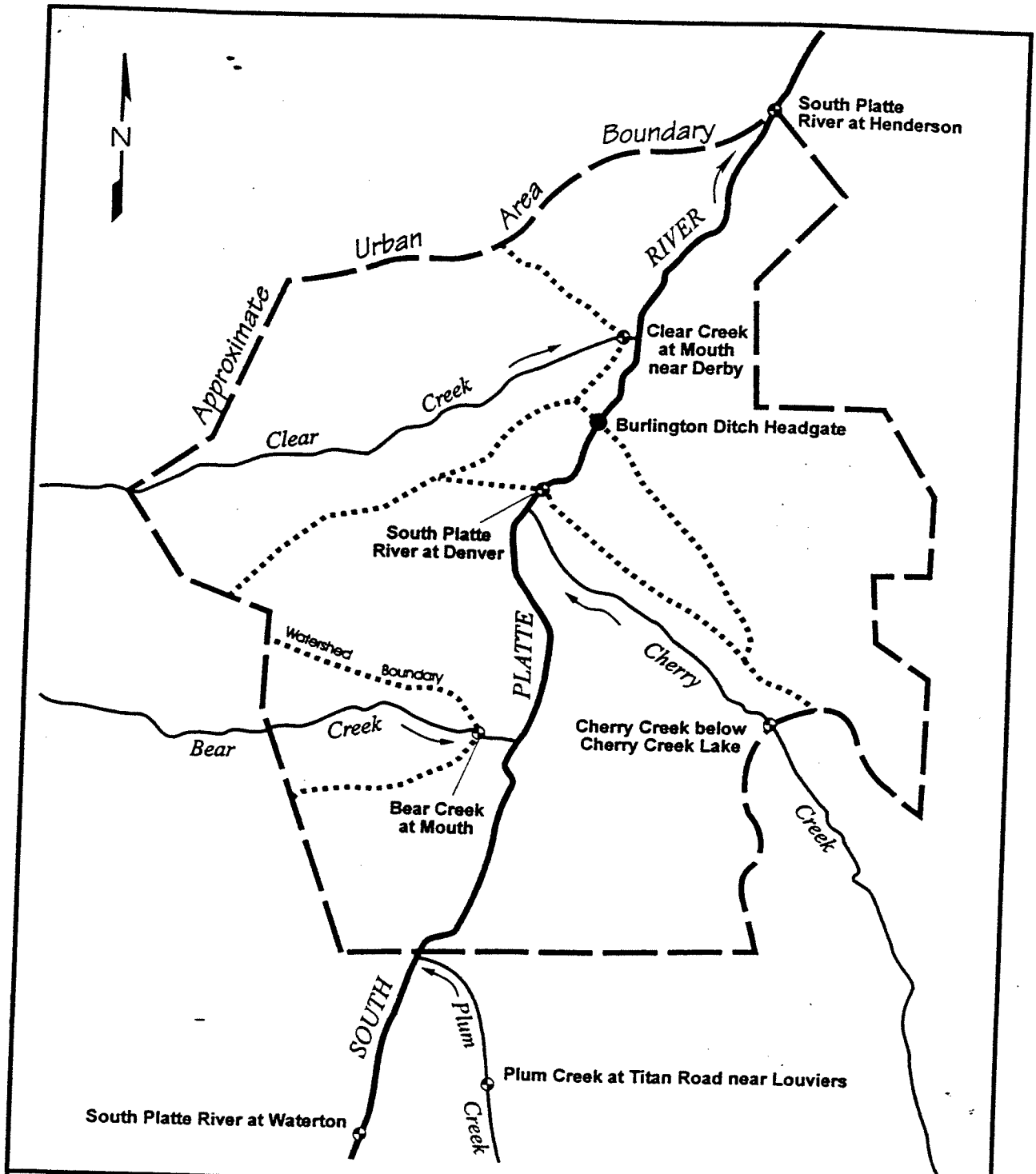


FIGURE 3-1

Location Map
Urban Gain Analysis
SB-74 Study

Scale: 1 inch equals approximately 4.5 miles

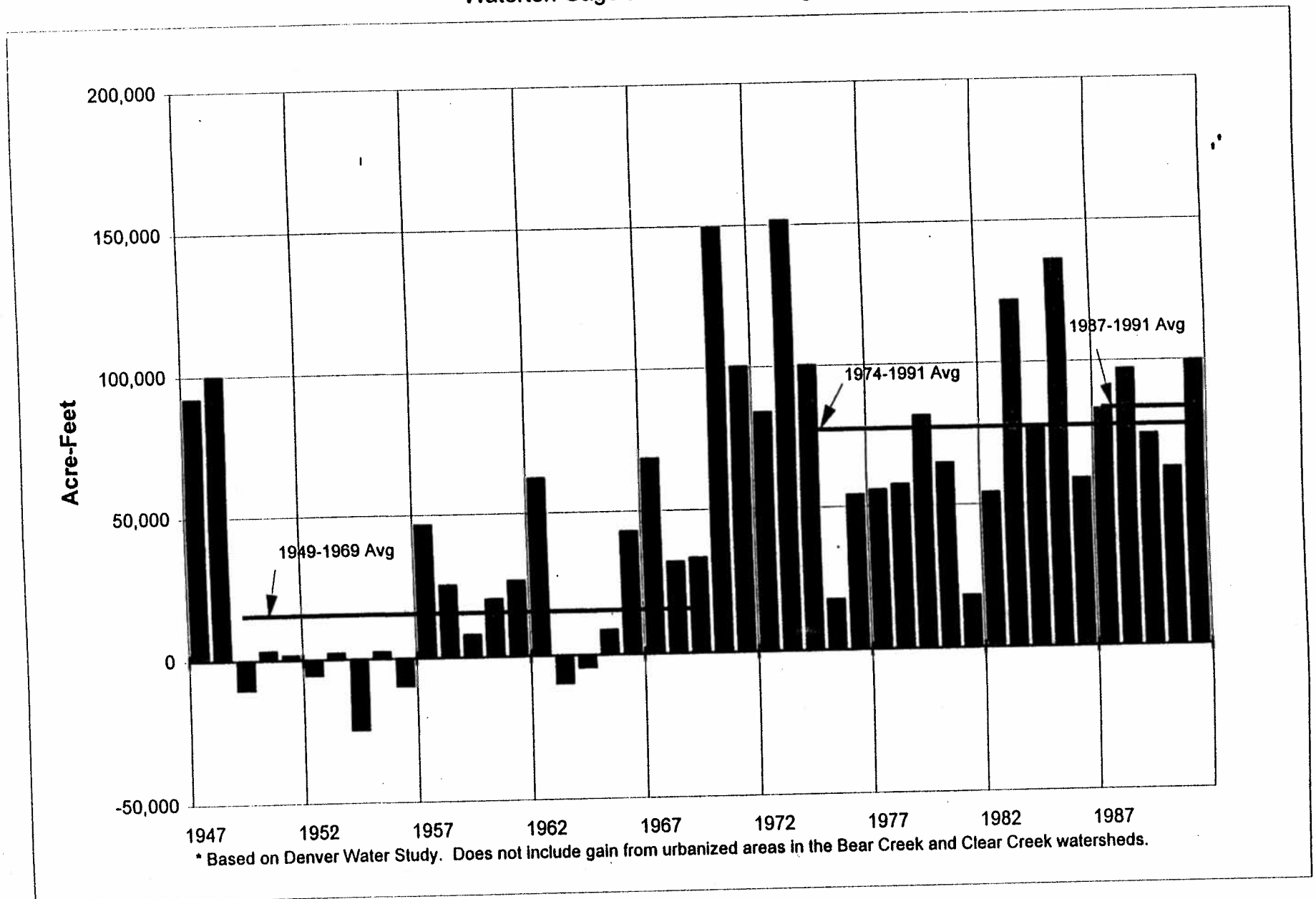
Spronk Water Engineers, Inc.
1000 Logan Street - Denver, Colorado 80203

Date: July 1997	Drawn by: JWM
Project No.: 213.01.CWC	Checked by: GKS
Base Map: USGS 1:250,000 scale - Denver, Colorado	

Figure 3-2

Computed Annual South Platte River Gains

Waterton Gage to Henderson Gage*



* Based on Denver Water Study. Does not include gain from urbanized areas in the Bear Creek and Clear Creek watersheds.

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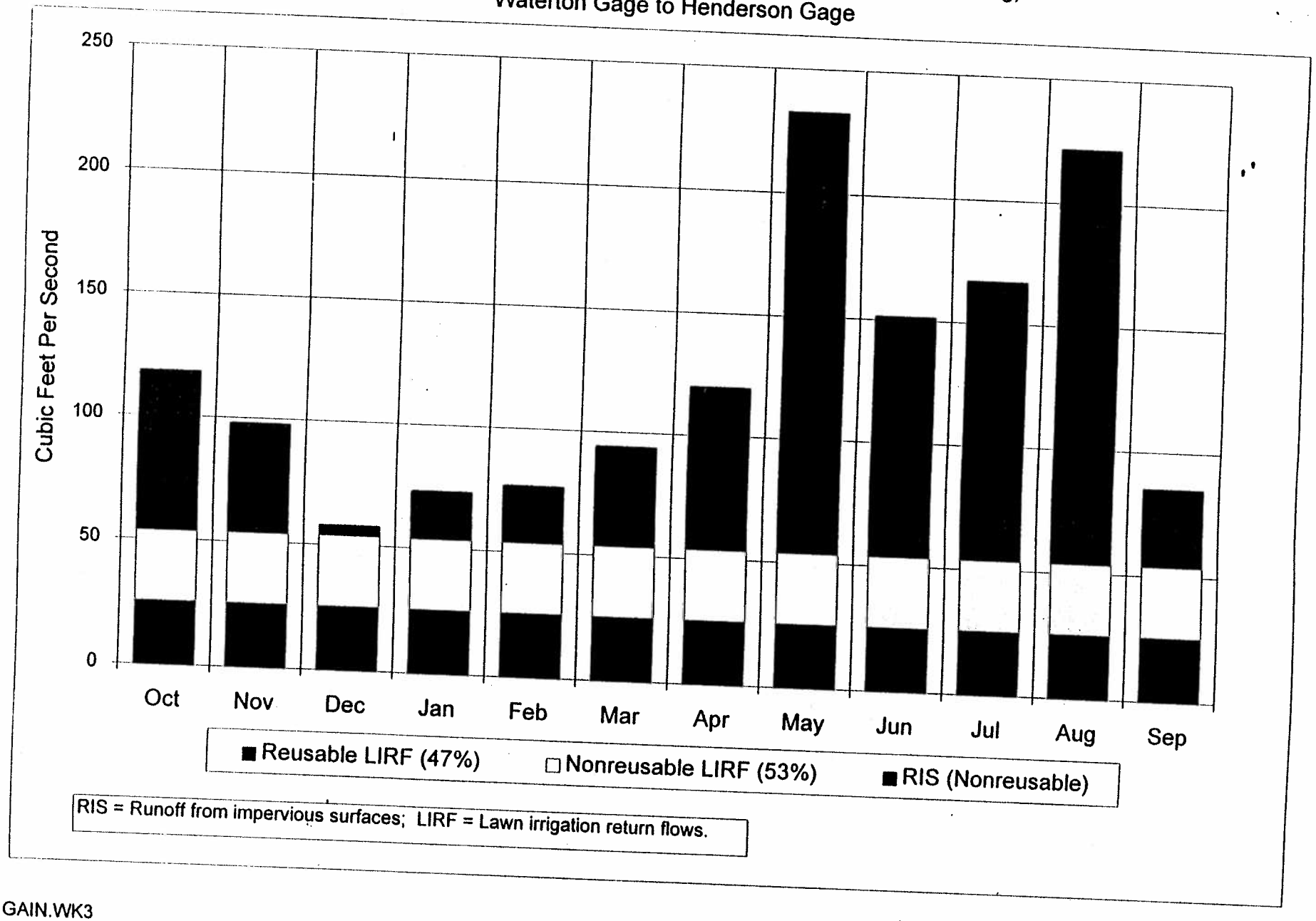
Figure 3-3

Computed Monthly South Platte River Urban Gains (1987-1991 Avg)

Waterton Gage to Henderson Gage



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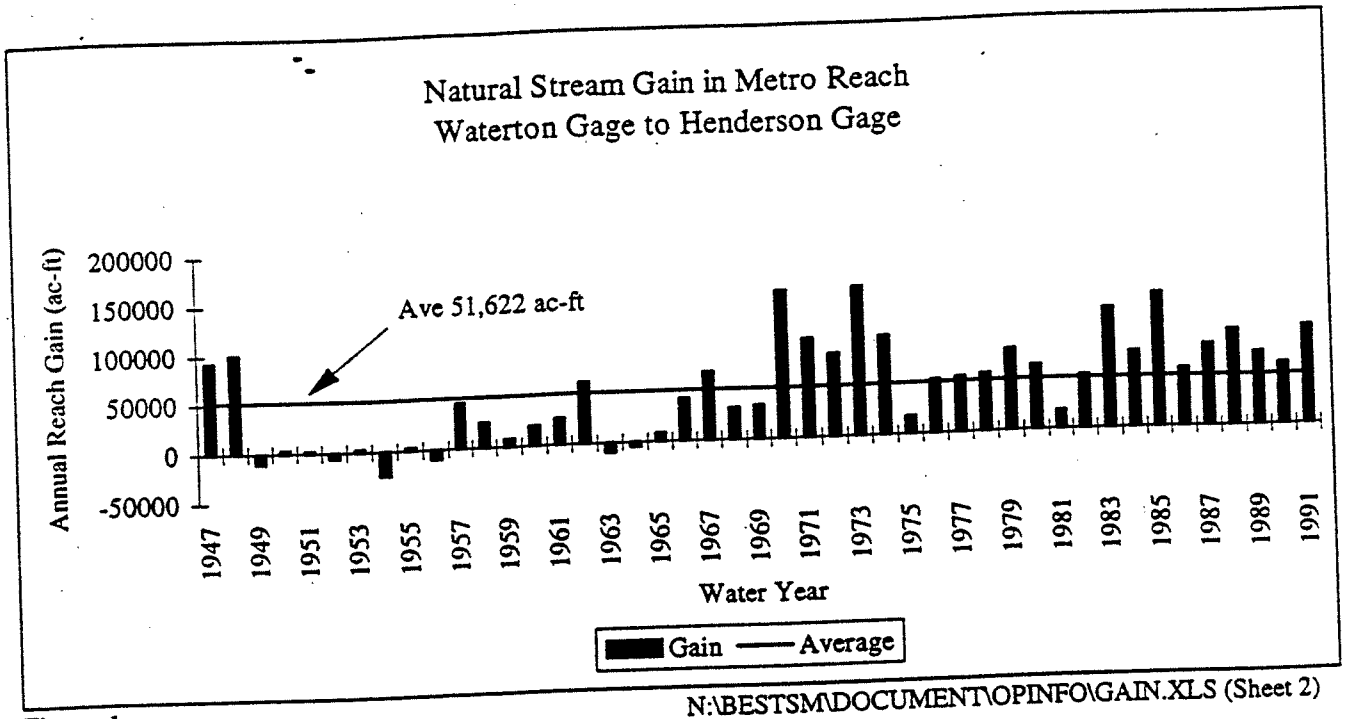

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Figure 1

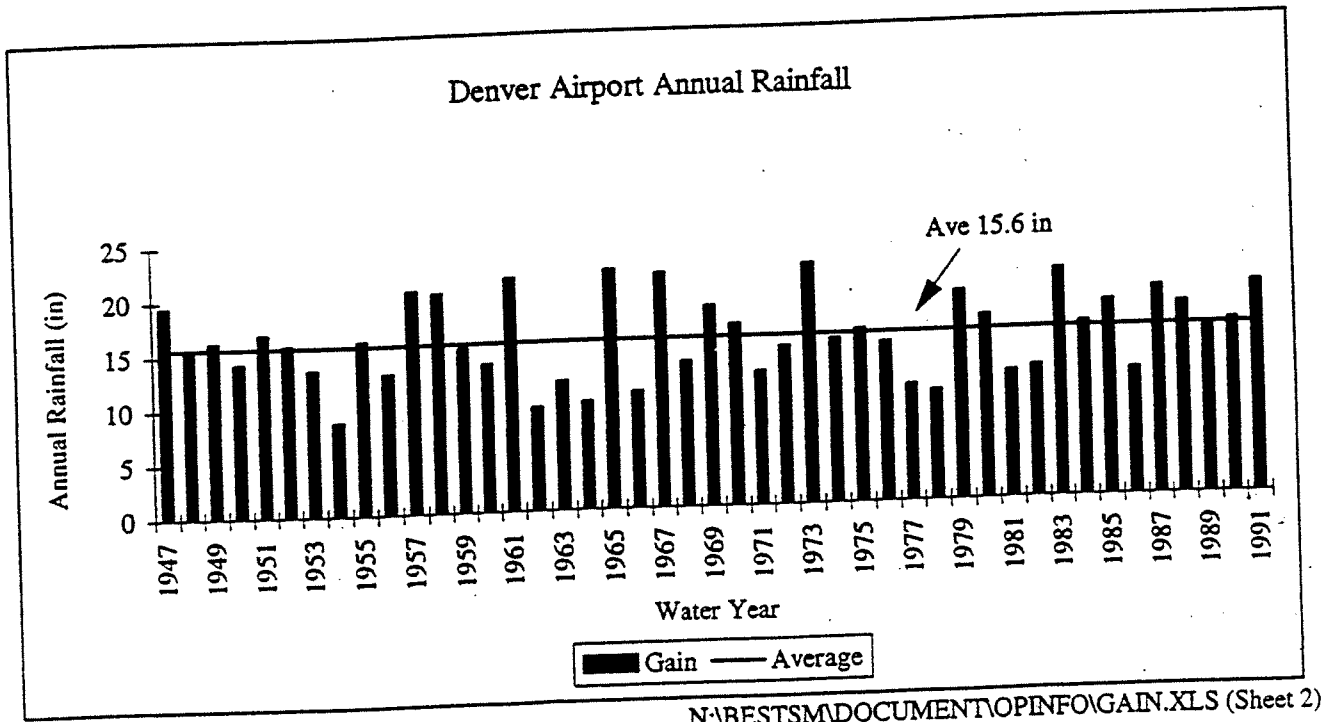

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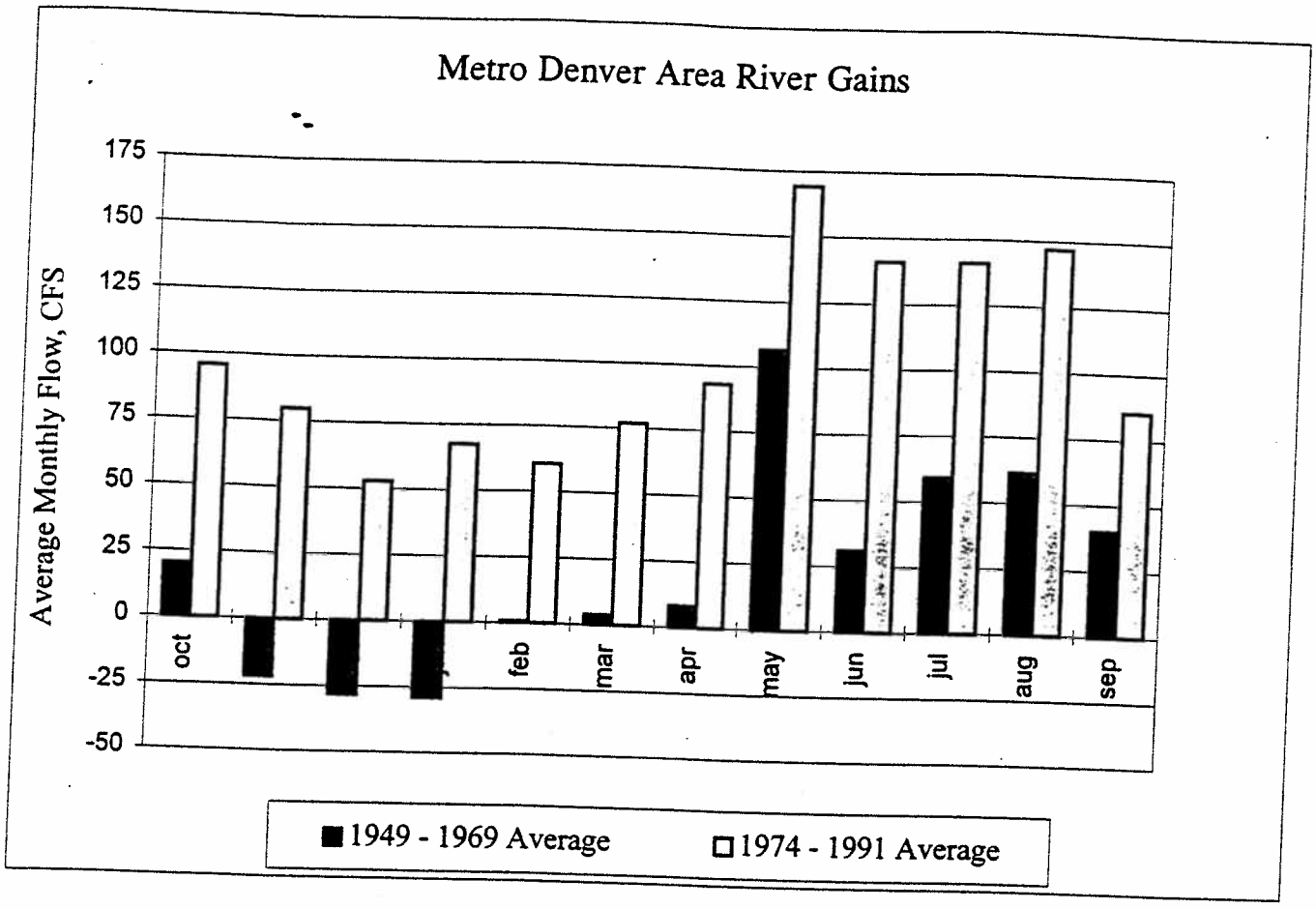
Figure 2


Metro Denver Area River Gains
Average Monthly Flow, CFS
175
150
125
100
75
50
25
0
-25
-50
oct
feb
mar
apr
may
jun
jul
aug
sep
1949 - 1969 Average
1974 - 1991 Average

4.0 EFFECT OF EXISTING EFFICIENCIES AND CONJUNCTIVE MANAGEMENT ON FUTURE WATER SUPPLY AND WATER RIGHTS ABOVE THE HENDERSON GAUGE

The focus of Chapter 4 is to explore water conservation and conjunctive use in terms of their long-term water supply potential and their effects on existing water rights above the Henderson Gage. Hydrosphere's approach to this task has consisted of the following steps:

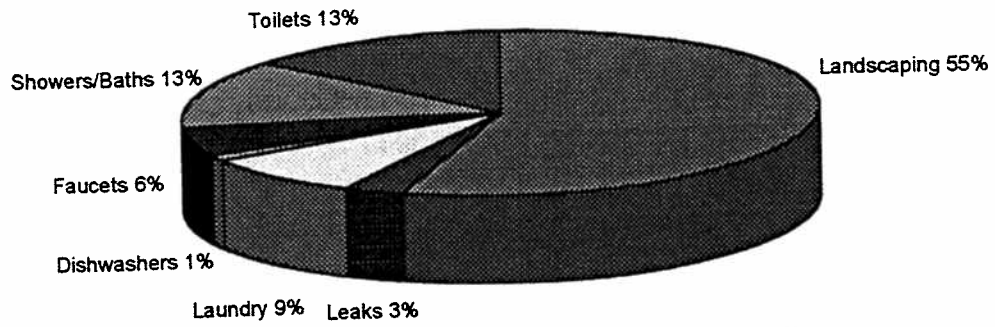
1. An inventory of existing water efficiency measures and practices.
2. An inventory of existing conjunctive management practices.
3. Development of quantitative estimates of the water supply effects of existing and projected future water efficiency measures and practices.
4. Development of quantitative estimates of the water supply effects of existing and estimated future conjunctive management practices.
5. An analysis of the impacts associated with efficiency and conjunctive management practices on South Platte River flows at the Henderson gage.
6. An evaluation of the combined effects of existing and future water efficiency and conjunctive management practices on existing water rights above the Henderson Gage.

The results of the information gathering and analysis efforts described above are summarized in this memorandum.

4.1 INVENTORY OF EXISTING WATER EFFICIENCY PRACTICES

Hydrosphere conducted a survey of the water conservation practices of Aurora, Boulder, Denver Water, and the Centennial Water & Sanitation District. The conservation measures and practices employed in these communities should provide a good indication of trends throughout the metropolitan area. While the survey identified the conservation measures described below as practices that are currently being employed by many water suppliers or are likely to be implemented in the future, the manner in which these practices are implemented varies substantially between different water suppliers.

Figure 4-1
Categories of Residential Water Use in the Denver Water Service Area



Source: Water Conservation Master Plan, Denver Water, 1992

Most of the water conservation practices currently being employed by metropolitan area water suppliers are designed primarily for the residential water use sector but are also applicable to the commercial and public sectors. These water efficiency measures are summarized below.

Table 4-1

Conservation Practices in Metro Denver Area

Conservation Measures	Aurora	Boulder	Denver	Highlands
Water-efficient fixtures & appliances:				
Voluntary program	X	X	X	X
Regulatory program[a]	X	X	X	X
Low water-use landscaping:				
Voluntary program	X	X	X	X
Regulatory program	X	X[b]		
Irrigation efficiency measures	X	X	X	X
Leak detection and repair	X	X	X	X
Education programs	X	X	X	X
Customer water use audits	X		X	
Water use restrictions	X[c]		X[d]	
Metering	X	X	X	X
Pricing incentives	X	X	X	

(a) Required under the Federal Energy Policy Act of 1992.
(b) Landscaping code applies only to municipal rights-of-way, parks, and new industrial parks.
(c) Mandatory rationing employed during drought periods, otherwise voluntary.
(d) Voluntary guidelines for every third day outdoor watering schedule.

4.2 WATER SUPPLY EFFECTS OF EXISTING AND FUTURE EFFICIENCY PRACTICES

The effectiveness of water conservation practices varies greatly among water suppliers as a function of which program elements are adopted, how long the programs have been in place, and the level of effort associated with educational programs. Various land use, demographic and economic factors also influence the effectiveness of water conservation programs. Without a detailed evaluation of development patterns, demographics and economic factors, it is not possible to accurately isolate the impacts of existing programs, nor is it possible to definitively quantify regional levels of savings from future programs.

The results of Denver Water's preliminary analysis of conservation savings is summarized in Table 4-2 below:

Table 4-2

Water Conservation Savings for the Denver Water Service Area 1980 - 1994

Conservation Measures	Years	Total Savings (acre-feet/yr.)
Water-efficient fixtures and appliances	1980 - 94	8,255
Leak detection and repair	1980 - 94	1,300
Customer water use audits	1987 - 94	804
Metering	1987 - 92	13,475
All other measures Low water-use landscaping Irrigation efficiency measures Education programs Pricing incentives	1980 - 94	5,666
Totals		29,500

Approximately 45 percent of the total estimated conservation saving for the Denver Service area is attributed to metering of about 86,000 single family residential taps that were unmetered prior to 1987. Because the practice of metering is commonly included

in water conservation programs throughout the Denver Metropolitan Area, we have assumed, for purposes of this analysis, that the effect of metering savings for all single family residential taps should be included in the estimate of overall conservation savings.

Table 4-3

Estimated Existing and Future Municipal Treated Water Use and Efficiency Savings for the Denver Metropolitan Area (acre-feet/year)

City	1996 Use	1996 Savings[a]	Future Use	Future Savings[b]
Denver Water	235,000	57,100	333,600	81,000
Aurora	49,500	12,000	69,800	16,900
Westminster	19,500	4,700	26,000	6,300
Arvada	16,500	4,000	22,000	5,300
Thornton	18,700	4,500	82,300	20,000
Consolidated Mutual	12,600	3,100	14,900	3,600
Douglas Co. Water Auth.	32,000	7,800	128,700	31,200
Englewood	10,200	2,500	11,200	2,700
Golden	5,000	1,200	8,000	1,900
Broomfield[c]			7,500	1,800
Northglenn	4,600	1,100	6,500	1,600
S. Adams Co. W & S Dist	5,500	1,300	11,000	2,700
Brighton	4,000	1,000	16,000	3,900
misc.	2,000	500	3,000	700
TOTAL	415,100	100,800	740,500	179,600

(a) 12.55 percent of 1996 Use.
(b) 15.0 percent of Future Use.
(c) 1996 Treated water use of 5,300 acre-feet and Future use of 6,500 acre feet for Broomfield is included in the respective use figures for Denver.

The effectiveness of water conservation measures in terms of actual water savings may vary substantially between water suppliers as a function of which program elements are employed, the manner in which they are implemented, how long the programs have

been in place, and various land use, demographic and economic factors. Without a detailed evaluations of these factors, it is difficult to isolate the impacts of existing and/or future water conservation programs from the other factors that influence water usage. For purposes of this study, because the water conservation practices employed by Aurora, Boulder, Denver Water, and Centennial (see Table 4-1 above) appear to be generally consistent, we assumed that the estimated water conservation savings realized to date by Denver Water are representative of the savings being achieved by other suppliers throughout the metropolitan area. Given this assumption, existing and future conservation savings can be estimated, based upon current and projected levels of demand as shown above in Table 4-3 for the Denver Metropolitan Area.

It is important to note that the future treated water use figures shown in Table 4-3 are based upon long-term demand projections for each of the water suppliers listed. Some metro area water providers may reach these demand levels sooner than others.

4.3 WATER SUPPLY EFFECTS OF EXISTING AND FUTURE CONJUNCTIVE MANAGEMENT PRACTICES

Conjunctive management, for purposes of this study, refers to the joint use of surface and nontributary groundwater systems in a manner that is designed to increase the delivery of sustainable water supplies to the metropolitan area. In many years, there are divertible surface water supplies in excess of the amount required to meet demands and fill storage reservoirs. Conjunctive use systems would capture and more fully utilize these unused surface supplies through either of the following techniques:

1. Expanded use of surface water supplies to directly meet municipal demands during average and wet years, while reserving groundwater for use in below average and dry years;

2. Expanded use of surface water supplies to recharge nontributary aquifers during average and wet years, while reserving groundwater for use in below average and dry years;

Both of these techniques could involve arrangements that would allow "borrowing" of water when available from surface water reservoirs with repayment through the delivery of groundwater back to the surface water supplier to meet direct demands during periods of drought. Under this arrangement, surface reservoirs could be more fully drawn down to meet expanded municipal demands and more effectively capture storable flows while drought protection would be provided by groundwater supplies. Basically, the concept of conjunctive management allows the linkage of groundwater and surface water systems so that nontributary aquifers become functionally equivalent to surface water storage. This allows water suppliers to more fully utilize available surface water supplies while reducing nontributary groundwater withdrawals and extending the life of nontributary aquifers. The MWSI Project, Phase II Conjunctive

Use Summary Report provides a more detailed discussion of conjunctive management concepts and alternative approaches.

4.4 EXISTING CONJUNCTIVE MANAGEMENT PRACTICES

Existing conjunctive management practices involve (1) limited recharge of Denver Basin aquifers by the Centennial Water and Sanitation District, and (2) experimental recharge of Denver Basin aquifers by the Willows Water District in cooperation with Denver Water and others.

The water supply effect of these existing conjunctive management practices are very limited. In the context of the water supply for Centennial, the District's 1996 total water demand was 9,889 acre-feet, which includes 1,561 acre-feet of deliveries from nontributary groundwater. The injection of 654 acre-feet to the Arapahoe aquifer results in a net nontributary groundwater withdrawal of about 907 acre-feet and accounts for about 6.6 percent of Centennial's 1996 water supply. Regionally, this is less than 0.3 percent of 1996 treated water deliveries.

The Willows Water District's recharge demonstration project was concluded in 1996, and is thus not considered to be a meaningful component of their existing water supply.

4.5 FUTURE CONJUNCTIVE MANAGEMENT

Future plans for conjunctive use are actively being examined by the Douglas County Water Authority in cooperation with Denver Water, as an ongoing part of the MWSI Project, and in possible follow-up studies. Conceptual plans for conjunctive use projects at several levels are currently being developed and refined for further evaluation and discussion by interested parties. With these refinements and discussions pending it is premature to identify any specific conjunctive use project that could be characterized as likely, or even possible.

4.6 ANALYSIS OF WATER SUPPLY EFFECTS

The water supply implications of the hypothetical conjunctive management Scenarios A and B are summarized below in Table 4-4.

Table 4-4

Summary of Conjunctive Use Modeling Results
(1947-91 Average Annual Acre-feet)

	Baseline	Scenario A	Scenario B
Groundwater Pumping	48,000	33,812	21,447
Groundwater Recharge	0	1,853	20,560
Net Groundwater Withdrawal	48,000	31,958	916
Blue River Water Captured	0	2,277	21,391
% of Blue River Water Captured	0	5%	51%
Uncaptured Blue River Water	41,694	39,417	20,303
South Platte Water Captured	0	13,557	24,402
% of So. Platte Water Captured	0	25%	45%
Uncaptured So. Platte Water	53,761	40,204	29,359
Reusable Return Flow	24,000	17,117	10,559

The potential water supply benefits associated with these conjunctive management scenarios are represented by additional capture of unused surface waters from the Blue and South Platte Rivers and long term reductions in nontributary groundwater withdrawals which would extend the useful life of these aquifers. Scenario A results in the capture of a total of 15,834 acre-feet of Blue and South Platte unused surface supplies without the construction of additional surface water storage reservoirs facilities or implementation of other measures. Scenario B results in the capture of a total 45,793 acre-feet of unused surface supplies. These additional surface supplies represent new yield to the participating water supply systems and would be a significant component of future water supply plans.

Due to the reductions in net groundwater withdrawals that occur with both Scenarios A and B, there is also a reduction the average annual volume of reusable return flows. In both scenarios, this reduction is more that offset by the amount of Blue River and South Platte water captured. Furthermore, it is unlikely that it will be physically possible to fully utilize these reusable return flows due to factors presented in the discussion of reuse in Chapter 5.

4.7 IMPACTS ON SOUTH PLATTE RIVER FLOWS AND AT THE HENDERSON GAGE AND EXISTING WATER RIGHTS

For purposes of this analysis, we have assumed that water demands in terms of underlying customer base in the metropolitan area will continue to grow to levels currently anticipated by metro area water providers. The continued use of water

efficiency measures and the possible implementation of conjunctive use arrangements will affect the mix of water supply sources that would be used to meet these growing demands. Many of the water efficiency measures that will result in future demand reductions are already in place, but at this time, no specific conjunctive use plans have been identified or agreed upon by metro area water providers. The supply sources used to meet future demands will vary between individual water suppliers depending upon the sources that are practically available to their systems. (For example, Denver Water has the ability to expand utilization of its Blue River and Moffat Tunnel systems to meet higher demands.) Thus, growing demands in the metro area will be met from available supply sources combined in varying ways by water suppliers. These water supply sources and the manner in which their utilization will impact flows in the South Platte are described below.

1. **Water imported to the South Platte from other river basins and nontributary groundwater** - These sources are considered to be "new water" that does not currently contribute to South Platte River flows. Diversions of imported water and pumping of nontributary groundwater will result in return flows at wastewater treatment plants and from lawn irrigation that are new to the river and will increase flow throughout the year.

2. **Reuse and exchanges** - Generally, water suppliers have the right to reuse return flows from imported sources and nontributary groundwater to extinction through exchanges and/or direct reuse. Historically most of the return flows from these sources has not been reused, resulting in a windfall to downstream water users, particularly those with relatively junior water rights. (See Chapter 3.) Increases in reuse and exchanges will tend to reduce streamflows in the South Platte below Denver throughout the year but particularly in months during summer months when exchange opportunities and demands for nonpotable reuse are greatest.

3. **Expanded utilization of native South Platte supplies** - This supply source includes increases in diversions under existing direct flow water rights, increases in reservoir drawdowns, and development of new storage facilities or enlargement of existing facilities to capture spring and early summer flows when available. Expanded utilization of native South Platte supplies will tend to reduce streamflows primarily during the spring and early summer when existing municipal rights may be able to divert more water and when unappropriated water is most likely to be available for storage under new rights. During the remainder of the year, streamflow would tend to increase due to return flows associated with increased use of South Platte supplies including reservoir releases.

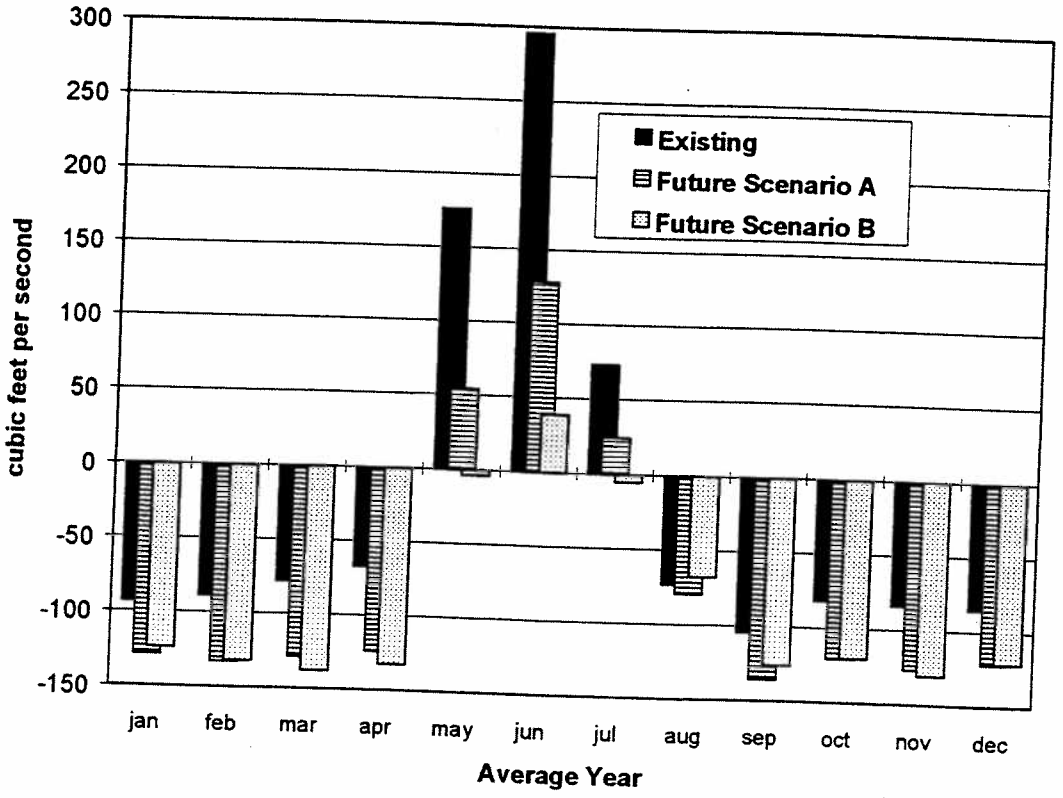
4. **Acquisition and conversion of agricultural rights to municipal uses** - This supply source includes both new conversions of agricultural water rights and termination of leases of municipal rights to agricultural users. This source will generally result in a minor amount of increase to streamflows because the process of transferring irrigation rights to municipal uses via the water court process is rarely 100% efficient. In practice, the stream tends to benefit slightly as a result of water rights change proceedings.

5. **Efficiency Practices** - Water conservation will tend to reduce diversions and the volume of return flows to the river and will thus reduce streamflows in the South Platte below the metro area.

For purposes of evaluating the effect of existing water efficiency practices and two future conjunctive management scenarios on streamflows in the South Platte at Henderson, a spreadsheet model was developed to account for the net accretive and depletive effects of different combinations of the supply sources described above.

Figure 4-2

Effect of Conservation and Conjunctive Use on South Platte Stream Flows



4.8 SUMMARY OF RESULTS

As a part of the SB-74 study, Hydrosphere examined the effects of water conservation measures and conjunctive management of surface water and groundwater resources by metro Denver area water providers on future water supply and on existing water rights above the Henderson Gauge. The following is a summary of the results of the analysis:

1. A variety of water efficiency practices have been effectively implemented by all major metro area water providers resulting in an estimated 100,800 acre-feet per year of existing savings.

2. Based upon current trends and projected future water conservation vings, it is estimated that future demands reductions will amount to about 179,600 acre-feet per year

3. Water efficiency practices provide a significant component of the existing metro area water supply. Without water conservation measures, the demand for treated water would be about 24 percent greater than 1996 treated water use and currently projected future treated water demand for the metro area.

4. Without water efficiency practices, there would be additional pressure for development of Denver Basin groundwater, additional transbasin diversions, more aggressive implementation of reuse and exchanges, acquisition and dry-up of irrigated agricultural land and development of South Platte surface storage projects.

5. Water efficiency practices generally result in reduced South Platte stream flows during the months of August through April and increased stream flows during the months of May through July. In the Colorado and Arkansas Basins, water efficiency results in an increase in streamflows in all months of the year over what would otherwise occur without conservation measures.

6. Existing conjunctive management practices consist of a small project being implemented by the Centennial Water and Sanitation District and a small demonstration project completed by the Willows Water District in cooperation with Denver Water and others. The 1996 water supply impact of Centennial's project was to reduce net nontributary groundwater withdrawals by about 654 acre-feet. Conjunctive use accounted for about 6.6 percent of Centennial's 1996 water supply.

7. Future plans for conjunctive management are currently being examined by the Douglas County Water Authority in cooperation with Denver Water, but at this time, it is premature to identify any specific conjunctive use project that could be characterized as likely, or even possible. Hypothetical conjunctive use plans examined in this report indicate potential water supply benefits ranging from

about 16,000 acre-feet per year in Scenario A to 46,000 acre-feet per year in Scenario B. Either of these levels represent a potentially significant component of future water supply.

8. Existing conjunctive management practices are too small to have any meaningful impact on streamflows in the South Platte River at Henderson. Future hypothetical conjunctive use Scenario A would tend to produce a net reduction in average streamflows in the South Platte throughout the year, except in the month of July. Scenario B would tend to produce a net reduction in average streamflows in the South Platte throughout the year, except for the month of August. These streamflow changes result primarily from increased utilization of native South Platte supplies.

9. Future conjunctive management Scenarios A and B would also rely upon increased utilization of Blue River water, resulting in streamflow reductions in the Blue River below Dillon Reservoir during the spring and early summer months.

10. Conjunctive management implemented in accordance with decrees would not injure existing water rights, but would tend to reduce flows available to downstream water users that rely upon relatively junior water rights.

5.0 EFFECT OF EXISTING WATER REUSE ON FUTURE WATER SUPPLY AND ON EXISTING WATER RIGHTS

This chapter examines, from a regional perspective the effects of water reuse by metro Denver area water providers on future water supply and on existing water rights. Existing and expected future amounts of reusable water available to metro Denver area water providers, and return flows resulting from those supplies have been quantified. Existing reuse activities and future reuse plans in the metro Denver area have also been characterized.

5.1 BACKGROUND

For the purposes of this report, water reuse is defined as the use by a municipal water provider of return flow resulting from that provider's first use of water. Water reuse is any specific arrangement that utilizes return flows so that they would not otherwise be available to the stream for allocation under the priority system. From a consumptive use perspective, water reuse includes either one reuse or reuse to extinction.

Under Colorado water laws, reusable water can generally come from four sources: 1) imported transbasin water; 2) nontributary groundwater; 3) the historically consumed portion of water rights changed from one use to another, such as from irrigation to municipal use; and 4) water diverted under a water right which has been decreed to allow reuse. Reusable return flows are assumed to include both wastewater discharges and lawn irrigation return flows which originate from reusable supplies.

Broadly speaking, water reuse can be accomplished either by direct reuse or by substitution. Examples of direct reuse include irrigation of golf courses or supply of power plants with appropriated treated wastewater. Examples of substitution include water exchanges, plans of augmentation, first use agreements and water trades which allow for diversion of water at one location in substitution for water added to the stream at another location.

5.2 REUSABLE RETURN FLOWS

As part of the effluent management investigations conducted in the Metropolitan Water Supply Investigation (MWSI), the water supply portfolios of metro Denver area providers were inventoried and reusable supplies and reusable return flows were quantified using 1993 and 1994 data (Hydrosphere, 1995). In that study, existing levels of reusable supplies were quantified based on water use accounting for individual providers, surveys, and discussions with individual providers. Future levels of reusable supplies were quantified based on best available planning data; including modeling studies, decrees and individual provider's reuse plans. Based on this

analysis, existing and estimated future reusable water supplies and reusable return flows are summarized in Table 5-1 below.

Table 5-1:
Reusable Supplies and Return Flows in the Metro Denver
(Acre Feet Per Year)

	Reusable supply		Reusable wastewater	
Provider	Present	Future	Present	Future
Denver Water	85,000	145,000	46,000	77,000
Aurora	49,000	70,000	26,000	38,000
Douglas County (1)	24,000	116,000	10,000	46,000
Thornton	9,000	45,000	5,000	24,000
Westminster	6,000	8,000	4,000	5,000
Arvada	4,000	5,000	1,000	2,000
Other (2)	24,000	43,000	12,000	19,000
Subtotal	201,000	432,000	104,000	211,000
Reusable LIRF's (3)			20,000	41,000
Total	201,000	432,000	124,000	252,000

(1) Includes all Douglas County Water Resource Authority
(2) Includes Brighton, Broomfield, Englewood, Golden/Coors, SACWSD and miscellaneous providers
(3) Lawn irrigation return flows

5.3 LEVELS OF REUSE

Levels of reuse vary to some degree from year to year, with higher levels o reuse occurring during average and below average years when yields from South Platte rights are relatively less and reusable supplies from transbasin and nontributary groundwater sources are relatively greater. Planned future levels of reuse were quantified based on individual providers' future reuse plans, and on provider responses to the Metro effluent reuse questionnaire. Existing and estimated future levels of reuse are summarized in Table 5-2 below.

Table 5-2:
Summary of Effluent Reuse
(Acre Feet Per Year)

Provider(s)	Current Use Subst.	Current Use Direct Reuse	Current Use Total	Planned Future Use Subst.	Planned Future Use Direct Reuse	Planned Future Use Total
Denver	18,500	0	18,500	30,000	17,000	47,000
Aurora	6,400	400	6,800	12,900	7,000	19,900
Douglas County (1)	2,000	400	2,400	23,500	3,500	27,000
Thornton	3,000	0	3,000	24,500	4,000	28,500
Westminster	3,700	0	3,700	4,900	1,500	6,400
Arvada	1,300	0	1,300	1,900	3,300	5,200
Other (2)	18,200	0	18,200	30,900	3,000	33,900
Totals	53,100	800	53,900	128,600	39,300	167,900

(1) Includes all Douglas County Water Resource Authority

(2) Includes Brighton, Broomfield, Englewood, Golden/Coors, SACWSD and miscellaneous providers

5.4 EFFECTS ON FUTURE WATER SUPPLY

Water reuse has been and will continue to be a major water supply source for the metro Denver area. As previously discussed, reuse accounts for about 11% of the region's existing water supply, or about 54,000 acre feet per year. Reuse will account for approximately 20% of the region's water supply, over 167,000 acre feet per year, in the foreseeable future. If water reuse were not an option available to metro area water providers, these levels of supply deficits would have to be pursued via other means, such as additional transbasin diversions, new South Platte supply development, water conservation, nontributary groundwater development or acquisition of irrigation water supplies.

Without reuse there would be additional pressure for development of Denver Basin groundwater, additional transbasin diversions, acquisition and dry-up of irrigated agricultural land and development of South Platte surface storage projects. Because reuse via exchanges and augmentation plans is a generally a relatively cost effective water supply source, replacement of the yield derived from reuse with other supply development options would result in significant increases in the price of water supplies. Water demand reductions, both through active water conservation programs and due to consumer price responses, would also occur.

5.5 EFFECTS ON EXISTING WATER RIGHTS

Water reuse activities described and quantified above have occurred or will occur in accordance with Colorado water laws under a variety of decrees for exchanges and plans for augmentation. Thus, by definition, water reuse activities implemented in accordance with decrees would not injure existing water rights. The water reused under these exchanges and augmentation plans is foreign to the natural flow of the South Platte and therefore generally unavailable for appropriation under the priority system.

The elimination of existing water reuse as a water supply option would decrease the metro Denver area's existing water supply by 54,000 acre feet per year, and would reduce the area's future water supplies by 168,000 acre feet per year to over 200,000 acre feet per year. Assuming that existing water demands would stay the same in terms of underlying customer base, water providers would have to resort to a combination of alternate water supply development and/or demand management measures. These would include transbasin diversions, new South Platte supply development, water conservation, nontributary groundwater development or acquisition of irrigation water supplies to make up the difference. While it is reasonable to assume that all providers would include some additional level of water conservation as a common element in their alternate water supplies, each provider or provider group would differ in their use of other supply sources.

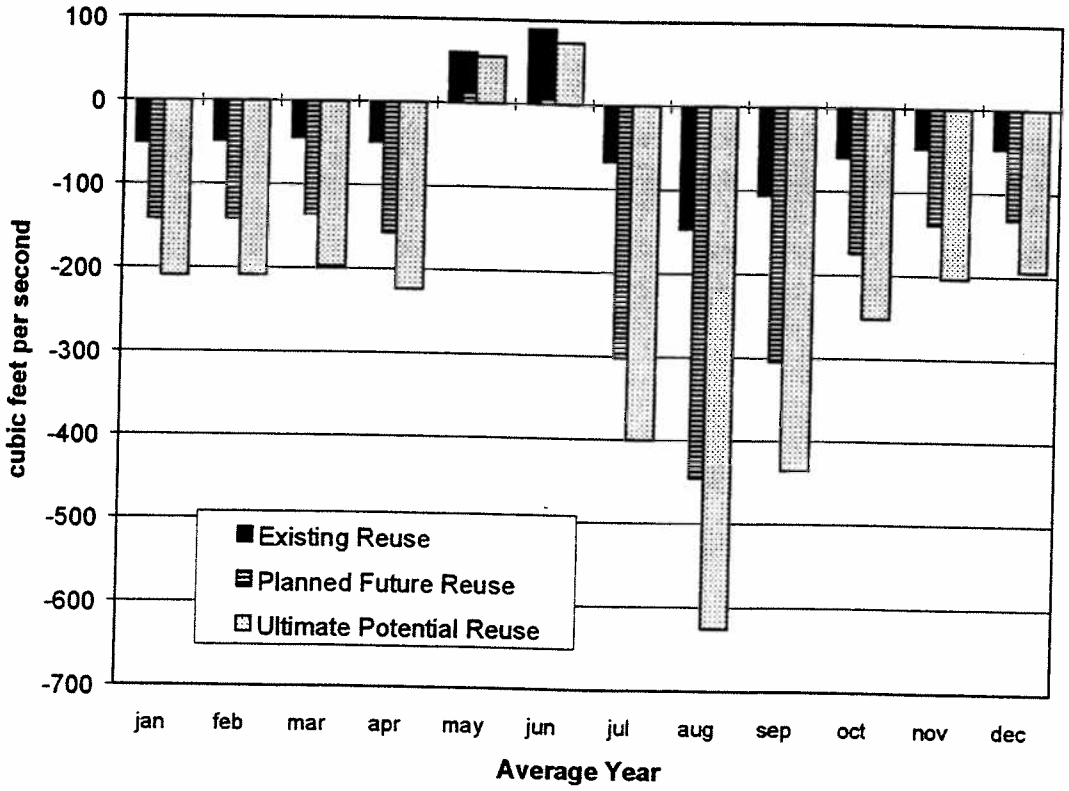
The net effect of replacement of reuse with water conservation and other water sources on stream flows in the South Platte, Colorado and Arkansas Basins would depend on the mix of "replacement" water supply sources implemented. For the purpose of this analysis, the following mix of replacement supplies was assumed:

Table 5-3: Assumed Mix of Water Supply Sources For Replacement of (acre feet per year)

Replacement Supply Source	Existing Reuse	Planned Future Reuse	Ultimate Potential Future Reuse
Transbasin Imports	10,000	35,000	60,000
Nontributary Groundwater	2,000	35,000	49,000
Agricultural Conversion	10,000	28,000	38,000
Water Conservation	11,000	35,000	35,000
South Platte Storage	21,000	35,000	53,000
Total	54,000	168,000	235,000

The effects on South Platte stream flows of water reuse at existing, planned future and ultimate potential levels was quantified by comparing alternate water supply scenarios which included either reuse as a water supply source or additional amounts of replacement sources as shown above. In this analysis, the accretive and depletive effects of importations, reservoir operations, water supply diversions, consumptive uses and return flows were calculated for each alternate future based on recent historical operational data for each of these sources. The following Figure 5-1 depicts the combined net change in average year physical supply to the South Platte River and its tributaries resulting from water reuse at a region-wide level.

Figure 5-1
Effect of Reuse on South Platte Stream Flows



This analysis indicates that existing reuse generally reduces stream flows during July through April due to the depletive effect of exchanges and augmentation plans and because these reuse measures reduce the need for transbasin diversions and storage releases which would otherwise increase return flows during these months.

Based on the assumptions discussed above, existing reuse activities in the metro Denver area result in average flow increase of approximately 60 cfs during mid-May through mid-August. Planned future and ultimate potential levels of reuse would result in average flow increases of approximately 200 cfs and over 300 cfs, respectively. The distribution of these flow increases among the Colorado and Arkansas Basins and among the various tributaries within these basins would be dependent on the specific nature of the replacement supplies that would be pursued by metro Denver area providers in the absence of reuse.

5.6 SUMMARY OF RESULTS

The following is a summary of the effects of water reuse by metro Denver area water providers on future water supply and on existing water rights:

1. Water reuse accounts for about 11% of the region's existing water supply, or about 54,000 acre feet per year. Reuse will account for approximately 20% of the region's water supply, over 167,000 acre feet per year, in the foreseeable future. Ultimate levels of reuse could exceed 200,000 acre feet per year, assuming that water providers aggressively pursue full utilization of their legally reusable supplies via nonpotable and potable direct reuse.

2. Without water reuse there would be additional pressure for development of Denver Basin groundwater, additional transbasin diversions, acquisition and dry-up of irrigated agricultural land and development of South Platte surface storage projects.

3. Water reuse implemented in accordance with decrees would not injure existing water rights. Water reused under exchanges and augmentation plans is foreign to the natural flow of the South Platte and therefore generally unavailable for appropriation under the priority system.

4. Water reuse does affect the physical supply of streams in the South Platte, Colorado and Arkansas Basins by virtue of the direct depletive effects of water reuse itself and the indirect effects of reduced need for transbasin and nontributary groundwater water supply sources due to the role of reuse as a water supply source.

5. Water reuse generally results in reduced South Platte stream flows and increased stream flows in the Colorado and Arkansas Basins.

6.0 A REVIEW OF DISTRIBUTION SYSTEM INFRASTRUCTURE IN THE DENVER METRO AREA TO IDENTIFY WAYS TO PROMOTE MAXIMUM UTILIZATION OF WATER RESOURCES AVAILABLE TO THE SOUTH PLATTE BASIN ABOVE THE HENDERSON GAUGE

The focus of this chapter is to explore opportunities for using existing water supply and distribution facilities to enhance and promote the development and use of water resources above the Henderson gauge.

6.1 BACKGROUND

As a part of this report, information was reviewed and compiled from a series of regional meetings which were conducted as part of the MWSI Project to identify potential cooperative "systems integration" opportunities. These meetings included extensive mutual education between water providers and other interested parties and have resulted in the organization of three sub-regional groups. The groups have identified cooperative water supply opportunities for further investigation. The opportunities to be studied would promote maximum utilization of water resources available to the South Platte Basin above the Henderson Gauge.

6.2 SOUTHERN GEOGRAPHIC SUB-REGION

Investigations now underway will seek to define the potential additional yield that could be cooperatively developed using Denver's existing water supply system and some of its Blue River and South Platte water rights in conjunction with water rights, storage, conveyance and delivery facilities currently or potentially available to members of the Douglas County Water Authority. These investigations will focus on the increased yield resulting from new off-stream storage, conjunctive use of surface water and ground water supplies, nontributary aquifer recharge, and borrowing/payback arrangements with Denver including the following:

1. New raw water pipelines from Strontia Spring and/or Chatfield Reservoirs to one or more off-stream surface storage facilities in Douglas County.

2. Delivery of Denver's unused Blue River supplies and excess South Platte Flows as available for direct use and/or recharge.

3. Delivery of nontributary groundwater to serve Denver Water demands during dry periods based upon Denver system surface storage triggers.

6.3 NORTHEAST GEOGRAPHIC SUB-REGION

Preliminary quantitative studies are now underway to define the potential additional yield that could be cooperatively developed using water rights, storage, conveyance and delivery facilities currently or potentially available to the Northeast Provider Group in conjunction with Denver's existing water supply system and some of Denver's water rights. This study will build upon effluent management and systems integration concepts previously identified in the MWSI Project. Specifically, the study will focus on the hydrology, water rights, operations, water quality and raw water storage aspects of contemplated actions including the following:

1. Developing the remaining substitution opportunities using downstream reusable return flows and the participants' upstream diversion points, subject to water rights, water quality and instream flow concerns.

2. The utility of additional storage below the Metro Wastewater Reclamation District Plant (the water quality impacts on water users located below points of substitution are items of particular mutual interest);

3. Enhancing the size, reliability and water quality of potable municipal supplies diverted from the South Platte River at or below the Burlington Ditch. Alternate sources of supply could include the Barr Lake/Beebe Draw area or the South Platte River near the Burlington Ditch. These sources could be regulated by local downstream storage.

4. Optimizing the delivery of nonpotable water from the Metro plant for appropriate uses. The utility of additional storage below Metro and the "trade potential" of participating in a nonpotable reuse plan in trade for additional potable water supplies from Denver Water are areas of particular mutual interest.

6.4 NORTHWEST GEOGRAPHIC SUB-REGION

A study is anticipated to define the potential additional yield that could be cooperatively developed through interconnections and cooperative use of storage facilities at one or more locations in the northwest area. Northwest water supply systems, seasonal operations for wet/average/dry years, participants' relevant water rights, and major system facilities including diversion points, canals, pipelines, reservoirs, treatment plants, principal treated water distribution lines and interconnections will be examined to identify critical linkages, capacities and bottlenecks. An operational analyses will be conducted to help identify constraints and opportunities including the following:

1. Attention would be focused on identifying storage levels in major reservoirs and levels of use of major conveyance facilities. Opportunities associated with periods of unused storage and conveyance capacity within individual systems will then be identified.

2. Monthly time series estimates of unused supplies available under the participating parties' water rights will be developed including estimates of supplies from the Moffat and Gumlick Tunnels, South Boulder Creek, Coal Creek, Ralston Creek and Clear Creek. Opportunities associated with these unused supplies will be identified.

3. Opportunities associated with reusable supplies and unused Clear Creek exchange potential (which may exist due to insufficient storage or individual exchange supplies) will be identified.

4. An analyses will be conducted to look at how unused supplies could be "firmed" from a regional perspective by delivery to demand locations or to available storage capacity using existing and assumed future interconnections. Initial analyses would focus on the regional opportunities associated with existing systems.

5. The benefits of additional storage capacity at Standley, Gross, Leyden Gulch and other locations will be examined.

7.0 THE EFFECT ON EXISTING WATER RIGHTS OF CURRENT RECHARGE TECHNOLOGY AND PRACTICES IN THE DENVER BASIN AQUIFERS

This chapter examines the current injection practices in the Denver Basin Aquifers and addresses their impact on water rights.

7.1 INJECTION PRACTICES IN THE DENVER BASIN AQUIFERS

Centennial Water and Sanitation District (Centennial) and Willows Water District (Willows) are the only Front Range municipal water suppliers who have undertaken field studies to quantify the potential of injection, storage, and recovery of Arapahoe aquifer water. At current levels the injection, storage, and recovery of water has not affected existing water rights. It is estimated 500,000 acre feet of injection storage capacity is available in the four Denver Basin aquifers.

1. **Centennial Water and Sanitation District - Aquifer Storage and Recovery Project** - Aquifer storage and recovery is an operational component of Centennial's water supply system. Injection water is brought from McLellan Reservoir, treated at the Centennial water treatment plant, and then delivered to wells for injection. In 1996 a total of 654 acre feet was injected into the Arapahoe aquifer. Injection rates at Centennial's wells approximately equal the wells' pumping rates. No adverse well hydraulic or water quality problems are reported. Centennial is currently equipping two additional wells for injection, Arapahoe well A-5 and Denver well D-10. Injection at D-10 will be the first Denver aquifer injection well.

2. **Willows Water District - Denver Basin Aquifer Recharge and Demonstration Project** - The Denver Basin Aquifer Recharge and Demonstration Project (Demonstration Project) is part of the High Plains States Ground Water Demonstration Program. This project is a cooperative including U.S Bureau of Reclamation, Willows Water District, Denver Water, the U.S. Environmental Protection Agency, the U.S. Geological Survey, the U. S. Fish and Wildlife Service, and the Colorado State Engineer's Office.

   The Demonstration Project consisted of a series of injection runs and pumping cycles. Treated surface water from Denver Water was injected into the Arapahoe aquifer. During pumping and injection, water quality and water level were monitored in the production well and a nearby monitoring well. The total volume of water injected and stored by the project is estimated to be 1,282.7 acre feet.

The EPA concludes:

> "Nothing learned in the project has indicated an unacceptable risk to ground water drinking supplies from artificial recharge through injection wells at this site"[1]

7.2 EFFECT ON EXISTING WATER RIGHTS

In 1995 the State Engineer's Office pursuant to S.B. 94-97 promulgated the Denver Basin Artificial Recharge Extraction Rules. These rules can be used to evaluate the effect of the extraction of stored water on existing wells and other water rights. The Denver Basin Artificial Recharge Extraction Rules address potential water rights injury issues and thereby address potential effects of aquifer recharge on existing water rights.

The "Rules and Regulations for the Permitting and Use of Waters Artificially Recharged Into the Dawson, Denver, Arapahoe, and Laramie-Fox Hills Aquifers" (a.k.a.: "Denver Basin Artificial Recharge Extraction Rules").

These rules and regulations are promulgated pursuant to the authority granted the State Engineer in Sections 37-80-102(1)(g) and (k), 37-90-138, C.R.S. (1990 Rep), and 37-90-137(9)(d), C.R.S. (1990 Rep, 1994 Supp).

These rules apply to the evaluation and processing of applications for permits to extract water which has been artificially recharged into one or more of the Denver Basin aquifers, identified as the Dawson, Denver, Arapahoe, or Laramie-Fox Hills aquifers located outside the boundaries of any designated ground water basin.

The naturally occurring water contained in these Denver Basin aquifers is a significant but finite resource. Artificial recharge of these aquifers by injection of surface and/or ground water for the purpose of subsequent extraction, or for maintaining water levels will extend the life of this resource. The rules promulgated herein are required to enable the State Engineer to administer the orderly withdrawal of any water artificially recharged into these aquifers.

Withdrawal of artificially recharged water may be accomplished through an existing well, or through a well specifically constructed for the purpose of extracting artificially recharged water. These rules and regulations apply to the permitting and construction of extraction wells, for the permitting of extraction through the extended use of existing wells, and for the assessment of application fees. Their purpose is to make the submission, consideration and evaluation of permit applications more uniform and certain. The granting of permits also provides the State Engineer the means to monitor and record the development and use of artificially recharged water.

These rules define the State Engineer's authority to monitor and observe the extraction and use of artificially recharged water and to require the installation of measuring devices, to prevent injury to existing surface water rights and existing users of, and rights to water from the Denver Basin aquifers, and to provide the means for enforcing these rules.

The purpose of these rules and regulations is to enable the State Engineer to account for and administer the orderly extraction of water which has been artificially recharged into any of the Denver Basin bedrock aquifers, and to prevent injury to existing water users and water rights holders.

These rules are limited to the permitting and extraction of artificially recharged waters from existing wells or from wells constructed specifically for extraction of artificially recharged water.

The naturally occurring waters of the Denver Basin bedrock aquifers are essentially nonrenewable by natural processes. The lie of this valuable resource can be prolonged by artificial recharge using surface water or other ground water available during periods of low demand or excess capacity.

Water recharged into the Denver Basin aquifers may be extracted during periods of drought, or may be left in the aquifer, resulting in lower rates of decline in local or regional water levels, thus maximizing the conjunctive use of the waters of the state.

1 John C. Halepaska and Associates (1997) Final Report Denver Basin Aquifer Demonstration Project, 70 p.

8.0 THE IMPACT OF DE MINIMIS STANDARDS FOR INJURY BASED UPON AN ANNUAL DEPLETION STANDARD

This chapter examines the physical impacts to stream systems in the state, as well as possible legal and administrative implications, of de minimis standards for injury based upon an annual depletions standard. In this report, de minimis means a small amount of depletion in a calendar year that could be allowed without requiring the owner of a well causing the depletion to augment, or replace the water depleted or removed, from the stream and aquifer system. Should such a standard be deemed necessary, the analysis also suggests issues that may require further consideration.

8.1 IMPACTS OF DE MINIMIS STANDARDS FOR INJURY

The legislative requirement to examine the impact of de minimis standards under Senate Bill 96-74 is somewhat vague. The bill does not state whether the examination is to be of a physical, engineering, or philosophical perspective. There is also little assistance provided in the language as to whether the "standard" is to apply to depletions throughout the state, depletions that occur to the South Platte River system from tributary or not-nontributary pumping, or depletions that result purely from Denver Basin aquifer pumping.

From a strict engineering perspective, depletion to a stream has an impact to the system no matter the source of the depletion. For example, a depletion as a result of pumping from the Denver Basin aquifer effects the South Platte and its tributaries just as pumping an alluvial well along Cherry Creek effects that same stream system. Only the relative timing and quantity of the depletion is different. Under many Denver Basin aquifer pumping scenarios, the maximum effect of the depletion may be years after pumping ceases, whereas most alluvial pumping effects are on a more immediate time frame.

8.2 PHYSICAL IMPACTS

To determine the physical impacts from an engineering or numerical standpoint would be difficult. Assuming for example, that the analysis was limited to Denver Basin not-nontributary pumping, the reviewer would have to discern which augmentation plans currently exist that might have possible depletions of less than the annual depletion standard, and then discern or make assumptions as to which pieces of property overlying the not-nontributary aquifer could be developed in such a manner as to have an effect less than the standard. All of these properties would then require a modeling analysis to insure that the depletion to the tributary stream is below the standard. A total depletion might then be calculated, but it would be full of assumptions concerning property size and amount of ground water available for withdrawal as a result of the property assumptions. If the study were to apply on a statewide basis, the assumptive

and predictive problems are multiplied. It has therefore been deemed impractical to attempt to determine the actual physical impacts of a de minimis standard. It is safe to assume that whatever numerical value is chosen, the effects would be cumulative for each new development falling under the standard.

8.3 LEGISLATIVE HISTORY

The legislature has not defined the term de minimis. However, in relation to Colorado law, the legislature has recognized certain types of uses as exempt from the priority system. Wells located outside the designated ground water basins as defined in section 37-92-602, C.R.S., which include small capacity wells generally used for residential and livestock uses on farms, in house use only wells, fire protection wells and very small commercial wells, may be exempt from the priority system if they meet the detailed criteria set forth in the statute. Further, small capacity wells of similar types of uses as described in 37-92-602, C.R.S., located inside of designated ground water basins are also exempt from regulation (see section 37-90-105, C.R.S.). No acre-foot amounts are associated with these types of wells, but in general, the pumping capacity is limited to a maximum of 15 gallons per minute. Some limited instances allow for up to 50 gallons per minute in designated ground water basin.

The only acre-foot limitations discussed in the relevant statutory law concerns livestock watering tanks (small dams) and erosion control dams (see sections 35-49-101 through 116, and 37-87-122, C.R.S.). Structures meeting the legislative criteria set forth under these laws are exempt from priority system. Briefly, these types of structures must be constructed on water courses which have been determined by the State Engineer to be normally dry, and are limited in the amount of water they can store. In the case of erosion control dams, 2 acre-feet is the maximum allowed and for livestock tanks, 10 acre-feet is the limit.

8.4 ADMINISTRATIVE HISTORY

Historically, the State Engineer has always maintained that "one drop" of depletion is injury to an over appropriated and on-call stream system. The State Engineer has applied this standard on all stream systems throughout the state through his permit review, consultation process, etc., regardless if the depletion results from tributary alluvial pumping, not-nontributary pumping, or as a consequence of a change of water right. From an overall water management perspective under the prior appropriation system of the state this unwritten policy of the State Engineer makes administration of the system much easier, in that it requires pumping proposals that might deplete the system to prove and insure that there is no injury, as opposed to the State Engineer making arguments to the contrary.

8.5 ADMINISTRATIVE IMPACTS AND IMPLICATIONS

Any annual depletion standard chosen, in and of itself, will be very difficult to implement. Is one acre-foot of annual depletion per project a good number? Is .5 acre-feet? Is 2 acre-feet? Whatever number is chosen, it would be difficult to develop an acceptable standard based on credible engineering analysis. And whether the number is 0.5 acre-foot or 1.5 acre-feet, the effects of such a de minimis standard become cumulative over time, presenting larger depletions to downstream senior water rights on a long term basis.

This leads to an inherent problem concerning enforcement of any particular de minimis number selected. For argument sake, assume that a 1 acre-foot per year maximum depletion as a result of pumping not-nontributary Denver Basin aquifer over the life of the aquifer is deemed to be de minimis. An applicant who owns property in the Denver Basin desires to adjudicate a plan for augmentation to allow for withdrawal of this not-nontributary water and the State Engineer's analysis, using the current Denver Basin model, shows depletions in year 100 at 1.05 acre-feet. Would this person be allowed to pump without replacing depletions to the stream system? Many engineers might argue that the calculation in this instance is only accurate to within plus or minus 5%, and therefore, would argue that they fit under the current standard. Under this scenario, if strict enforcement of the standard was required, it may increase the State Engineer's participation in cases he currently does not oppose.

Assuming that a number can be developed and agreed upon, and further assuming it applies to all depletions on any stream system in the state, current requirements for augmentation under the Water Rights Determination and Administration Act of 1969 to off-set injury to vested senior water rights, would become a moot point in many instances. If the overall depletions from the proposed project fall under the agreed upon standard, no replacement under a plan for augmentation would be required. Under some standard depletion scenarios that can reasonably be envisioned, the need for the presumptions of non-injury in exempt well permitting requirements under section 37-92-602, C.R.S., would also become obsolete.

If one assumes that a de minimis depletive standard is to apply only to Denver Basin aquifer pumping, several concerns become apparent. Again, as stated above, depletion is depletion to the tributary stream system, whether that depletion is a result of Denver Basin aquifer pumping or alluvial aquifer ground water use. Admittedly, the issue of timing is very different. However, if the standard was applied only to depletions as a result of Denver Basin pumping, it may be difficult to constrain the ground water developer on the South Platte or Arkansas Rivers from arguing that his or her depletion is no different than the depletion allowed as a result of Denver aquifer

pumping. This same argument might also be made for alluvial withdrawals on any other stream system in the state.

If a depletion standard is to be set for depletions that occur as a result of not-nontributary pumping from the Denver basin aquifers only, at a minimum, language may need to be considered to ensure that the standard would not be applied to depletions as a result of alluvial and tributary ground water pumping in other areas of the state. Given that the effects of timing of depletions from an alluvial aquifer withdrawal are much more immediate, it may be prudent to consider some assurance to water users of protection from more immediate depletive effects.

As noted above, the adoption of a de minimis standard concerning acceptable depletion to a stream system raises some concerns. On a more positive note, it is also important to recognize possible benefits that may accrue as a result of such a standard. First, the standard may have the effect of benefiting smaller existing and future subdivisions in the state by reducing the overall engineering, legal and augmentation related costs associated with developing and maintaining sometimes complex augmentation plans that seemingly require drops of water to be sprinkled into the streams of the state. Secondly, in a somewhat related matter, it may reduce the participation of the State Engineer in these same small cases, thereby decreasing associated court costs and engineering fees of the state, allowing staff to focus on other issues of state water management. Such a standard may also be perceived by taxpayers as a more reasonable, less bureaucratic interpretation of the spirit of the law, making the government that serves them more accessible and service oriented.

8.6 CONCLUSION

Analysis of impacts of the adoption of a de minimis standard for injury from a physical, engineering standpoint would not be practical, but the impacts would be cumulative, over time. Administrative impacts of the adoption of such a policy vary, depending upon the intent and scope of the legislation. Insurance of non-applicability to non-Denver Basin aquifer pumping is suggested.

Possible benefits to the system include less legal, engineering and administrative costs for smaller subdivisions and water users in the state. The State Engineer and his staff may also see some of the same benefits, allowing for greater concentration on other water management issues in the state. Social implications between the state and the taxpayers may also be served through a more receptive taxpayer perception of government.

The State Engineer recommends that the SB-74 Special Water Committee consider and receive public comment on a de minimis standard for depletion from the pumping of a Denver Basin aquifer based on an annual pumping volume of 3 acre-feet per year. The actual stream depletion would vary depending upon the location of the well

and based upon the results of modeling as discussed in chapter 9. The depletion could vary between 20 to 30 percent of the amount pumped. This annual depletion would be similar to annual depletions caused by exempt domestic wells permitted under the criteria established in 37-92-602, C.R.S. This annual pumping volume would be for non-exempt wells issued pursuant to 37-90-137 C.R.S.

9.0 THE EFFECT OF THE FOUR PERCENT REPLACEMENT AND THE TWO PERCENT RELINQUISHMENT REQUIREMENTS ON FUTURE WATER SUPPLIES, EXISTING WATER RIGHTS AND THE NEED FOR REPLACEMENT OF POST PUMPING DEPLETION RESULTING FROM WITHDRAWAL OF DENVER BASIN GROUND WATER

An evaluation of the effect of the current replacement (4%) and relinquishment (2%) requirements on future water supplies, water rights and need for replacement of post pumping depletions resulting from withdrawal of Denver Basin ground water required; a) updating and improvement of existing ground water models, b) use of the model to evaluate current depletions and predict long term future depletions to the discharge areas of the South Platte River Basin drainages, and c) evaluation of the model results and effect on existing water rights, future water supplies, and Denver Basin Aquifers.

This portion of the study will provide a current assessment and evaluation of the requirements and definitions created by Senate Bill 85-5 which was intended to prevent injury to surface rights in the South Platte River Basin drainages based on the information and knowledge available at that time. Staff of the State Engineer have developed an improved ground water model and reviewed previous studies to evaluate the assumptions in the current law with respect to assumed aquifer conditions and depletion/replacement requirements. The intent was to determine if the two percent relinquishment requirement for non-tributary (NT) and the four percent replacement requirement for not non-tributary (NNT) ground water pumping are sufficient to replace injurious stream depletions now and in the future.

9.1 BACKGROUND

There were several assumptions and non-technical considerations which produced the SB 85-5 or post 1985 ground water use rules. A brief and simplified summary of the current rules is provided here for general background information.

The ground water in the Denver Basin Aquifers are typically described as tributary, NT, and NNT. The SB-5 rules included full replacement of actual depletions from the NNT Dawson aquifer and tributary wells. For wells pumping in the NT areas of the basin, they are required to relinquish 2% of their pumping. Wells developed in the NNT areas of the basin are required to replace (augment) 4% of the actual quantity pumped. Replacement of actual injurious post pumping depletions is part of the requirements of SB 5.

The intent of SB 5 was to assure that the withdrawal of ground water from the Denver Basin aquifers will not materially affect vested water rights to the flow of any natural stream or tributary ground water. The authors of SB 5 used the information available at the time to frame what was intended to prevent injury to surface water rights due to development and use of the Denver Basin aquifers by replacement of stream depletion.

However, SB 96-74 required an evaluation of the effect of current law on future water supplies and on existing water rights using the most current information available and the latest modeling technologies.

The origin of the 4% replacement value apparently evolved from the results of the "Robson Report" ("Bedrock Aquifers in the Denver Basin – A Quantitative Water Resources Appraisal"; published as USGS Professional Paper 1257). Robson estimated net discharge to drainages from all four Denver Basin Aquifers during pristine conditions was 54.7 cfs (39,600 ac-ft per year). He also estimated the total volume of drainable water in storage to be about 259 million acre-feet. The theoretical maximum allowable annual pumping rate from the bedrock aquifers using a 100 year life criterion would be 1% of the total volume of drainable water in storage or approximately 2.6 million ac-ft per year. It is however, highly unlikely and probably not economically feasible for wells to recover the entire volume of drainable storage.

During the SB 5 negotiations, it is believed an assumption was made that if the obligation to replace the entire amount of stream accretion (54.7 cfs) was spread uniformly over the theoretical maximum allowable annual pumping rate, the replacement obligation would be less than 1.6%. There are inaccuracies associated with these assumptions and calculations. First, and most importantly, is the fact that a significant component of stream depletion was ignored or simply under estimated; that is recharge from the drainages to the Denver Basin aquifers that will inevitably occur. Secondly, it may have been assumed that the pumping would be simultaneous and spread uniformly. It is unreasonable to assume that all of the wells could be installed and begin pumping at the theoretical maximum allowable annual pumping rate simultaneously. Also, based on the pumping estimates derived in this study, about half of the total pumping occurs in NNT (4%) areas.

9.2 MODEL OVERVIEW

After the passage of Senate Bill 74 in the 1996 legislative session, the State Engineer's Office undertook the tasks of evaluating the effect of four percent replacement and two percent relinquishment requirements on future water supplies and on existing water rights. The State Engineer's Office evaluated the need for replacement of post pumping depletions resulting from withdrawal of Denver Basin ground water and the use of NT and NNT ground water and its long-term impact on water rights.

To accomplish these objectives, a model of the Denver Basin aquifer system was developed using the USGS MODFLOW code. Data for the model was obtained from previous studies by Robson, Banta, and the State Engineers Office in 1985 pursuant to Senate Bill 5. The model was configured with a grid consisting of 120 rows, 84 columns, and six layers. Each grid represents one square mile and was drawn to correspond to a section of land. The six layers represent the Upper Dawson, Lower Dawson, Denver, Upper Arapahoe, Lower Arapahoe, and Laramie-Fox Hills aquifers.

The modeling was completed in four phases. The first phase consisted of calibrating a steady state model to near pristine conditions. The second phase consisted of converting the steady state model to a transient model. The third phase consisted of using the transient model to simulate historic pumping beginning in 1880 and ending in 1996.

In order to accomplish the third phase, estimates of historical pumping were derived using the SEO registered well data base and average annual well withdrawal factors. The average annual withdrawal factors were generally borrowed from Robson and appear to be reasonable. Pumping estimates using this procedure agree fairly well with Robson's and Banta's estimates for the period 1958 to 1985.

About 59,000 acre-feet of pumping from the Denver Basin bedrock aquifers was estimated for 1996. About 47% of the total pumping was used for municipal use, 26% for domestic and livestock use, 7% for industrial and commercial use, and 20% for irrigation. About 47% of the pumping was from the Arapahoe aquifer and about 17% to 18% was from each of the other three aquifers. About 52% of the pumping was from areas defined as NNT and 48% from areas defined as NT. Nearly 18% of the total pumping was from designated basins.

It is estimated that only about 12% of the total pumping for 1996 was subject to the provisions of SB 5 because most wells were constructed or permitted before the effective date of SB 5. The 12% estimate assumes small capacity domestic and livestock wells to be exempted and that the provisions of SB 5 apply in designated basins because the policies, rules and regulations of the Colorado Ground Water Commission for the administration of ground water from the bedrock aquifers closely resemble the provisions of SB 5.

The theoretical maximum allowable annual pumping rate from the bedrock aquifers using a 100 year life criterion would be 1% of the estimated 300 million acre-feet of drainable storage or 3 million acre-feet per year. The estimated 59,000 acre-feet of pumping for 1996 was only about 2% of the maximum allowable. It is highly unlikely and probably not economically feasible for wells to recover the entire volume of drainable storage.

The final phase consisted of using the transient model to simulate projected pumping. Pumping estimates from 1970 to 1996 indicate an average annual rate of increase in pumping of 1377 acre-feet per year. This average rate of increase was the basis for a linear BASE projection to the year 2100.

The BASE projection indicates pumping would increase from about 59,000 acre-feet per year in 1996 to about 135,000 acre-feet per year by the year 2050 and 202,000 acre-feet per year by the year 2100. Assuming a per capita water use of 175 gallons per day per person and 75% of the additional pumping would be for domestic and municipal use, BASE projections would provide water for an additional population of about 291,000 by 2050 and about 547,000 people by 2100.

Pumping was also projected using average rates of increase of 150% and 50% of the BASE rate of increase. A fourth projection was made allowing the rate of increase in pumping to decline to zero by the year 2050. This fourth projection is based on the premise that the use of Denver Basin ground water will continue to increase for nearly 50 years while other water supply sources are developed and conjunctive use technology improves.

Current population projections estimate an additional 3.2 million people in Water Division 1 (South Platte River Drainage) and an additional 1.1 million people in Water Division 2 (Arkansas River Drainage) by the year 2100. Considering where most of the increase in population might occur, the fact that the Denver Basin is only one-eighth of the total area of Water Divisions 1 and 2, that only a minor percentage of the total population has or will use ground water as it's sole source, and that dependence on ground water will probably decrease as costs associated with lifting the water increase; it can be suggested that the BASE pumping projection reasonably coincides with estimated population projections.

The transient model was used to evaluate the effects of pumping using the four pumping projections described above. It was assumed projected pumping would be distributed the same as the 1996 level of pumping and was input to the model accordingly. Other simulations were made using the BASE projection rates to better define the separate effects of pumping NT and NNT water.

The parameters describing the extent of the aquifers and their ability to transmit and store water represent reasonable data sets. It is not expected that errors in these parameters would effect the conclusions drawn from the model results. However, predicted depletions are sensitive to river conductances. The model is probably more sensitive to river conductance than any of the other input parameters. Increasing river conductance values will shorten the period of time required for predicted depletions to drainages to reach their maximum. On the other hand, decreasing the river conductance values will prolong the period of time required for predicted depletions to drainages to reach their maximum. It is important to note that the total volume of predicted depletions to drainages will equal the volume of water pumped no matter what river conductance is input to the model.

During the steady-state calibration phase of this study, runs were made increasing and decreasing the river conductances by an order of magnitude. When river conductance values were decreased, predicted potentiometric surfaces in the aquifers were higher than expected and higher than measurement data suggested. This indicated the higher values finally selected for river conductance were more acceptable.

Subsequent to the passage of SB 5, the State Engineers Office undertook the task of defining, within each of the Denver Basin aquifers, the areas of NT and NNT ground water. A provision of SB 5 was that all aquifers be reduced to water table conditions thereby limiting movement of ground water between aquifers to a downward direction. A river conductance sensitivity analysis performed on the SB 5 models indicated decreasing the river conductance two orders of magnitude moved the NT/NNT line

about one mile closer to the stream. Even though it was felt that the smaller value was too small, revising the value upward was of little consequence to fulfilling the objectives of that study. The river conductance sensitivity analysis performed in this study supports the belief that the value used in the SB 5 models was too low.

9.3 DEPLETIONS TO DRAINAGES

Depletions to the net discharge to drainages or simply depletions to drainages consists of two components. Ground water from the bedrock aquifers discharge to drainages. This discharge may be to springs and seeps along the drainage at points above the stream and stream alluvium and a portion of this discharge may be lost to evapotranspiration without actually entering the stream. Other discharge would be directly to the stream or stream alluvium. Depletion of the discharge to drainages is the first component of depletions to drainages. Water from streams and stream alluvium also recharge the bedrock aquifers. Pumping from the bedrock aquifers can increase the recharge from the streams representing the second component of depletions to drainages.

The model has been used to determine depletions to drainages using four projected pumping scenarios. Incremental pumping is pumping added to the 1996 level of pumping and incremental depletions to drainages are the depletions attributable to the incremental pumping. The results for the year 2100 are summarized below:

Projection	Incremental Pumping (cfs)	Incremental Depletions to Drainages % of incremental pumping
150% of BASE	234.2	16.7
BASE	164.5	17.5
50% of BASE	86.4	18.6
ZERO growth by 2050	45.5	24.8

Model results for the projected pumping runs indicate depletions to drainages will increase with time and will reach maximums by the year 2100. This trend is also applicable to the zero growth by 2050 projection. Depletions to drainages are predicted after 100 years of pumping and depletions will continue beyond the 100 years even if all pumping was to cease. About 25 cfs of depletion to drainages is indicated 110 years after pumping at the BASE pumping projection level ceases. Results for the 150% of BASE projection indicate net discharge to drainages would be negative 9.2 cfs by the final stress period which means recharge from stream alluvial systems to the bedrock aquifers would exceed ground water discharge to the drainages.

If it is assumed all pumping at the 1996 level is not subject to SB 5 requirements and all of the incremental pumping is subject to SB 5 requirements, then model results indicate 2% relinquishment and 4% replacement is insufficient to offset depletions to drainages.

Pumping in the NT non-designated areas was increased by 20% above the 1996 level at the beginning of the simulation and then held constant with a resulting increase in incremental depletion to drainages of about 14% of pumping in the 100th year or about 9% of pumping when averaged over the 100 year simulation period. Pumping in the NNT non-designated (Dawson excluded) areas was also increased by 20% above the 1996 level at the beginning of the simulation and then held constant with a resulting increase in incremental depletion to drainages of about 39% of pumping in the 100th year or about 28% of pumping when averaged over the 100 year simulation period. The same runs were made using river conductance values one order of magnitude lower. The results of those simulations indicated the average replacement required would be in the range of 10% for pumping in NNT non-designated (Dawson excluded) areas and in the range of 4% for the NT non-designated areas. The comparison of these results is complicated because depletions expressed as a percentage of pumping are dependent upon the amount of pumping simulated. Also, incremental pumping input to the model was diminished depending upon the total amount of pumping and the associated dry up of model cells.

Again, assuming all of the increased (incremental) pumping is subject to the provisions of SB 5, (much of the incremental pumping is actually anticipated from pre SB 5 wells) the model results suggest that 2% relinquishment of NT ground water pumping and 4% replacement (actual replacement for wells completed in the Dawson aquifer) of NNT ground water pumping is insufficient to offset depletions to drainage discharge. In reality 2% relinquishment does little to nothing to offset depletions to drainages attributable to the remaining 98% of pumping. In other words, a well pumping 100 acre-feet per year and returning 2 acre-feet per year to the bedrock aquifer would have about the same effect as a well pumping 98 acre-feet per year and returning nothing.

Mathematical models of ground water flow are at best only approximations of the real systems they are designed to represent. There is some uncertainty in all model input parameters. The model was calibrated for steady-state and historic conditions and represent a reasonable tool for estimation of the depletions to drainages as the result of pumping from the Denver Basin aquifers.

Results and conclusions are probably not that sensitive to errors in estimating the historic pumping because the effects of historic pumping have been subtracted from the final results isolating the effects of additional pumping. Better definition of historic pumping could perhaps improve the estimation of other model parameters during the calibration process. Additional historic data could be collected from some of the major water suppliers and perhaps some type of random sampling study could be conducted to determine if some of the average annual use factors used to predict historic use are valid. The projected pumping was assumed to have the same distribution as pumping estimated for 1996 with 52% of the water being NNT and 48% NT. If greater percentages of the pumping were projected for NT areas then predicted depletions would decrease. It is also interesting to note that depletions, when expressed as a percent of pumping, decrease with increased pumping.

9.4 SUMMARY

The model indicates that the vested water rights to the flow of the South Platte River Basin drainages may be materially injured due to ground water withdrawal from wells legally developed in the Denver Basin both prior to and subsequent to the enactment of SB 5. The results of the model indicate that, depending on the future projection of ground water pumping, the average replacement required to protect vested surface water rights is in the range of 28% for pumping in NNT non-designated (Dawson excluded) areas of the Denver Basin Aquifers. For the NT non-designated areas, the average replacement required is in the range of 9%. However, if river conductance values were decreased one order of magnitude, the average replacement required would be in the range of 10% for pumping in NNT non-designated (Dawson excluded) areas and in the range of 4% for the NT non-designated areas.

Of significant concern is the fact that regardless of any changes in replacement requirements applicable to future ground water development (post 1998), depletion of the net discharge from the Denver Basin Aquifers to all of the South Platte River Basin drainages will continue due to pumping from wells developed prior to 1985 and between 1985 to 1998. Most of the developed wells are not currently pumping at their maximum allowable annual pumping rate but could do so in the not too distant future. In addition, there are numerous decrees and permits, adjudicated and approved, that have not yet been developed. If and when they are developed, they will also contribute significantly to the depletion of the net discharge from the Denver Basin Aquifers. In reality, the ground water contribution to the South Platte River Basin drainages is already as good as gone from the surface drainages, the only question is when will the full effect occur.

It is estimated depletions will exceed the net discharge to the South Platte River Basin drainages around the year 2040. Depletion of the drainages will continue to increase as recharge from the drainages to the aquifers increase. Depletions will continue as long as water levels in the aquifers remain below the alluvium.

The data obtained for use in the model indicated that the estimated 59,000 acre-feet of pumping for 1996 was only about 2% of the annual maximum allowable pumping using a 100 year life criterion. The pumping projected in the BASE simulation at the year 2100 would be about 10% of the maximum allowable pumping using a 100 year life criterion.

The Denver Basin aquifers are expected to experience local and regional drawdown effects due to pumping. These areas of drawdown will face increased costs for the withdrawal of the same quantity of water currently being pumped. The water supply entities would most likely pursue alternate renewable water supplies or more cost effective ground water development such as well fields in other areas of the Denver Basin. The latter would of course result in the reoccurring cycle of drawdown effects.

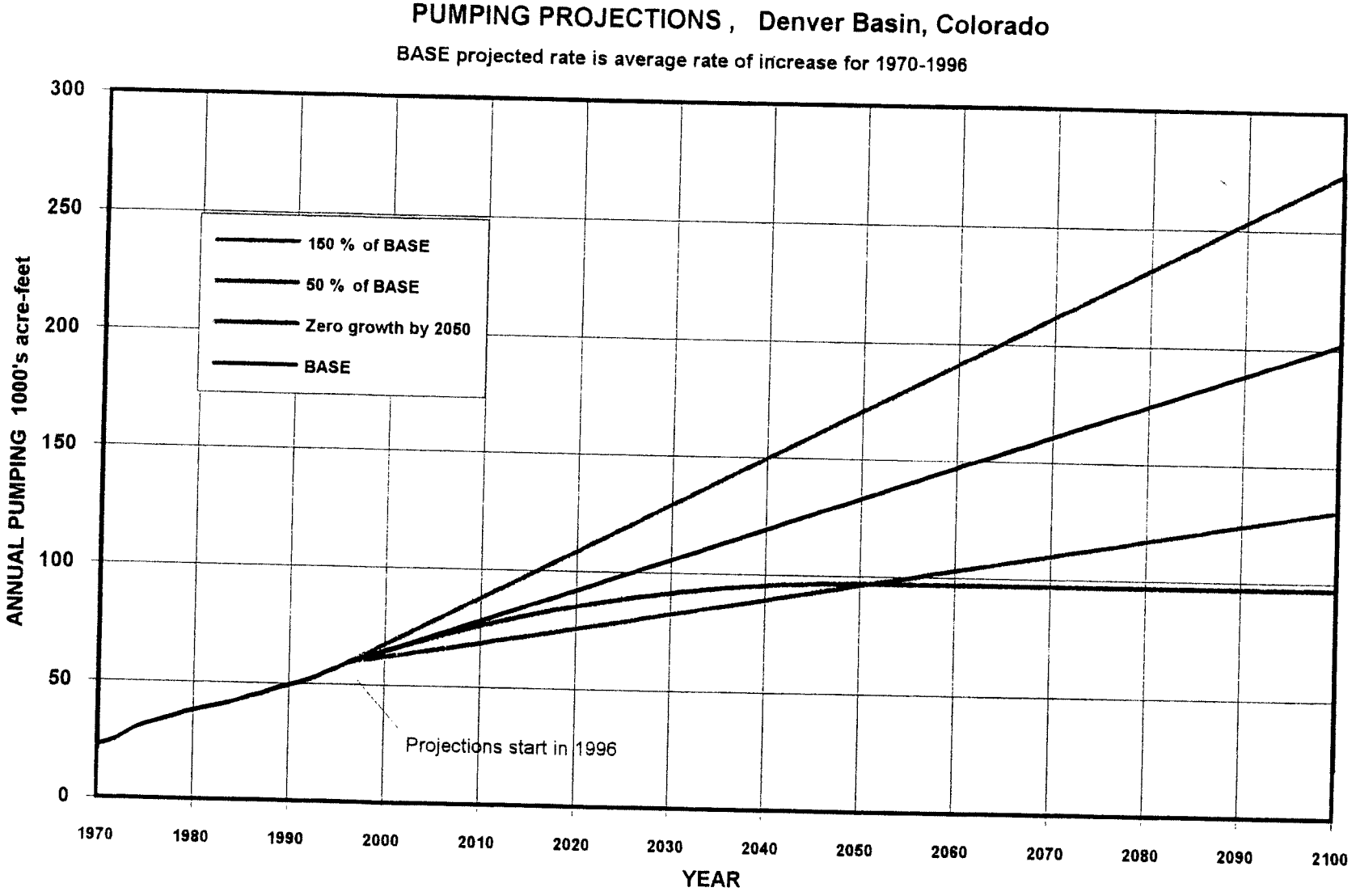

PUMPING PROJECTIONS , Denver Basin, Colorado
BASE projected rate is average rate of increase for 1970-1996
ANNUAL PUMPING 1000's acre-feet
300
250
200
150
100
50
0
150 % of BASE
50 % of BASE
Zero growth by 2050
BASE
Projections start in 1996
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
YEAR

Figure 29

10.0 NONTRIBUTARY GROUNDWATER USE AND LONG-TERM IMPACT ON WATER RIGHTS

This chapter is an analysis of the " use of nontributary ground water and its long term impacts on water rights." For the purposes of this analysis it is assumed that we are addressing impacts that result from the pumping of the Denver Basins Aquifers, that we are considering such impacts whether they result from nontributary or not-nontributary pumping, and looking at the impacts on surface water rights and tributary ground water rights in the South Platte and Arkansas River drainages as well as the impacts to designated ground water rights, both during Denver Basin Aquifer pumping and after such pumping ceases.

10.1 BACKGROUND

It is estimated that the Denver Basin Aquifers contain about 300 million acre-feet of drainable water. These aquifers are considered to be non-renewable since they receive only a small amount of natural recharge annually in comparison to the 300 million acre-feet in storage. Current law provides for minimum aquifer lives of 100 years, and allows withdrawal of one (1) percent of the water per year based on how much water is underlying the land owned or controlled by the appropriator.

Prior to 1973, ground water in the Denver Basin Aquifers was permitted or decreed in accordance with the appropriation doctrine (not limited by landownership) and there is little information concerning how decisions were made as to when to classify this groundwater as nontributary. Existing wells permitted or decreed prior to July 6, 1973, are generally referred to as PRE 213 wells which is a reference to SB 213 which was enacted on that date. SB 73-213 was the first time that the withdrawal of nontributary goundwater was based on the quantity of water underlying lands owned by the applicant and a 100 year aquifer life.

Since at least the 1970's it has been recognized that pumping the Denver Basin Aquifers (whether it be nontributary or not-nontributary water) does have impacts on the flow of surface streams, including their alluvium. Prior to well development, the Denver Basin Aquifers were discharging to various tributaries of the South Platte and Arkansas Rivers. Discharges may be directly to the stream or stream alluvium or may be to springs or seeps above the steam or its alluvium.

Although prior to the enactment of SB 85-5 there was not a technical definition of nontributary groundwater, groundwater in the Denver Basin Aquifers was typically described as either nontributary or tributary. Under SB 73-213 the landownership and 100 year aquifer life standards were only applied to the nontributary water. When groundwater in the Denver Basin Aquifers was tributary, its withdrawal for certain uses required water court approval of a plan for augmentation. Very little water from the Denver Basin Aquifers was appropriated as "tributary" during the period from July 6, 1973 to July 1, 1985.

During the committee work leading up to the adoption of SB 85-5, a draft of the USGS Robson Report was available and it was recognized that, based on that modeling, the contribution (discharge) of all the Denver Basin Aquifers to front range surface streams was approximately 39,600 acre-feet annually (54.7 cfs). The committee recognized that this amount of aquifer contribution to the surface streams was a small percentage of the amount of water that could be withdrawn on an annual basis (an estimated 3 Million acre-feet), and also recognized that some stream depletions were already resulting from previous withdrawals, although this amount of depletion was not quantified. Whether or not the committee recognized that pumping of the aquifers would result in a reversal of flow at the stream/aquifer contact and cause significant additional depletions to the surface streams, or that the pumping vs depletion relationship was not linear, is unclear.

Under SB 85-5 the groundwater in the Denver Basin Aquifers was typically described as either nontributary or not-nontributary. Wells pumping in the nontributary areas were required to relinquish 2% of the annual amount pumped, meaning that they could only consumptively use 98% of the water withdrawn. Well withdrawing from the non-nontributary area either had to replace actual injurious stream depletions or 4% of the amount pumped annually, depending on which aquifer they were pumping from and how far they were from the stream/aquifer contact. Not-nontributary pumping required water court approval of a plan for augmentation for their replacement and such plans were to include the replacement of actual injurious stream depletions after pumping ceased.

10.2 WELL PUMPING EFFECTS

Recent modeling work by the Colorado Division of Water Resources estimates these pre development stream drainage discharges at about 60.9 cfs or about 44,000 acre-feet annually. Of these discharges about 35.8 cfs was to the South Platte River system and 7.4 cfs to the Arkansas River system. About 17.7 cfs of this discharge was to the ground water systems of drainages within the designated basins.

As wells withdraw water from the Denver Basin Aquifers, the discharge to the drainages will decrease and the recharge from the surface streams to the aquifers will increases. Eventually, if pumping continues, the hydraulic connection between the aquifers and the stream systems can be broken. When all hydraulic connection of the aquifers to the stream systems is broken, depletions to the stream drainages will maximize at an estimated rate of 984,000 acre-feet annually. The largest portion (940,000 acre-feet)of this maximum depletion results from flow from the streams to the aquifers after the hydraulic connection is broken. It should be noted that this rate of stream depletion is highly sensitive to the value selected for river conductance in the model. A one order of magnitude reduction of river acre-feet. However, the State Engineer believes that river conductance used in the new model to be the most accurate. The cessation of aquifer discharge to the surface streams and the maximizing of recharge from the streams to the aquifers will occur at different points and at different times in the various drainages.

A factor to consider in determining how water rights are affected by pumping of the Denver Basin Aquifers is the status of that Denver Basin underground water rights. There are water rights that were previously decreed or permitted whose ability to pump might not be limited by future legislation, or there are inchoate rights based on the current statutory method of appropriation that can be modified by future legislation.

For purposes of discussion it helps to break the impacts of Denver Basin Aquifer ground water withdrawals into three groups. The first group may be described as decreed or permitted water rights that were established prior to July 1, 1985 (PRE 85). The second group may be described as decreed or permitted water rights established between July 1, 1985 and today (85-96). The last group are those inchoate water rights the may be decreed or permitted in the future (POST 96) and be affected by any new legislation enacted as a result of the Senate Bill 96-74 studies.

PRE 85 water rights are primarily nontributary ground water rights that are allowed to withdraw from the Denver Basin Aquifers without any obligation to relinquish or replace any portion of the depletions that may occur to the surface stream systems. The withdrawal of water under these water rights has caused stream depletions and will continue to cause depletions in the future.

Many 85-96 water rights have been decreed or permitted but very little of this water is currently being withdrawn. Under the provisions of Senate Bill 85-5, these water rights fall in to two categories; either nontributary requiring relinquishment of 2% of the water withdrawn, or not-nontributary requiring replacement to surface stream system of a certain amount (generally 4%) during the pumping period and may require continuation of some amount of replacement after pumping ceases. In designated basins not-nontributary replacements are generally required to the stream alluvium or the uppermost aquifer and no post-pumping replacement is required.

There is insufficient data currently available to determine how much of the groundwater that is being withdrawn is either PRE 85 or 85-96 groundwater or whether 85-86 groundwater is 2% or 4%.

10.3 HOW OTHER WATER RIGHTS WILL BE AFFECTED

How long term pumping of the Denver Basin Aquifers effects the tributary surface and ground water rights will be somewhat dependent on what rate and where future pumping occurs. It is unlikely that all landowners will construct wells and it is unlikely that all the water in the aquifers will be fully withdrawn within 100 years. However, based on modeling results, it is clearly possible to cause the total reduction in discharges and maximization of recharges as discussed above without pumping the aquifers at a 100 year aquifer rate.

Stream depletions are not linear to and do not occur at the same rate as pumping. However, stream depletions will continue after pumping ceases for many years (even hundreds of years) until recharge returns the aquifer water levels to their original condition.

Insufficient data is readily available to accurately assess what total amount of water is associated with existing water rights or at what rate withdrawals under these water rights may escalate in the future, it is likely that existing water rights will, within about 100 years, cause reduction in Denver Basin Aquifer discharges to the surface stream systems of the entire estimated 60.9 cfs of pre well development discharges and a large portion if not all of depletions resulting from recharge from the streams to the aquifers. The effect to surface stream systems caused by such reduction discharges will exceed the amount of water to be either relinquished or replaced to the surface stream systems under the requirements of the water rights granted since 1985.

Due to the hydrologic characteristics of the Denver Basin Aquifers, reductions in discharges to the surface streams occur on a relatively constant year around basis. Therefore, in the South Platte River Basin, long term depletions resulting from pumping of the aquifers may not always impact other water rights since those water rights may not have any demand for water at the time a depletion occurs. However, it should be anticipated that development of existing water rights on the South Platte River System will continue until at some point there may be a call senior to Denver Basin depletions at all times of the year. The Arkansas River System is currently considered over-appropriated throughout most of the year. Effects on drainages within the designated basins will be primarily to water levels in the alluvial ground water systems since there is generally no surface water flow in these areas. The Colorado Ground Water Commission has found that the ground water systems of Kiowa Creek, Lost Creek, and Black Squirrel Creek are already over-appropriated, but that ground water is still available for withdrawal in Big Sandy Creek.

10.4 CONCLUSION

When one considers the potential unreplaced surface stream depletion associated with PRE 85 water rights and 85-96 water rights, it appears that the horse is already out of the barn and that operation of these existing water rights, under current decrees and well permits may themselves maximize the unreplaced surface stream depletions that can result from withdrawal of Denver Basin Aquifer water. However, it may be nearly 100 years before the operation of these existing water rights cause such effects. Until this occurs, withdrawals by new water rights will cause an increase in stream depletions and should be replaced by these new users.

Whether the current replacement requirements will be sufficient for making up stream depletions associated with new pumping is difficult to determine. Any ability to make such a determination will be dependent upon obtaining accurate groundwater diversion records for both existing and new well owners. the State Engineer currently has limited resources in which to obtain these records. Although well owners are required to maintain ownership

and address information in the State Engineer's records, few do and even when the State Engineer can contact these users not all measure their diversions or maintain records of past diversions. "Without the ability to obtain diversion records by mail or other efficient method, the staff of the State Engineer would have to resort to visiting each well on a regular basis to read meters (assuming they were installed and operating) or to issue orders to install and provide annual records from totalizing flow meters. Additional staff to obtain this data will be required and an estimate of FTE needs is being prepared.

From the discussion in Chapter 9 on the impacts of the long term pumping of the Denver Basin aquifers, it is evident that the amount of replacement water to be made available from wells that would be permitted in 1998 and thereafter should be increased. The average range of replacement water varies between 10 and 28 percent depending upon primarily the river inductance value used in the groundwater model (see paragraph one of the summary section) as well as the amount of pumping simulated.

Because of the river conductance sensitivity, selected to provide the best groundwater model calibration, it is recommended that the final decision on revisions, if any, to existing replacement water statutes, be based on input from the peer review committee. The peer review committees will be receiving this draft report at the same time as members of the SB-74 Special Water Committee. The peer review committee will be given the opportunity to review this report and provide oral and written comments on the proper river conductance to use. They may also suggest additional research to refine this value. With the peer groups input on this important matter, we would hope to be able to provide a recommendation on the proper amount of replacement water for Denver Basin aquifer both during pumping and for the post-pumping period also.

The testimony provided at public meetings by the affected interests on this very important issue will also provide input to the CWCB, SEO, and the Special Water Committee.

11.0 OVERVIEW OF THE SCOPE OF PARTICIPATION BY THE STATE OF COLORADO IN PROCESSES ASSOCIATED WITH THE IMPLEMENTATION OF THE ENDANGERED SPECIES ACT OF 1973 WITH RESPECT TO THE WATER RESOURCES OF THE SOUTH PLATTE RIVER BASIN AND DENVER BASIN

This chapter summarizes several options to fund actions by the State of Colorado and Colorado water users in fulfillment of commitments identified in the recently signed Cooperative Agreement for the Platte River Recovery Implementation Program. It also describes some options for administrative structures for managing the funds.

11.1 BACKGROUND

The State of Colorado, Nebraska, Wyoming and the U.S. Department of the Interior have reached agreement in principle on the elements of a proposed program to restore and protect the habitat of listed endangered species in central Nebraska. This program will also serve as the reasonable and prudent alternative for existing and new water use and development in the North and South Platte Basins in Colorado.

The agreement, which has taken three years to negotiate, is a critical part of the effort to address water and wildlife issues within the Platte River Basin. It will lead to a $75 million dollar investment in land and water management over a 15 year period to benefit wildlife in the central Platte River Basin in Nebraska including three federally protected endangered birds - the whooping crane, least tern, piping plover - and the pallid sturgeon, an endangered fish.

The agreement is designed to leverage resources from throughout the basin to address habitat and species issues. In exchange, the U.S. Fish and Wildlife Service, the federal agency which administers the Endangered Species Act, has agreed to streamline its regulatory review of individual water projects in the Platte River Basin that could affect the endangered species' habitat. Specifically, the U.S. Fish and Wildlife Service has agreed that the basinwide, long-term investment in land and water provided for in the agreement could serve as the required mitigation for individual water supply projects in the future.

In the past, without benefit of a basinwide program, the U.S. Fish and Wildlife Service has reviewed projects for regulatory compliance with the Endangered Species Act on a case-by-case basis. Such reviews have resulted in considerable conflict, since water project operators and the three states have contended that it is impossible to accurately assess the effects of individual water management actions in the Platte River Basin in isolation from all the other actions. These conflicts have produced long delays and resulted in considerable cost to water project operators and others.

The Colorado Department of Water Resources plans to conduct public meetings regarding the pact to ensure full public understanding and discussion of the agreement. While the agreement is supported in principle a binding commitment of funding for Colorado's participation in the program requires the appropriate legislative processes.

11.2 KEY ELEMENTS OF PLATTE RIVER BASIN ENDANGERED SPECIES COOPERATIVE AGREEMENT

The Agreement provides for:

1. **A Significant Investment In Wildlife Conservation:** U.S. Department of Interior and the states of Colorado, Nebraska, and Wyoming will invest $75 million in land and water management over an approximately 15 year period to benefit three endangered birds -- the whooping crane, interior least tern, and piping plover -- and one endangered fish species, the pallid sturgeon. These species are protected under the federal Endangered Species Act. Specifically, timing of river flows will be improved for river-dependent wildlife by changing how some water projects in the Platte River Basin are operated and by investing in new water re-regulation capacity to benefit federally protected species. Land adjacent to the Platte River necessary to support these species will also be protected.

2. **Regulatory Certainty and Significant Savings for Water Supply Agencies Throughout the Platte River Basin:** Existing and new water projects throughout the Platte River Basin will receive expedited Endangered Species Act review when undergoing federal permitting, thereby removing a source of regulatory uncertainty that has become increasingly pronounced in recent years. Specifically, the U.S. Fish and Wildlife Service will rely on the proposed basin-wide investment in endangered species and habitat protection when determining the mitigation requirements of individual water supply projects -- both existing and future projects -- the Platte River Basin. The agreement could save municipal and agricultural water supply agencies in the South Platte and North Platte River Basins in Colorado millions of dollars in avoided permitting and litigation costs.

3. **Time Frames Within Which to Achieve Specific Actions:** The agreement provides for a three year initial period during which required federal review under the National Environmental Policy Act and Endangered Species Act will occur. After this required review, and assuming unacceptable changes to the agreement do not result, the agreement will be implemented in increments. The first increment will be from 10 to 13 years in duration. Milestones related to meeting the land and water management goals of the agreement will have to be met on an annual basis. After the first increment, the parties to the

agreement will negotiate terms from a second increment if necessary to address the needs of the species.

4. **Specific Obligations From Each of the States and the Federal Government to Protect 10,000 Acres of Land and to Improve Flow Conditions by an Average of 130,000-150,000 Acre/Feet Per Year:**

   a. **Colorado's obligations include:** pay $300,000 per year during the first three years to help support the National Environmental Policy Act review process and the development of a strategy to secure water supplies from the basin program through improved water conservation and other supplies; plan and develop the Tamarack flow re-regulation plan on the Tamarack Ranch State Wildlife Area, estimated to cost $4.2 million over 15 years; contribute $9.9 million in cash over fifteen years to fund additional water conservation and supply projects and land protection in Nebraska; additional payments, currently estimated at $300,000 per year to mitigate the depletive effects of future water development in the South Platte and North Platte Basins in Colorado, which mitigation requirements will be tied to population increases in Colorado.[1]

   b. **Nebraska's obligations include:** pay $700,000 over the first three years to help support the National Environmental Policy Act review process and the development of a strategy to secure water supplies from the basin program through improved water conservation and other sources; donate land valued at $5.3 million to the basin-wide program; establish a designated account in Lake McConaughy from which water releases can be made to improve flow conditions in the habitat critical to meeting the needs of the endangered species. The water and annual operations of the account is valued at $9 million over a fifteen year period.

   c. **Wyoming's obligations include:** pay $300,000 over the first three years to help support the National Environmental Policy Act review process and the development of a strategy to secure water supplies from the basin program through improved water conservation and other sources: plan and develop an enlargement to the Pathfinder Reservoir to re-regulate flows on the North Platte River, estimated to cost $3.5 million over 15 years; contribute $4 million in cash over fifteen years to fund additional water conservation and supply projects and land protection in Nebraska.

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[1] No commitments have been made as to the source of these funds. Funding discussions will occur over the next several months, and to the extent that state funds are identified, all state funds are subject to legislative appropriation.

d. **The U.S. Interior Department's obligations include:** pay $2.5 million each year for fifteen years towards the goals of the program.

11.3 FUNDING ASSUMPTIONS AND CRITERIA

There are many legal, political, and policy issues inherent in each of the options presented below. The options have not been researched, but are presented here to stimulate discussions and to determine which may be most promising, and therefore warrant further research.

The options are presented with the following qualifications.

1. While we recognize that several different factors could significantly alter any future funding commitments, we assume for planning and discussion purposes that the Program will remain intact through the NEPA process and will be implemented largely as currently envisioned. To assume otherwise (i.e., to assume that we only should consider partial funding) could lock us onto a path that may be inadequate to meet the funding obligations over the entire 13 - 16 year first increment, thereby jeopardizing the benefits that the State of Colorado and Colorado water users stand to derive from the Program. With this in mind, Colorado's full funding might be assumed to be approximately $1.5 million per year in 1997 dollars, or about $20 million over the life of the Program, to provide regulatory certainty for existing water facilities, future water development and operations, maintenance, and replacement activities throughout the South Platte Basin.

2. We believe that any funding option or combination of options ought to be equitable. We recognize that some options presented will be perceived to be less equitable than others. We do not comment on the equity of any particular option, since we believe these questions are best left to public dialogue. The chart below is designed to help assess the equity of any particular option. The ultimate funding mechanism could involve a combination of options, requiring that equity be judged in terms of the entire package and not simply in terms of its individual elements.

M & I entity emphasis	<---------->	Ag irrigation entity emphasis
Funding burden spread over all Colorado residents	<---------->	Funding burden limited to residents within service areas of entities benefiting from the program

Funding burden spread over all water facilities in the Platte Basin	<---------->	Funding burden limited to those facilities with a federal nexus
Funding burden confined to existing water facilities and residents in Platte Basin	<---------->	Funding burden borne by future development

3. To the extent the State actually participates financially in the Program, the administrative structure set up to manage the funds should be as accessible and responsive as possible to the broadest possible cross-section of Colorado's citizenry. Inherently, some administrative structures will be more responsive and accessible than others. Again, we do not comment about which structures might best fit this criterion, since this question is perhaps best addressed in the course of public dialogue.

11.4 FUNDING OPTIONS

1. State General Fund

Annually, the general Assembly could appropriate such funds as are necessary to fulfill the State of Colorado's commitments to the Program.

2. Water User Fees

a. **Section 7 consultation fees:** Fees could be assessed by the USFWS in the course of completing section 7 consultations for projects that choose to rely upon the basin-wide program. The fee structure could be similar to that currently in use on an interim basis for the Front Range "existing facility owners." Fees assessed against "existing facility owners" on the present interim basis would continue over the life of the program. Alternatively, a different fee structure could be formulated.

b. **Water use surcharge:** Water supply entities in the Platte River Basin could agree to assess their customers a small use fee per quantity of water delivered. The water entities would in turn make direct payments to the program. The fee could be structured in a stratified or block-rate manner to reflect differences in water use patterns and financial capability. For example, a municipal water agency with an average annual demand of 50,000 acre-feet/year could assess its customers 1 cent/1000 gallons. This would generate $163,000 ({50,000 acre-feet per year * 326,000 gallons per acre-foot / 1000 gallons} * 1 cent = $163,000). Distributed across 50,000 households, this fee would amount to $3.26 per year for each household. Similarly, a ditch company serving 25,000 acres

at 2.5 acre-feet per acre could assess its shareholders 1 cent per acre-foot. This would generate $62,500. Distributed across the acreage irrigated by the ditch company, this would add a two and half cent operation cost per acre to the shareholders' annual expenses. These fees could be voluntary and limited to members of the Platte River Project as an expectation and requirement of membership, or water supply entities could be directed by state statute to establish the fees.

3. **Other Fees and Taxes**

a. **Wildlife Cash:** Revenue from the sale of fishing and hunting licenses could be dedicated to the Program by legislative appropriation.

b. **Development Impact Fees:** By state statute, units of local government (municipalities and counties) could be directed to collect impact fees on new development (i.e., construction permits, special use permits, etc.) for deposit into a dedicated enterprise account. Rates could be specified in the statute or certified to the local government units by a Board of Directors appointed or elected by standing local government elected officials.

c. **Ad Valorem Tax:** By state statute, units of local government could be directed to levy ad valorem taxes on taxable real property rights, including water rights, for deposit into a dedicated enterprise account. Rates could be specified in the statute or certified to the local government units by a Board of Directors appointed or elected by standing local government elected officials to manage the account.

d. **Water Right Change/Transfer Tax:** By statute, water courts could be directed to levy a tax on all water right changes for deposit into dedicated enterprise fund. Rates could be specified in the statute or certified to the water court by a Board of Directors appointed or elected by standing local government elected officials to manage the account.

4. **Inter-governmental Agreement**

Through an inter-governmental agreement, public agencies could form and fund the necessary entity to achieve the goals of the program.

5. **CWCB Construction Fund:**

a. **Fish and Wildlife Resources Mitigation Account:** In 1997, the General Assembly approved changes to the administration of the Fish and Wildlife Resources Mitigation Account within the CWCB Construction Fund. The changes specifically allow interest income to the account to be spent on

measures that mitigate the effects of past water development activities on species and habitat protected under the federal Endangered Species Act or thought to be in decline but not yet listed under the Act.

b. **Severance tax funds:** In 1996, the General Assembly approved changes in the distribution of severance tax funds. Part of the change involved earmarking $100,000 per year for deposit into the CWCB Construction Fund to support water resource planning activities in energy impacted counties. Application is made each year to the Minerals, Energy, and Geology Advisory Board (MEGA Board).

c. **Grants:** The CWCB can award grants from the Construction Fund. It already has awarded two grants totaling $375,000 to the Lower South Platte River Group, Inc. to develop recharge capability on a pilot basis in the lower South Platte River. Grants typically are confined to planning and feasibility work.

d. **Loans:** The CWCB makes loans from the Construction Fund for water development and management activities. Repayment terms are established by the Board.

11.5 ADMINISTRATIVE OPTIONS

1. State Administrative Structure

A separate account could be established by legislation in the Executive Director's Office of the Department of Natural Resources to receive revenue from one or more of the options identified above. Expenditures from the account for Program purposes would be subject to legislative approval annually.

2. Regional or Local Administrative Structure

By legislation, a regional organization, such as a Water Conservation District, could be established to administer funds derived from one or more of the options described above and deposited into a dedicated account. The regional organization could cover all or a portion of the South Platte Basin. The regional organization would be governed by a Board of Directors, which could mange and make payments from account to fulfill Colorado's commitments to the Program : By statute, this Board of Directors could be appointed or elected by standing local government officials from the Platte basin, thus ensuring local control. The Board could be authorized to own and manage real property, enter into leases, and otherwise manage involvement in the Program.

12.0 ASSESSMENT OF WATER REUSE OPPORTUNITIES TO ENHANCE THE RELIABILITY AND YIELD OF WATER RESOURCES OF THE SOUTH PLATTE RIVER BASIN AND DENVER BASIN

This Chapter summarizes the results of Chapters 2 through 7 in terms of two possible alternative water supply "futures". Each "future's" ability to enhance metro area water supplies, given competing resource demands, has been assessed. Each scenario consists of a "mix" of water supply measures representative of the combined actions of metro Denver area water providers to increase the region's sustainable water supply.

12.1 ALTERNATIVE "FUTURES"

The two alternative "futures" developed in this analysis are based upon seven possible categories of water supply sources as listed below. Both "futures" have been formulated to meet the metro Denver region's aggregated long-term future water demands as currently projected by individual water providers for the longest-term planning horizons available. Because approaches to water demand projections vary between individual providers, these future demands cannot be associated with any particular date and should not be characterized as "ultimate".

The two water supply "futures" analyzed consist of a mix of water sources based upon hypothetical and alternative "moderate" and "aggressive" levels of water efficiency practices, reuse, and conjunctive management. The terms "moderate" and "aggressive" refer to the relative roles of water use efficiency and water reuse in the overall mix of water supply categories in each "future."

Under the "moderate" future, the mix of water supply sources is based upon individual water providers' current plans with respect to all sources and assumes a general continuation of current levels of water use efficiency programs into the future. Under the "aggressive" future, the roles of water use efficiency and water reuse have been substantially increased to what could be characterized as "aggressive-but-not-extreme" levels.

Representative increases in water use efficiency would include mandatory retrofit of all existing development with water efficient fixtures, increased utilization of xeriscaping, and mandatory rainfall/soil moisture sensors for all new sprinkler systems. Representative increases in water reuse would include 10,000 acre feet per year of additional effluent exchanges on the South Platte between the Metro wastewater plant and Chatfield, a 30,000 acre foot per year indirect potable reuse plant below Metro, and 12,000 acre feet per year of additional augmentation and indirect potable reuse in the Cherry Creek and Plum Creek basins. The increased roles of efficiency and reuse in the "aggressive" future would result in decreases in the need for water from other sources. These alternative "futures" are summarized in Table 12-1.

Table 12-1
Alternative Future Supply Mixes
(acre feet)

Supply Source	Existing	Moderate Future	Aggressive Future	Moderate to Aggressive Change
Water Use Efficiency	101,000	180,000	280,000	100,000
Water Reuse	54,000	168,000	220,000	52,000
Transbasin Imports	168,000	277,000	232,000	(45,000)
Nontributary Groundwater	23,000	81,000	11,000	(70,000)
In-Basin Agricultural Transfers	89,000	126,000	89,000	(37,000)
South Platte Sources	147,000	182,000	182,000	0
Totals	582,000	1,014,000	1,014,000	0

12.2 ALTERNATIVE WATER SUPPLY SOURCES

We have assumed that future water demands in the metro Denver region would be met by a combination of six possible categories of water supply sources. The specific mix of sources used will vary among water suppliers depending upon individual provider's circumstances. These water supply sources have been described in previous chapters and are listed below.

1. Water use efficiency measures
2. Reuse and exchanges
3. Water imported to the South Platte basin from other river basins
4. Nontributary groundwater
5. Expanded utilization of South Platte supplies
6. Acquisition and conversion of in-basin agricultural rights

12.3 COMPETING RESOURCE DEMANDS

Water supply planning must be sensitive to several areas of competing resource demands. For purposes of this analysis, we have provided an assessment of the two identified alternative futures in terms of their effects on several competing resource demands which are described below.

1. **Endangered Species** - Water supply alternatives that deplete South Platte River flows, particularly during the spring and summer months may impact habitat endangered species in the Platte River. Water supply alternatives that increase diversions from the West Slope may impact endangered fish in the Colorado River basin.

2. **Basin of Origin Protection** - The potential for adverse environmental and socioeconomic impacts to basins of origin from which water is diverted is a major concern. This issue has resulted in extensive litigation and will continue to generate controversy over proposals to increase transbasin diversions from existing projects and/or to build new projects.

3. **Loss of In-Basin Irrigated Agricultural Land** - During recent years, the large scale acquisition and transfer of water from South Platte irrigated agricultural land to cities has raised concerns that are similar to those associated with Colorado and Arkansas basin of origin protection, particularly in areas north of the Denver area.

4. **Groundwater Pumping** - Under Colorado law, Denver Basin groundwater users are entitled to withdraw an average of one one-hundredth of the total recoverable amount of water beneath their property or service area in any year. If demands that otherwise would be served by nontributary groundwater can be met using renewable sources of supply, the life of the aquifer can be extended.

5. **Downstream Junior Water Rights** - Diversions of imported water and pumping of nontributary groundwater have resulted in increased municipal return flows at wastewater treatment plants that are new to the river. Historically most of the return flows from these sources has not been reused, resulting in a temporary windfall to downstream junior water rights. As discussed in previous chapters, water use efficiency, reuse, and increased use of South Platte supplies under the priority system by municipalities will tend to reduce the amount of windfall water available to junior water rights.

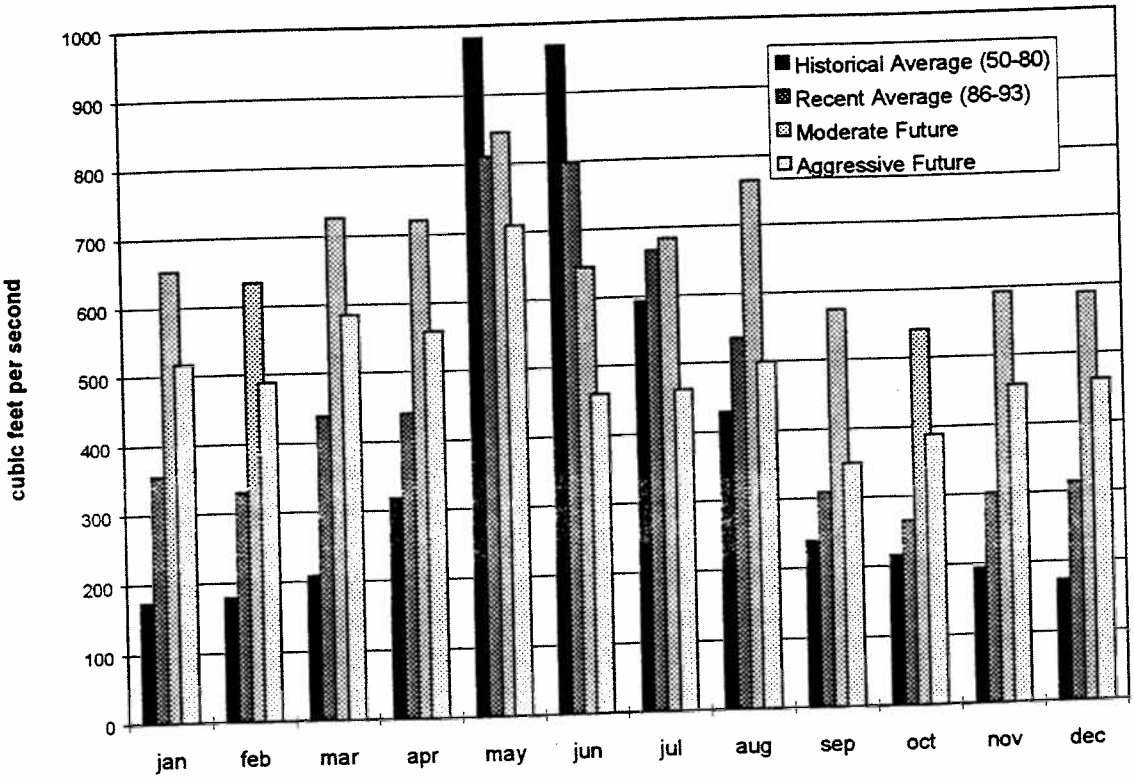
6. **Environmental Impacts** - There are environmental issues and concerns associated with all of the currently available water supply sources. However, the water supply sources that have generated the most controversy involve large storage projects, major transbasin diversions, and major transfers of agricultural water from areas that are not in close proximity to the cities proposing the transfers. To the extent that water supply planning can be structured to rely upon sources that avoid or minimize environmental controversy, the uncertainties, risks, and costs associated with local, state and federal permitting can be reduced.

12.4 ASSESSMENT OF ALTERNATIVE FUTURES

For purposes of evaluating the comparative impacts of existing levels of development with the impacts of the "moderate" and "aggressive" futures on stream flows in the South Platte at Henderson, the spreadsheet model described in Chapter 3 was used to account for the net accretive and depletive effects of the different combinations of the supply sources shown in Table 12-1. These South Platte River stream flow changes are illustrated in Figure 12-1.

Figure 12-1

Average Flow at the Henderson Gauge
Under Historical, Recent, and Alternative Future Development



It is important to note that Figure 12-1 is based upon average flows and thus does not reflect substantial variations that would occur between individual years and months. The stream flow trends illustrated by Figure 12-1 are summarized as follows:

1. Comparison of the Historical vs. Recent Averages

a. The higher Recent Average flows of July through April have been caused primarily by return flows from substantial increases in transbasin imports and the increased use of nontributary groundwater.

b. The lower Recent Average flows of May and June have been due primarily to increased utilization of South Platte storage facilities and water rights by metro area water providers to meet growing demands.

c. The total annual volume of recent average annual flows at Henderson is about 53,000 acre-feet greater than the historical average annual flows.

2. Comparison of the Recent Average with the Moderate Future Average

a. The higher Moderate Future flows would be due primarily to greater return flows from increased transbasin diversions, increased use of nontributary groundwater, and increased urban storm water runoff.

b. The lower Moderate Future flows in June is due primarily to increased use of South Platte storage facilities and water rights and a substantial increase in reuse of return flows from imports and nontributary groundwater.

c. The total annual volume of Moderate Future flows at Henderson would be about 144,000 acre-feet greater than the recent average annual flows.

3. Comparison of the Recent Average with the Aggressive Future Average

a. The higher Aggressive Future flows during the months of September through April would be due primarily to greater return flows from increased transbasin diversions and return flows from increased urban storm water runoff.

b. The lower Aggressive Future flows of May through August would be due to the combined effects of increased utilization of South Platte storage facilities and water rights, substantial increases in efficiency, increased reuse of return flows from imports, and reductions in nontributary groundwater use.

c. Under the Aggressive Future scenario, the total volume of average annual flows at Henderson would be about 22,000 acre-feet greater than the recent average annual flows.

4. Comparison of the Moderate Future with the Aggressive Future Averages

a. The higher Moderate Future average flows during all months of the year would be due to the combined effects of additional water efficiency, additional reuse, less return flows from smaller increases in transbasin diversions and reductions in the use of nontributary groundwater.

b. Under the Aggressive Future scenario, the total volume of average annual flows at Henderson would be about 122,000 acre-feet less than under the Moderate Future. While this difference appears to be quite large, it should be noted that under the Aggressive Future, annual flows would nonetheless average 22,000 acre-feet more than the actual recent average flows.

12.5 ASSESSMENT OF COMPETING WATER RESOURCE DEMAND FACTORS

The primary purpose of this analysis is to demonstrate the tradeoffs between competing demands for water resources associated with alternative water supply sources available to the Denver metropolitan area. Different supply sources will be viewed favorably or unfavorably depending on one's perspective. For example, while West Slope interests tend to favor options that maximize use of supplies available within the South Platte Basin, water users and endangered species interests downstream from Denver may prefer options that import more water to the South Platte. The seven categories of water supply sources used to formulate the Moderate and Aggressive futures were generally assessed in terms of their relative impacts on competing resources. The results of this assessment are summarized in Table 12-2 below and are discussed in the following section.

Table 12-2: Summary of Relative Impacts of Water Supply Source Categories

Category	Endangered Species	Basin of Origin	In-Basin Irrigated Agriculture	Nontributary Groundwater Use	Downstream Water Rights	Environmental Impacts
Water Use Efficiency	+/-	+	+	+	-	+
Water Reuse	+/-	+	+	+	-	+/-
Transbasin Imports	+/-	-	+	+	+	-
Nontributary Groundwater	+	+	+	-	+	+
South Platte Development	+/-	+	+	+	-	-
In-Basin Agricultural Transfers	**neutral**	+	-	+	**neutral**	+

\+ = generally positive impacts
\- = generally negative impacts
+/- = mixed impacts

1. **Water Efficiency Measures**

   a. **Endangered Species** - Reduced demands and diversions are generally beneficial to both South Platte and Colorado River endangered species, although reduced return flow to the South Platte could have negative impacts to Platte River endangered species.

   b. **Basin of Origin Protection** - Reduced demands and diversions are generally beneficial to basins of origin.

   c. **In-Basin Irrigated Agriculture** - Reduced demand would tend to reduce the need for agricultural transfers.

   d. **Nontributary Groundwater Use** - Reduced demands would tend to reduce the rate of groundwater pumping.

   e. **Downstream Junior Water Rights** - Reduced demands and associated reductions in return flows from imported sources would tend to reduce downstream flows available to junior water rights.

   f. **Environmental Impacts** - Reduced demands and diversions tend to be beneficial to instream flows and may postpone or eliminate the need for new water development projects.

2. **Reuse and Exchanges**

   a. **Endangered Species** - This supply source would tend to reduce downstream South Platte flows and offset the demand for imports from other basins. This would tend to reduce both base flows and peak flows available to South Platte endangered species and help to maintain flows for Colorado River endangered species.

   b. **Basin of Origin Protection** - Reuse and exchanges tend to offset the need for diversions are thus generally beneficial to basins of origin.

   c. **In-Basin Irrigated Agriculture** - Reuse and exchanges would tend to reduce the need for agricultural transfers.

   d. **Nontributary Groundwater Use** - Reuse and exchanges could tend to reduce the rate of groundwater pumping to the extent that reusable supplies are available to suppliers that rely upon nontributary groundwater.

   e. **Downstream Junior Water Rights** - This supply source would tend to reduce downstream flows available to junior water rights.

   f. **Environmental Impacts** - South Platte stream flow depletions associated with reuse and exchanges would occur both below the upstream points of diversion for municipal water providers and downstream from the metro area. However, reduced West Slope diversions would tend to be

beneficial to instream flows. In addition, this supply source may help to postpone or eliminate the need for new water development projects.

3. **Water Imported to the South Platte from other River Basins**

   a. **Endangered Species** - Return flow from imported water would tend to be generally beneficial to South Platte endangered species, especially if return flow were to increase peak flows during the spring and early summer months. To the extent that imported water is diverted form the Colorado River Basin, flows to downstream habitat for endangered fish would be diminished.

   b. **Basin of Origin Protection** - This supply source, by definition, is generally contrary to basin or origin protection, except in cases where mitigation measures and/or cooperative development approaches result in net benefits.

   c. **In-Basin Irrigated Agriculture** - Imports would tend to reduce the need for agricultural transfers. This would be generally beneficial in terms of maintaining irrigated agriculture but may not be beneficial to individual farmers or irrigation companies that plan to market their water to cities.

   d. **Nontributary Groundwater Use** - From a regional perspective, imports would tend to offset demands that may otherwise be met with nontributary groundwater and would reduce the rate of groundwater pumping.

   e. **Downstream Junior Water Rights** - Water imported to the South Platte from other basins will generally result in increased return flows downstream from Denver, to the extent that return flows are not consumed through direct reuse or exchange.

   f. **Environmental Impacts** - Additional diversions from other basins will tend to adversely impacts instream flows and water quality in the basin of origin.

4. **Nontributary Groundwater**

   a. **Endangered Species** - Increased reliance on nontributary groundwater tends to reduce demands for South Platte or Colorado basin water supplies. Also, return flows from the use of nontributary groundwater, to the extent they are not consumed through reuse or exchange, are generally beneficial to Platte River endangered species.

   b. **Basin of Origin Protection** - From a regional perspective, increased reliance on nontributary groundwater tends to reduce demands for additional transbasin imports.

   c. **In-Basin Irrigated Agriculture** - Use of nontributary groundwater may tend to reduce the need for agricultural transfers.

d. **Nontributary Groundwater Use** - Increased reliance on nontributary groundwater, by definition, will increase the rate of groundwater pumping.

e. **Downstream Junior Water Rights** - Return flows from nontributary groundwater, to the extent they are not consumed through reuse or exchange, would be generally beneficial to downstream flows available for diversion under junior water rights.

f. **Environmental Impacts** - This supply source tends to be generally beneficial to instream flows in the South Platte below the metro area and may tend to temporarily postpone the need for new surface water development projects.

5. **Expanded Utilization of Native South Platte Supplies**

a. **Endangered Species** - Increased utilization of South Platte surface water supplies would tend to reduce South Platte peak flows available to endangered species, but would tend to reduce increase supplies available to Colorado River endangered fish species.

b. **Basin of Origin Protection** - Increased utilization of native South Platte surface water supplies would generally tend to offset the need for increased diversions from other basins.

c. **In-Basin Irrigated Agriculture** - Increased utilization of South Platte surface water supplies could tend to reduce the need for agricultural transfers. This would be generally beneficial in terms of maintaining irrigated agriculture but may not be beneficial to individual farmers or irrigation companies that plan to market their water to cities.

d. **Nontributary Groundwater Use** - Increased utilization of South Platte surface water supplies if used for conjunctive management would reduce the rate of groundwater pumping and could extend the life of nontributary aquifers.

e. **Downstream Junior Water Rights** - Increased utilization of South Platte surface water supplies would tend to reduce downstream flows available to junior water rights.

f. **Environmental Impacts** - Increased utilization of South Platte supplies would tend to reduce both peak and base instream flows. However, if used for conjunctive management, could also reduce or eliminate the need for development of new large surface water development and storage projects.

6. **Acquisition and Conversion of In-Basin Agricultural Rights**

a. **Endangered Species** - This supply source generally results in somewhat greater return flows and thus may be generally beneficial to South Platte endangered species.

b. **Basin of Origin Protection** - To the extent that metro area demands are met through the transfer of South Platte agricultural water rights, this source could offset the need for imported water.

c. **In-Basin Irrigated Agriculture** - This supply source, by definition, would increase agricultural transfers.

d. **Nontributary Groundwater Use** - Agricultural transfers could offset or reduce the need for groundwater pumping and could extend the life of nontributary aquifers.

e. **Downstream Junior Water Rights** - This supply source generally results in somewhat greater downstream return flows and thus may be generally beneficial to downstream junior water rights.

f. **Environmental Impacts** - This supply source generally results in somewhat greater return flows and thus may be generally beneficial instream flows and to South Platte endangered species. Agricultural conversions may postpone or eliminate the need for new water development projects.

There are no alternatives that are entirely beneficial to all involved interests. However, this assessment demonstrates that the range of water supply options available to the metro Denver area provides some flexibility and possible opportunities for cooperative approaches and balancing of impacts.

Water use efficiency and water reuse already play a major role in the metro Denver region's water supply systems, currently meeting over 25% of the region's water demands. The relative importance of water use efficiency and water reuse could potentially increase significantly in the future. This could result in reduced future reliance on nontributary groundwater, smaller increases in transbasin diversions and less dry-up of irrigated agricultural land.

13.0 ASSESSMENT OF SURFACE AND GROUNDWATER DEVELOPMENT IN THE LOWER SOUTH PLATTE RIVER IN ACCORDANCE WITH THE SOUTH PLATTE RIVER COMPACT

This Chapter summarizes the current and future water development needs in the Lower South Platte area, recognized as that part of the basin below the Henderson Gauge. Also outlined is the Lower South Platte River Group's (LSPRG) and others efforts to address the water needs of the Lower South Platte region as they relate to the South Platte River Compact.

13.1 BACKGROUND

Water development in the South Platte River commenced in the upper reaches of the basin in 1859 and proceeded to progress downstream within the basin as seepage waters and return flows from the earlier surface diversions transformed the "disappearing river" into a constant flow that was reliably available to those diverters located downstream. Irrigators in the area considered to be the lower South Platte River began diverting flows in 1872 and, before 1900, had essentially developed the canal systems that remain in place today. The lower South Platte River, also known as former water district 64, is considered to extend from the west boundary of Washington County eastward to the Colorado-Nebraska state line as shown in Figure 1.

After the turn of the century, water usage in the lower South Platte River in Colorado was and continues to be regulated by provisions of the South Platte River Compact that was signed by representatives of the states of Colorado and Nebraska on April 27, 1923. The background and details of the compact and a report by the Colorado Compact Commissioner, Delph Carpenter, are included as Appendix 1. The salient provisions of the South Platte River Compact are:

> The river was divided into an "Upper Section" and a "Lower Section." The Upper Section is the South Platte River in Colorado that is upstream of the west boundary of the Washington County line, and this part of the basin is not impacted by the provisions of the Compact. The Lower Section is the part of the South Platte River in Colorado between the west boundary of the Washington County line and the common line between the states (the same description as former water district 64), and is impacted by the provisions of the Compact.
>
> The "Flow of the River" is the flow at the interstate station (Julesburg) plus inflows accruing between the station and the Western Canal.

Between October 15 and April 1 of each year, Colorado has the uninterrupted use of the flow of the river subject to Article VI of the Compact.

Article VI of the Compact allows Nebraska the right to construct the Perkins County Canal to divert up to 500 cfs under a December 17, 1921 priority date, subject to the following constraints:

a) Colorado appropriations, existing and future, are not affected in the upper section.
b) Colorado appropriations in the Lower Section senior to 12/17/1921 are not affected.
c) Colorado is allowed 35,000 AF of storage senior to the Perkins County canal regardless of the timing of perfection of this amount.

Between April 1 and October 15 of each year, Colorado must curtail diversions that are junior to June 14, 1897 if the flow at the interstate station is less than 120 cubic feet per second (cfs). (The 1897 date and the 120 cfs flow rate correspond to the water right attributed to the Western Canal in Nebraska)

The South Platte River Compact has allowed the development of water in Colorado upstream of the Washington County line to continue without impact from water rights in Nebraska. However, direct flow water rights in the Lower Section of the river did not continue to be developed after the Compact because the flow at the state line is frequently less than the 120 cfs required during the irrigation season making those water rights unreliable. Colorado continues to have approximately 1600 cfs of direct flow water rights located in the Lower Section of the river that are senior to the June 14, 1897 compact date. Those rights are diverted through 19 major canals or through wells that pump those rights as alternate points of diversion. In addition, there are about 900 irrigation and M & I wells located in the Lower Section and one major reservoir, Julesburg, that divert its water in this reach. Total irrigated acreage in the area is about 130,000 acres.

The historical amount of flow coming into the Lower Section of the river at the Washington County line has been historically measured by the Balzac gage, which has kept flow records since 1917. The average annual inflow to the Lower Section has been about 325,000 acre feet per year. The gaging station located at Julesburg has kept records since 1902. The average annual outflow from Colorado to Nebraska has been about 374,000 acre feet per year. Of interest is the fact that since records were kept at the Julesburg station, the average trend in flow at the state line has been steady, if not slowly increasing over time as shown in Figure 2. This is

largely due to transmountain diversions that have been brought into the South Platte River basin and have been available to Colorado water users, leaving steady streamflows at the state line. The annual average amount of water imported into the basin is about 410,000 acre feet per year.

Water continues to be available to Colorado that is in excess of the amounts required by the Compact as shown in Figure 3. That analysis shows that an average of about 313,000 acre feet of water is excess to the Compact requirements in the form of inflows to and river gains within the Lower Section.

13.2 FUTURE WATER DEVELOPMENT NEEDS IN THE LOWER SOUTH PLATTE RIVER

With the exception of groundwater, the South Platte River Compact has largely limited the development of water in the lower South Platte River since its implementation. In fact, several ditches that were junior to the Compact have been abandoned due to unreliable water supplies. However, today there are new needs to develop available flows that are in excess to the Compact in order to maintain existing uses in Colorado and meet future water needs.

The Endangered Species Act has created new and increased needs for water in Colorado. In the Big Bend reach of the Platte River in central Nebraska, there are three bird species and one fish species that are listed as threatened and endangered pursuant to the Endangered Species Act. This listing has already impacted several existing water projects within Colorado, and has the potential to impact many more in the future as water projects that need federal permits, including renewals, are reviewed. Reviews by the U.S. Fish and Wildlife Service require that such projects must not increase depletions to the Platte River system. Existing projects are evaluated as though they were new to the river system, and they are required to replace their depletions that affect the species' critical habitat. Because of the problems and high costs that are encountered with individual reviews of projects subject to the Endangered Species Act, the states of Colorado, Nebraska, and Wyoming and the Department of Interior have worked on and have reached preliminary agreement on a basin-wide recovery plan that would address the listed species problems. The agreement essentially provides that the impacts of existing projects will be offset by the development of water and habitat for the species, and that any new water related project will not create additional depletions to flows needed for the critical habitat of the affected species. For Colorado, the agreement would require the state to develop at least 10,000 acre feet of water annually for their contribution to offset existing uses. Also, the requirement to offset depletive effects of new projects on the critical habitat will require the reregulation of additional water in

Colorado and will reduce the amount of flows that can be used by Colorado for new uses.

Another paramount need for water users located in the lower river is to protect their existing uses of water. Since wells were incorporated into the priority system along with the more senior ditches and reservoirs by the 1969 Water Right Determination and Administration Act, augmentation of those existing wells has been necessary. Continuing to maintain and improve the reliability of these augmentation supplies is an important future need, especially with the results of the Colorado v. Kansas litigation on the Arkansas River in mind.

As the towns along the lower South Platte River in Colorado grow, it is also important for them to be able to develop additional supplies of water for municipal and industrial needs that are reliable and of acceptable quality. While these needs are not large, the limited availability of water in the summer months makes such development difficult. The towns of Sterling and Julesburg currently face the problems of getting reliable water supplies for their anticipated needs.

There are species in Colorado known as "species of concern" which are candidates for listing as threatened and endangered by the USFWS. Included in this category are several species of minnows that reside in the South Platte River system in eastern Colorado. If these species were to become listed in the future, similar problems would face water users in Colorado as brought about by the Nebraska threatened and endangered species, but the impacts would be located within Colorado. In order to avoid the consequences associated with the federal listing, there is an effort to improve habitat for these species and keep them from becoming listed as threatened and endangered by the USFWS. This effort also involves water, and those needs are currently under study by the Colorado Division of Wildlife and others.

There are several ways to meet the water demands that exist in the Lower South Platte River using the flows that are in excess to the Compact and the proposed basin-wide recovery plan. The most effective method is to divert flows that are physically and legally available in the wintertime or water available during high flow conditions and reregulate or store those flows so they can be used during the irrigation season. The most efficient way to control this water is to increase storage within the lower river system, including the enlargement of existing reservoirs. However, development of reservoir storage can be relatively expensive. Another method that can be less expensive than reservoir development is to reregulate the available flows through groundwater recharge projects. This process involves the diversion of flows through existing ditches or through wells, delivering the water to locations away from the river, and causing those flows to infiltrate into the alluvial aquifer through ponds or the bottoms of canals so that the recharged water will

migrate back to the river at a time of need. Groundwater recharge is less efficient at controlling water supplies, but this process has been developed and used successfully along the South Platte River for the past 20 years. Again, these methods would tap available wintertime and/or high flows and store them for use at more critical times of the year.

13.3 EFFORTS TO ADDRESS NEEDS IN THE LOWER SOUTH PLATTE RIVER

There have been efforts to address water supply needs in the lower river over the years. With the implementation of the 1969 Act, augmentation supplies to offset well usage over the entire lower river were developed by Groundwater Appropriators of the South Platte (GASP). Some individual projects to augment wells were also implemented. Over the last few years, the Lower South Platte Water Conservancy District (LSPWCD) has initiated development of a plan to augment wells located in the eastern end of the river in Colorado. The most recent effort to address water needs in the Lower South Platte River is managed by the South Platte Lower River Group, Inc. (SPLRG). This effort grew out of a recognition that there were new demands for water supplies on the lower river that have come about relatively recently, i.e. Endangered Species Act, issues related to the Arkansas River litigation, and species of concern. A coalition of entities including GASP, LSPWCD, Northern Colorado Water Conservancy District (NCWCD), the Platte River Project (PRP, an extension of the Colorado Water Congress created to deal with South Platte River endangered species issues), the Colorado Department of Natural Resources (CWCB, SEO, and DOW), and water users in the lower river formed a non-profit organization to evaluate needs and implement projects to meet those needs.

Since their inception last year, the group has been very active, and they have combined funding ($40,000) and in-kind services (estimated to be over $150,000) from members along with grants from the Colorado Water Conservation Board ($375,000) to promote the development of needed projects in the lower river. SPLRG, Inc. has already initiated or assisted ditch companies on several groundwater recharge projects in the lower river to reregulate excess flows into the irrigation season to benefit wells. Several filings have been made in Water Court for such water rights. In addition the group has helped design the concept for the Tamarack Plan, a plan to develop Colorado's 10,000 acre feet of water for the basin-wide recovery effort. Lastly, SPLRG has worked with Colorado State University and other entities to develop a user-friendly computer tool for data verification and analysis that can be used in water development and augmentation projects on the South Platte River. The SPLRG continues to look at additional projects to meet the multiple needs of the lower river for the future.

13.4 CONCLUSIONS

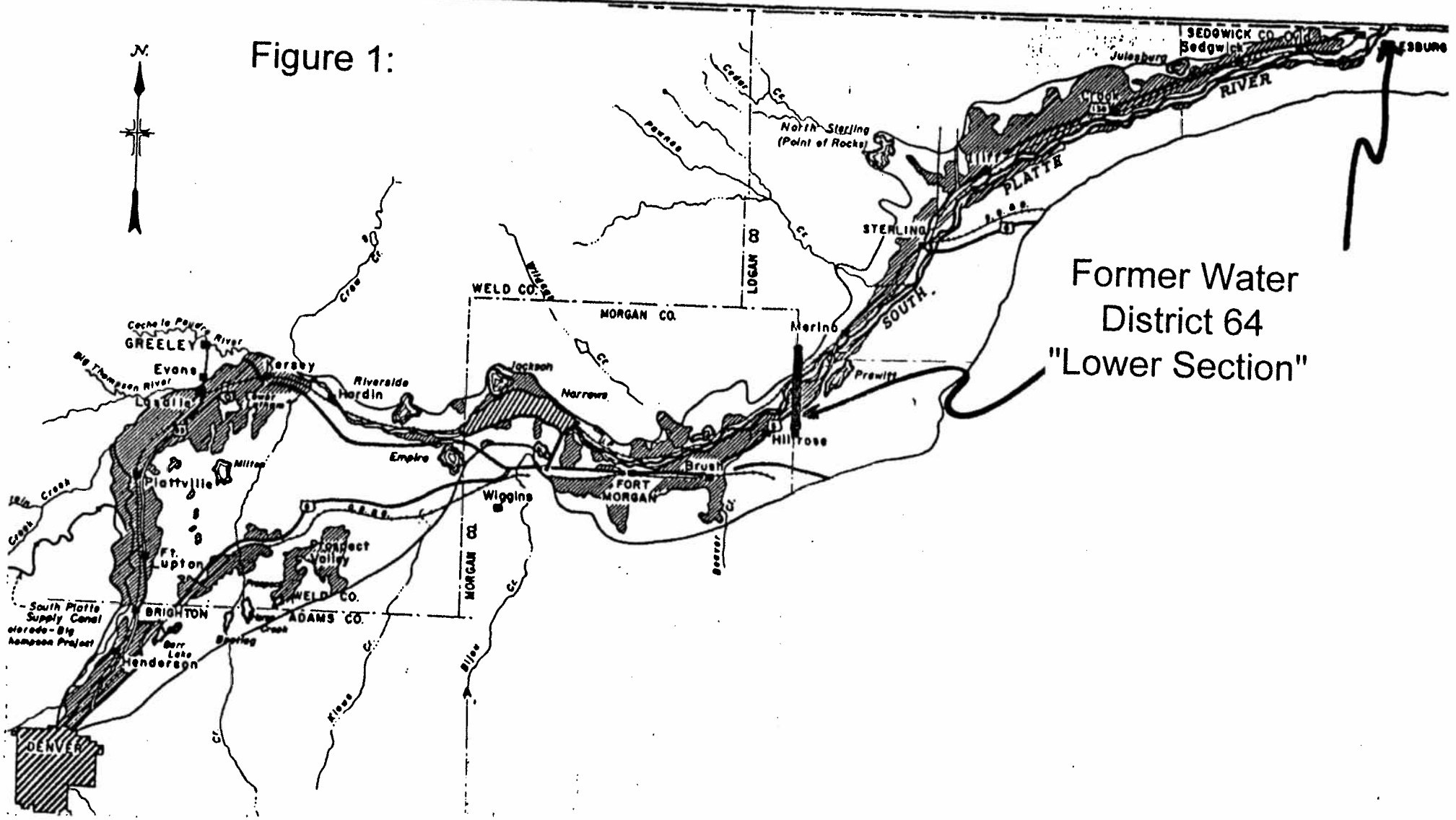
The majority of water development in the lower South Platte River in Colorado occurred prior to 1900 as flows became reliable due to return flows from upstream development, and the water supply system has not changed much since that time. The area in Colorado that lies upstream of the Washington County line is unaffected by the South Platte River Compact and has developed without limitations from downstream states. The South Platte River Compact between Colorado and Nebraska has controlled water uses in the Lower Section during that time, and ditches that were junior to the Compact date of June 14, 1897 have been abandoned due to the unreliability of flows subject to the Compact.

There are new needs for water development in the lower South Platte River including issues related to the Endangered Species Act, the need to firm augmentation supplies for existing wells, new water demands for growth in the region, and the enhancement of habitat to prevent listing of "species of concern" that exist in the South Platte River in Colorado.

Water in excess of the Compact exists during periods of high flow and during the wintertime when Colorado has full use of the river pursuant to the Compact. The amount of excess water available under the Compact would be reduced under the basin-wide recovery program developed by the states of Colorado, Nebraska, and Wyoming and the Department of the Interior (USFWS and USBR), but there should be sufficient water remaining to meet the needs of Colorado in the future.

Efficient methods exist that can reregulate excess flows into more critical times to meet the needs of the lower river. The South Platte Lower River Group, Inc. is a non-profit organization with widespread participation that has initially been successful at examining and resolving some of the issues on the lower South Platte River.

Figure 1:



Former Water District 64 "Lower Section"

Figure 2:

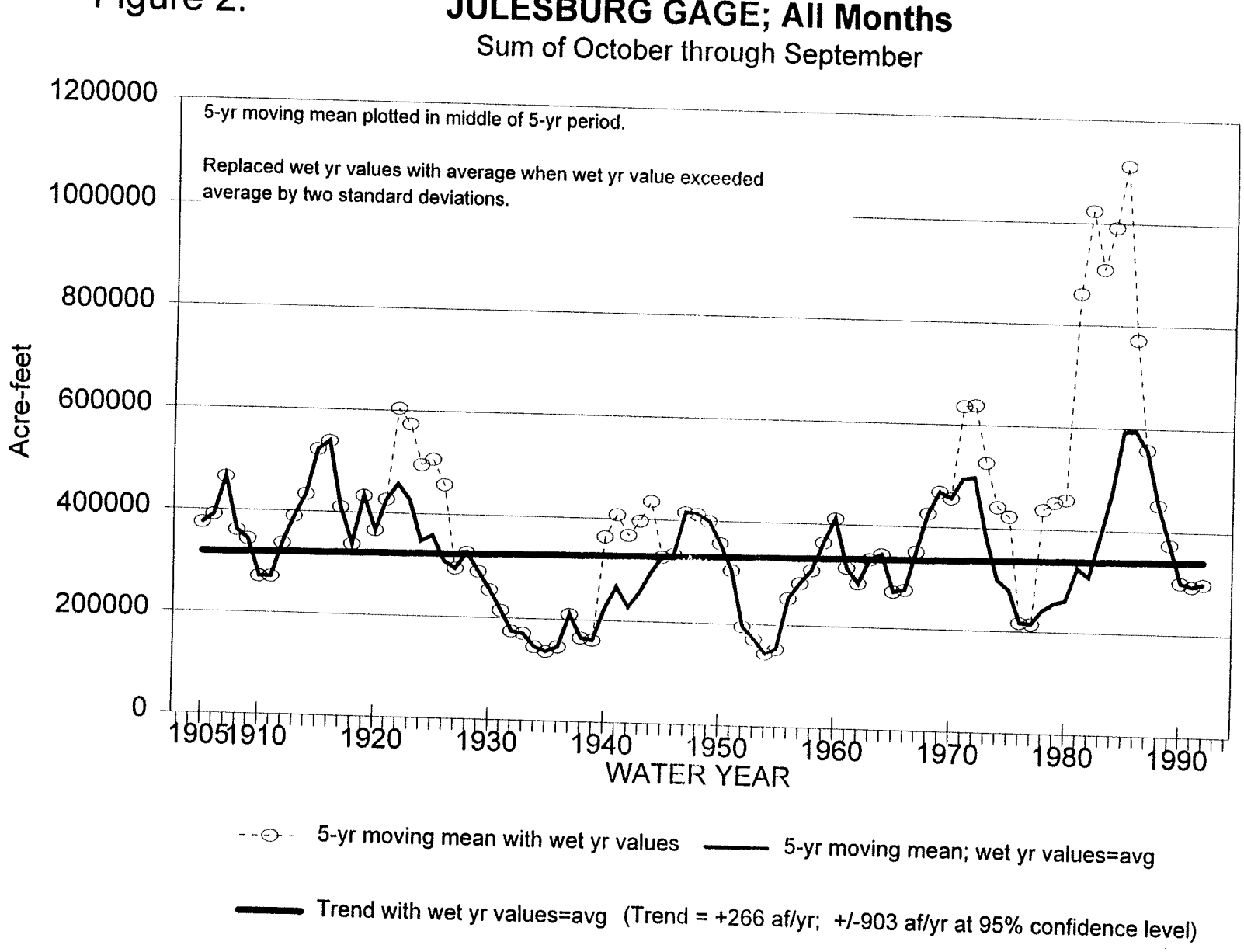
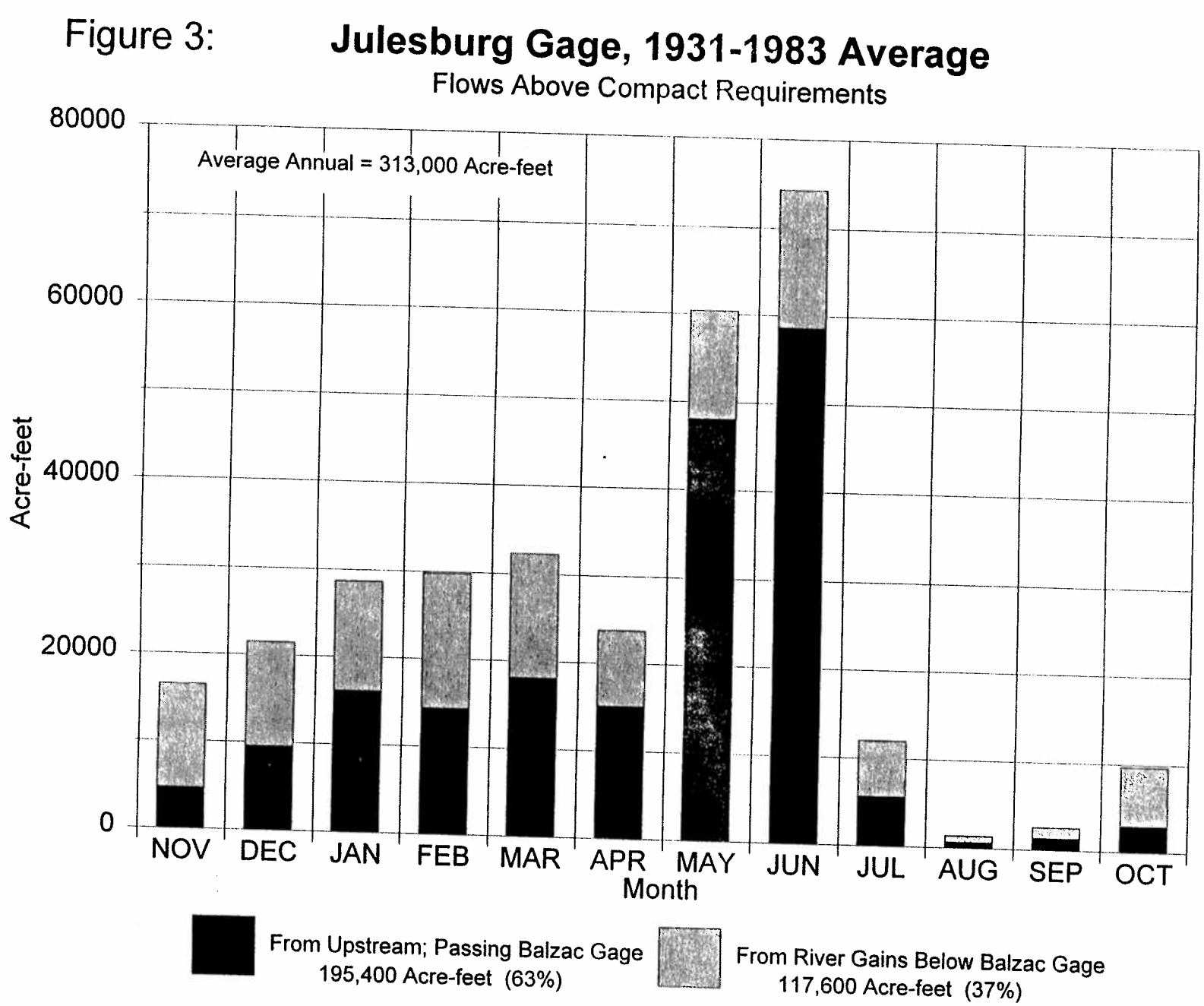

JULESBURG GAGE; All Months
Sum of October through September
5-yr moving mean plotted in middle of 5-yr period.
Replaced wet yr values with average when wet yr value exceeded average by two standard deviations.
Acre-feet
1200000
1000000
800000
600000
400000
200000
0
1905
1910
1920
1930
1940
1950
1960
1970
1980
1990
WATER YEAR
5-yr moving mean with wet yr values
5-yr moving mean; wet yr values=avg
Trend with wet yr values=avg (Trend = +266 af/yr; +/-903 af/yr at 95% confidence level)

Figure 3:


Julesburg Gage, 1931-1983 Average
Flows Above Compact Requirements
Average Annual = 313,000 Acre-feet
80000
60000
40000
20000
0
Acre-feet
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
Month
From Upstream; Passing Balzac Gage
195,400 Acre-feet (63%)
From River Gains Below Balzac Gage
117,600 Acre-feet (37%)

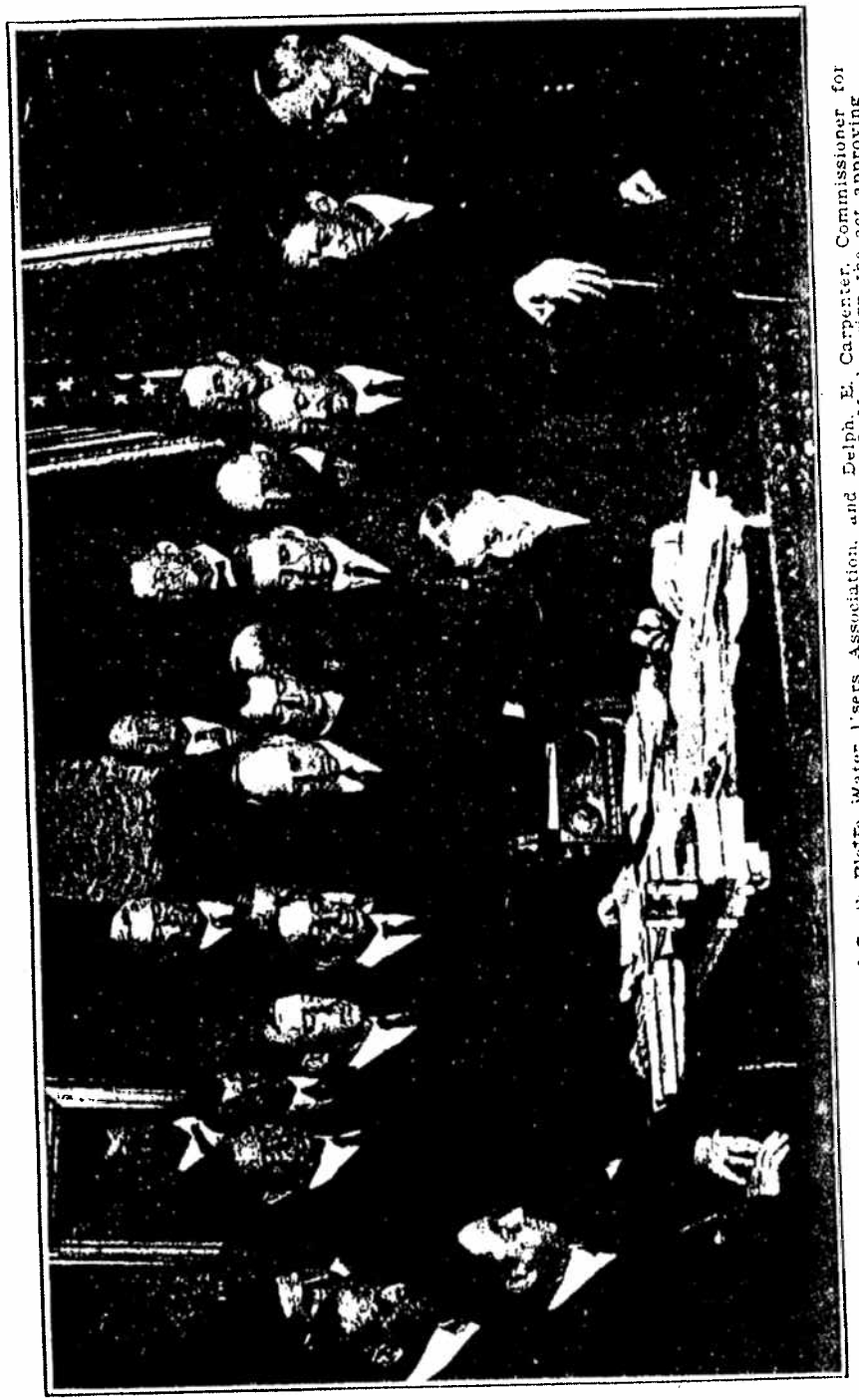
APPENDIX
(CHAPTER 13)

SOUTH PLATTE RIVER COMPACT

This document is being reprinted by THE GROUNDWATER APPROPRIATORS OF THE SOUTH PLATTE RIVER BASIN, INC. Even now, in 1989, the Colorado-Nebraska compact is a subject that comes up on a daily basis when water is discussed. Reading this publication from time to time helps reinforce our understanding of those proceedings and gives insight into their purpose.

G.A.S.P.

Colorado Proceedings



Hon. Chas. I. Colwell, President of South Platte Water Users Association, and Delph. E. Carpenter, Commissioner for Colorado, with members of the Colorado Legislature, witnessing Gov. Clarence J. Morley sign the act approving the South Platte Compact, at the executive chambers, Denver, February 26, 1925. Photo Courtesy Denver Post.

Foreword

The South Platte Compact between Colorado and Nebraska marks the successful conclusion of the first effort to adjust by treaty an interstate river controversy between two or more states of the arid region. The entire South Platte Valley is arid and the waters distributed by the compact sustain more than half the population and constitute the basis of more than half the wealth of Colorado.

The Platte river has its sources in Colorado. Its two principal branches, the North Platte and the South Platte, unite at North Platte, Nebraska, to form the Platte river which flows thence through Nebraska to the Missouri at Plattsmouth. It is the principal river of Nebraska and its two branches water large areas in Colorado and Wyoming. With the exception of the North Platte Project of the Bureau of Reclamation, all irrigation development has been by private initiative and without Federal aid.

The North Platte rises in North Park, Colorado, and flows thence northerly into Wyoming, through which state it passes Pathfinder Reservoir, Casper, Douglas and Fort Laramie, and flows into Nebraska, irrigating adjacent lands in that state. The North Platte has always furnished the greater part of the natural water supply of the Platte river.

The South Platte rises in South Park, Colorado, and flows thence northeasterly to the Cache la Poudre, a principal tributary, whence it flows easterly past the cities of Fort Morgan, Sterling and Julesburg into Nebraska and thence to its junction with the North Platte. In its course from South Park to the mouth of the Cache la Poudre it passes through the City of Denver. It furnishes water to Denver, Boulder, Fort Collins, Greeley and a number of Colorado cities. It receives large contributions from several tributaries which are fed by the melting snows of the Continental Divide. These streams serve extensive areas of very productive agricultural lands and the South Platte waters similiar areas from Platte Canon (southwest of Denver) to Julesburg. The stream and its tributaries serve 1,500,000 acres of highly developed lands in Colorado.

The Platte has always been recognized as non-navigable. Numerous attempts were made by fur traders and trappers to transport their winter's catch to St. Louis by boats launched at Fort Laramie, Fort St. Vrain, Fort Lupton and other points along both branches of the Platte. All these attempts failed and those engaged in the expeditions were compelled to complete the journey to St. Louis by pack trains or wagons. The Platte was a "mile wide and a foot deep" in the spring months and a bed of desert sand during the summer.

The Oregon trail passed up the valley from Fort Kearney, Nebraska, to the "California Crossing" of the South Platte near Big Springs, Nebraska. It then crossed the narrow intervening divide between the South Platte and the North Platte and followed the south bank of the North Platte to the mouth of the Sweetwater, a Wyoming tributary entering the North Platte in the basin of the Pathfinder Reservoir. The trail followed the Sweetwater to its source at South Pass and thence down the slopes of the Colorado River to Fort Bridger. This was the principal national highway between the West and the East until the construction of the Union Pacific railroad.

From the "California Crossing" another highway followed the south bank of the South Platte river to "Denver City" and the mines developed during the "Pikes Peak" gold rush of 1859.

From time immemorial the South Platte was known as a "disappearing river." During the months of July, August and September the flow disappeared into the river sands from Fort Morgan, Colorado, to the junction with the North Platte. Similar conditions obtained on the North Platte and the main Platte frequently went dry to Fort Kearney. Caravans traveling the Oregon and Denver City trails encountered high waters in May and June, but were compelled to dig into the sands for water in July, August and September of every year.

The Nebraska portion of the Platte Valley along the main river is semi-arid. The territory watered by the two principal branches is arid from North Platte to the Rocky Mountains and requires irrigation.

The gold rush of 1859 caused cultivation of the river bottom lands of the South Platte and its tributaries and, by 1870, practically all river bottoms were served by small ditches. The bench or uplands, bordering the narrow strips of river bottoms, were considered sterile and worthless. But the South Platte Valley later became the cradle of reclamation of the arid uplands of the "Great American Desert."

In 1869, Nathan C. Meeker, agricultural editor of the New York Tribune, journied west over the Union Pacific to Cheyenne and thence by stage along the eastern front of the Rocky Mountains to the Arkansas and down that stream to the Missouri, seeking a locality where he could demonstrate the agricultural value of western uplands. Upon his return to New York he announced the intention of forming a colony for such purpose and was given the support of the New York Tribune by Horace Greeley. The Colony organized at Cooper Union Hall, New York, during the winter of 1869-70, and in the spring of 1870 a location committee selected lands along the Cache la Poudre river and established Greeley, Colorado, as the center of their activities. Mr. Meeker was the chairman of this committee and the land selected had been partially viewed by him the previous year. Four large canals were contemplated for the reclamation of uplands (theretofore considered sterile), three of which were to derive their water supply

from the Cache la Poudre and the fourth its supply from the Big Thompson. Only two of these canals (Union Colony Canals Nos. 2 and 3) were constructed.

This venture in agriculture became the source of general ridicule and prophesies of certain failure. But the enterprise was an immediate success and disproved all previous theories respecting the fertility of upland soils. A general era of irrigation development throughout the arid west followed the Meeker demonstration culminating in the enactment of the Reclamation Act (1902). About 5 per cent of the irrigated lands of the arid west are now served by works constructed by the United States. The remaining 95 per cent have been reclaimed through individual effort or the investment of private capital.

Authorities universally agree that the economic development of the lands of any stream basin, by irrigation, should commence at the headwaters and proceed gradually down stream using and reusing the waters which return to the streams from the irrigated lands.

Development of the South Platte Valley has conformed with this fundamental principle. Early irrigation along the upper reaches of the stream yielded large water returns. This supply was diverted by lower ditches and applied to lower lands and, step by step, the process was repeated. As a result, the "disappearing river" no longer exists. It is now a stream of constant flow to and across the interstate line, although its waters have been repeatedly diverted, used, rediverted and reused for irrigation of 1,500,000 acres. The return waters of the South Platte and of the North Platte have stabilized the flow of the main river below North Platte and have made possible the adjustment between the states, with assurance of increased future development in Nebraska. It is an undisputable fact that the flow of the main river is more dependable than it was of nature. Irrigation along both the North Platte and the South Platte rivers has operated to store and equalize the flow of the main river, with benefit and without cost to lower users.

During the 90's there was an era of irrigation development in Nebraska. A number of canals were constructed, both from the main river and its two principal branches. Those upon the main river depended upon the waters of the North Platte. The waters of the South Platte had been many times over-appropriated in Colorado long prior to 1890, and the return flows had not then progressed to the interstate line. However, several small canals were constructed to divert water from the South Platte in Nebraska, and in 1897 the large canal of the Western Irrigation District, heading immediately below the interstate line (east of Julesburg), was constructed to use the available waters of the South Platte, consisting of late fall, winter and early spring flows, and occasional short flows during periods of high water. At that time the South Platte was usually dry from Sterling, Colorado, easterly. But irrigation development progressed down

stream, by use of the return flows from the upper irrigated lands in Colorado, and by 1909 the dry river of 1897 had been converted into one of small but constant flow at the interstate line and these waters were diverted and used by the Western Irrigation District upon the 15,000 acres of land served by its irrigation canals.

Some friction developed between the water users in the two states during extremely dry years, and in 1916 the Attorney General of Nebraska brought suit, in behalf of that State, but in the name of the Western Irrigation District, to enjoin diversions made by certain users in Colorado. The many defendant ditch companies organized a protective association and engineers and an attorney were employed to prepare and conduct the defense.

The attorney for the Colorado water users recommended that all preparation should have a two-fold purpose (1) as a basis for an ultimate treaty between Colorado and Nebraska to settle all problems respecting the equitable distribution of the waters of the South Platte, including a settlement of the pending litigation and (2) as evidence to be introduced in the pending suit or other litigation, in the event no treaty could be arranged between the states. The plan was adopted and elaborate studies were made of the problems of the entire river system.

His suggestion of settlement of interstate river problems by interstate treaty was a matter of first impression and it was recognized that such a plan must be supported by a campaign of education before any treaty could be concluded or approved. Preparation proceeded under the two-fold plan and the facts so ascertained became the basis of the treaty under consideration. But intervening events brought the treaty plan of interstate adjustments to public attention and approval.

During the year 1919 problems of flood control and power development along the lower Colorado river were pressed to the attention of the seven states of the Colorado river basin. A series of meetings were held terminating at Denver, August 25-27, 1920, at which time the attorney for the South Platte water users acted as the legal advisor to the Governor of Colorado and suggested an interstate treaty between the Colorado river states. His suggestion was promptly approved and was later accepted as the policy of the interested states by action of the seven state legislatures. Consent of Congress given by special act approved August 19, 1921. As a result of proceedings had under this legislation the Colorado River Compact was concluded at Santa Fe, November 24, 1922.

A brief of the law of interstate compacts and the application of the treaty-making powers of the states to the settlement of interstate river controversies had been in process of preparation since 1912, by the Commissioner for Colorado, and a memorandum thereof was submitted to the Judiciary Committee of the House of Representatives 67th Congress, 1st Session, on June 4, 1921, at a hearing in re H. R. 6821, a bill for an act to permit the Colorado

River Compact. This brief is attached to the Commissioner's published report to the Colorado Legislature recommending ratification of the Colorado River Compact.

The nation-wide interest in the Colorado river treaty proceedings hastened the work of the South Platte Commission, appointed in 1921, and cleared the way for a South Platte compact. The attorney for the water users of the South Platte acted as the Commissioner for Colorado on both the Colorado River and South Platte River Commissions and, immediately following the conclusion of the Colorado River Compact, the work of the South Platte Commission was resumed and continued until the conclusion of the South Platte River compact April 27, 1923.

The commissioner for Nebraska is an engineer of unusual attainments and brought to the work a broad knowledge of the facts which greatly facilitated the work of the Commission.

The study and research necessary to sustain the application of the treaty-plan of interstate distribution of the waters of the South Platte laid the foundation for the suggestion and conclusion of the Colorado River Compact and the application of the policy of resort to interstate diplomacy, in lieu of litigation, had its origin with South Platte problems.

The Nebraska Legislature ratified the South Platte Compact at its 1923 session but the Colorado Legislature had adjourned and did not reconvene until its regular session in January, 1925, when the compact received the unanimous approval of both houses. The interstate litigation was dismissed in 1923.

The problems of Arkansas and South Platte rivers are quite similar; their sources are in the same region and they are characterized by the same type of disappearing flow. The history of interstate disputes respecting the use of the waters of the two streams brings into bold contrast the advantage of the interstate diplomacy as compared with litigation. The compact on the South Platte was concluded, all pending litigation dismissed and future litigation avoided within a short period of seven years and at a minimum expense, while the Arkansas dispute (between Kansas and Colorado users) has been in the courts for more than a quarter of a century and is little nearer solution than at the time the institution of the original case before the Supreme Court.

MESSAGE OF GOVERNOR SWEET

January 8, 1925, Governor William E. Sweet in his message to the 25th General Assembly of the State of Colorado, spoke as follows on interstate water problems on the South Platte:

"The last General Assembly directed the negotiation of water compacts with adjoining states. The Interstate Rivers Compact Commissioner for Colorado, Delph E. Carpenter, was reappointed and has received my unqualified support with excellent results. Litigation involving the waters of the South Platte river has been dismissed and a compact concluded between Colorado and Ne-

braska. It was ratified by the Nebraska Legislature and will be submitted for your early and favorable consideration. It should be approved by Congress prior to March 4."

MESSAGE OF GOVERNOR MORLEY

January 13, 1925, Governor Clarence J. Morley thus addressed the 25th General Assembly:

"The work of negotiating treaties with our neighboring states respecting the future use of the waters of our rivers should proceed with all convenient dispatch. Our agriculture and institutions depend upon the use of the waters of the streams which rise within our borders. All our streams are interstate and increasing development is hastening conflict. If the rights of the interested states are not determined by compacts, the increasing development may result in general interstate litigation.

"The compact executed April 27, 1923, between commissioners for the states of Colorado and Nebraska and heretofore ratified by the legislature of Nebraska should receive the prompt and favorable consideration of the General Assembly. It is important that the rights of the two states should be settled."

January 12, Governor William E. Sweet submitted the South Platte River Compact and the report of the Commissioner for Colorado to the 25th General Assembly:

"Denver, Colorado, January 12, 1925.

"To the Honorable The Senate of the State of Colorado, Denver, Colorado.

"Gentlemen:

"I herewith transmit for your consideration a certified copy of the South Platte River Compact, between the States of Colorado and Nebraska, also the report of the Commissioner for Colorado.

"This compact settles the long-pending controversy between the two states respecting the use and disposition of the waters of the South Platte river. It has been ratified by the Nebraska Legislature and I earnestly recommend your approval.

Respectfully submitted,

WM. E. SWEET,
Governor."

SOUTH PLATTE RIVER COMPACT BETWEEN THE STATES OF COLORADO AND NEBRASKA

The State of Colorado and the State of Nebraska, desiring to remove all causes of present and future controversy between said states, and between citizens of one against citizens of the other, with respect to the waters of the South Platte river, and being moved by considerations of interstate comity, have resolved to conclude a compact for these purposes and, through their respective Governors, have named as their commissioners:

Delph E. Carpenter, for the State of Colorado; and Robert H. Willis, for the State of Nebraska; who have agreed upon the following articles:

ARTICLE I.

In this compact:

1. The State of Colorado and the State of Nebraska are designated, respectively, as "Colorado" and "Nebraska."

2. The provisions hereof respecting each signatory state, shall include and bind its citizens and corporations and all others engaged or interested in the diversion and use of the waters of the South Platte river in that state.

3. The term "Upper Section" means that part of the South Platte river in the State of Colorado above and westerly from the west boundary of Washington County, Colorado.

4. The term "Lower Section" means that part of the South Platte river in the State of Colorado between the west boundary of Washington County and the intersection of said river with the boundary line common to the signatory states.

5. The term "Interstate Station" means that stream gaging station described in Article II.

6. The term "flow of the river" at the Interstate Station means the measured flow of the river at said station plus all increment to said flow entering the river between the Interstate Station and the diversion works of the Western Irrigation District in Nebraska.

ARTICLE II.

1. Colorado and Nebraska, at their joint expense, shall maintain a stream gaging station upon the South Platte river at the river bridge near the town of Julesburg, Colorado, or at a convenient point between said bridge and the diversion works of the canal of the Western Irrigation District in Nebraska, for the purpose of ascertaining and recording the amount of water flowing in said river from Colorado into Nebraska and to said diversion

works at all times between the first day of April and the fifteenth day of October of each year. The location of said station may be changed from year to year as the river channels and water flow conditions of the river may require.

2. The State Engineer of Colorado and the Secretary of the Department of Public Works of Nebraska shall make provision for the co-operative gaging at and the details of operation of said station and for the exchange and publication of records and data. Said state officials shall ascertain the rate of flow of the South Platte river through the Lower Section in Colorado and the time required for increases or decreases of flow, at points within said Lower Section, to reach the Interstate Station. In carrying out the provisions of Article IV of this compact, Colorado shall always be allowed sufficient time for any increase in flow (less permissible diversions) to pass down the river and be recorded at the Interstate Station.

ARTICLE III.

The waters of Lodgepole Creek, a tributary of the South Platte river flowing through Nebraska and entering said river within Colorado, hereafter shall be divided and apportioned between the signatory states as follows:

1. The point of division of the waters of Lodgepole Creek shall be located on said creek two miles north of the boundary line common to the signatory states.

2. Nebraska shall have the full and unmolested use and benefit of all waters flowing in Lodgepole Creek above the point of division and Colorado waives all present and future claims to the use of said waters. Colorado shall have the exclusive use and benefit of all waters flowing at or below the point of division.

3. Nebraska may use the channel of Lodgepole Creek below the point of division and the channel of the South Platte river between the mouth of Lodgepole Creek and the Interstate Station, for the carriage of any waters of Lodgepole Creek which may be stored in Nebraska above the point of division and which Nebraska may desire to deliver to ditches from the South Platte river in Nebraska, and any such waters so carried shall be free from interference by diversions in Colorado and shall not be included as a part of the flow of the South Platte river to be delivered by Colorado at the Interstate Station in compliance with Article IV of this compact, provided, however, that such runs of stored water shall be made in amounts of not less than ten cubic feet per second of time and for periods of not less than twenty-four hours.

ARTICLE IV.

The waters of the South Platte river hereafter shall be divided and apportioned between the signatory states as follows:

1. At all times between the fifteenth day of October of any year and the first day of April of the next succeeding year, Colorado shall have the full and uninterrupted use and benefit of the waters of the river flowing within the boundaries of the state, except as otherwise provided by Article VI.

2. Between the first day of April and the fifteenth day of October of each year, Colorado shall not permit diversions from the Lower Section of the river, to supply Colorado appropriations having adjudicated dates of priority subsequent to the fourteenth day of June, 1897, to an extent that will diminish the flow of the river at the Interstate Station, on any day, below a mean flow of 120 cubic feet of water per second of time, except as limited in paragraph three (3) of this Article.

3. Nebraska shall not be entitled to receive and Colorado shall not be required to deliver, on any day, any part of the flow of the river to pass the Interstate Station, as provided by paragraph two (2) of this Article, not then necessary for beneficial use by those entitled to divert water from said river within Nebraska.

4. The flow of the river at the Interstate Station shall be used by Nebraska to supply the needs of present perfected rights to the use of water from the river within said state before permitting diversions from the river by other claimants.

5. It is recognized that variable climatic conditions, the regulation and administration of the stream in Colorado, and other causes, will produce diurnal and other unavoidable variations and fluctuations in the flow of the river at the Interstate Station, and it is agreed that, in the performance of the provisions of said paragraph two (2), minor or compensating irregularities and fluctuations in the flow at the Interstate Station shall be permitted; but where any deficiency of the mean daily flow at the Interstate Station may have been occasioned by neglect, error or failure in the performance of duty by the Colorado water officials having charge of the administration of diversions from the Lower Section of the river in that state, each such deficiency shall be made up, within the next succeeding period of seventy-two hours, by delivery of additional flow at the Interstate Station, over and above the amount specified in paragraph two (2) of this Article, sufficient to compensate for such deficiency.

6. Reductions in diversions from the Lower Section of the river, necessary to the performance of paragraph two (2) of this Article by Colorado, shall not impair the rights of appropriators in Colorado (not to include the proposed Nebraska canal described in Article VI), whose supply has been so reduced, to demand and receive equivalent amounts of water from other parts of the stream in that state according to its Constitution, laws, and the decisions of its courts.

7. Subject to compliance with the provisions of this Article, Colorado shall have and enjoy the otherwise full and uninterrupted use and benefit of the waters of the river which hereafter may flow within the boundaries of that state from the first day

of April to the fifteenth day of October in each year, but Nebraska shall be permitted to divert, under and subject to the provisions and conditions of Article VI, any surplus waters which otherwise would flow past the Interstate Station.

ARTICLE V.

1. Colorado shall have the right to maintain, operate, and extend, within Nebraska, the Peterson Canal and other canals of the Julesburg Irrigation District which now are or may hereafter be used for the carriage of water from the South Platte river for the irrigation of lands in both states, and Colorado shall continue to exercise control and jurisdiction of said canals and the carriage and delivery of water thereby. This Article shall not excuse Nebraska water users from making reports to Nebraska officials in compliance with the Nebraska laws.

2. Colorado waives any objection to the delivery of water for irrigation of lands in Nebraska by the canals mentioned in paragraph one (1) of this Article, and agrees that all interests in said canals and the use of waters carried thereby, now or hereafter acquired by owners of lands in Nebraska, shall be afforded the same recognition and protection as are the interests of similar land owners served by said canals within Colorado; *Provided, however*, that Colorado reserves to those in control of said canals the right to enforce the collection of charges or assessments, hereafter levied or made against such interests of owners of the lands in Nebraska, by withholding the delivery of water until the payment of such charges or assessments; Provided, however, such charges or assessments shall be the same as those levied against similar interests of owners of lands in Colorado.

3. Nebraska grants to Colorado the right to acquire by purchase, prescription, or the exercise of eminent domain, such rights of way, easements or lands as may be necessary for the construction, maintenance, operation, and protection of those parts of the above mentioned canals which now or hereafter may extend into Nebraska.

ARTICLE VI.

It is the desire of Nebraska to permit its citizens to cause a canal to be constructed and operated for the diversion of water from the South Platte River within Colorado for irrigation of lands in Nebraska; that said canal may commence on the south bank of said river at a point southwesterly from the town of Ovid, Colorado, and may run thence easterly through Colorado along or near the line of survey of the formerly proposed "Perkins County Canal" (sometimes known as the "South Divide Canal") and into Nebraska, and that said project shall be permitted to divert waters of the river as hereinafter provided. With respect to such proposed canal it is agreed:

1. Colorado consents that Nebraska and its citizens may hereafter construct, maintain, and operate such a canal and thereby may divert water from the South Platte river within Colorado for use in Nebraska, in the manner and at the time in this Article provided, and grants to Nebraska and its citizens the right to acquire by purchase, prescription, or the exercise of eminent domain such rights of way, easements or lands as may be necessary for the construction, maintenance, and operation of said canal; *subject, however*, to the reservations and limitations and upon the conditions expressed in this Article which are and shall be limitations upon and reservations and conditions running with the rights and privileges hereby granted, and which shall be expressed in all permits issued by Nebraska with respect to said canal.

2. The net future flow of the Lower Section of the South Platte river, which may remain after supplying all present and future appropriations from the Upper Section, and after supplying all appropriations from the Lower Section perfected prior to the seventeenth day of December, 1921, and after supplying the additional future appropriations in the Lower Section for the benefit of which a prior and preferred use of thirty-five thousand acre feet of water is reserved by subparagraph (a) of this Article, may be diverted by said canal between the fifteenth day of October of any year and the first day of April of the next succeeding year subject to the following reservations, limitations and conditions:

(a) In addition to the water now diverted from the Lower Section of the river by present perfected appropriations, Colorado hereby reserves the prior, preferred and superior right to store, use and to have in storage in readiness for use on and after the first day of April in each year, an aggregate of thirty-five thousand acre feet of water to be diverted from the flow of the river in the Lower Section between the fifteenth day of October of each year and the first day of April of the next succeeding year, without regard to the manner or time of making such future uses, and diversions of water by said Nebraska canal shall in no manner impair or interfere with the exercise by Colorado of the right of future use of the water hereby reserved.

(b) Subject at all times to the reservation made by subparagraph (a) and to the other provisions of this Article, said proposed canal shall be entitled to divert five hundred cubic feet of water per second of time from the flow of the river in the Lower Section, as of priority of appropriation of date December 17, 1921, only between the fifteenth day of October of any year and the first day of April of the next succeeding year upon the express condition that the right to so divert water is and shall be limited exclusively to said annual period and shall not constitute the basis for any claim to water necessary to supply all present and future appropriations in the Upper Section or present appropriations in the Lower Section and those hereafter to be made therein as provided in subparagraph (a).

3. Neither this compact nor the construction and operation of such a canal nor the diversion, carriage and application of water thereby shall vest in Nebraska, or in those in charge or control of said canal or in the users of water therefrom, any prior, preferred or superior servitude upon or claim or right to the use of any water of the South Platte river in Colorado from the first day of April to the fifteenth day of October of any year or against any present or future appropriator or user of water from said river in Colorado during said period of every year, and Nebraska specifically waives any such claims and agrees that the same shall never be made or asserted. Any surplus waters of the river, which otherwise would flow past the Interstate Station during such period of any year after supplying all present and future diversions by Colorado, may be diverted by such a canal, subject to the other provisions and conditions of this Article.

4. Diversions of water by said canal shall not diminish the flow necessary to pass the Interstate Station to satisfy superior claims of users of water from the river in Nebraska.

5. No appropriations of water from the South Platte river by any other canal within Colorado shall be transferred to said canal or be claimed or asserted for diversion and carriage for use on lands in Nebraska.

6. Nebraska shall have the right to regulate diversions of water by said canal for the purposes of protecting other diversions from the South Platte river within Nebraska and of avoiding violations of the provisions of Article IV; but Colorado reserves the right at all times to regulate and control the diversions by said canal to the extent necessary for the protection of all appropriations and diversions within Colorado or necessary to maintain the flow at the Interstate Station as provided by Article IV of this compact.

ARTICLE VII.

Nebraska agrees that compliance by Colorado with the provisions of this compact and the delivery of water in accordance with its terms shall relieve Colorado from any further or additional demand or claim by Nebraska upon the waters of the South Platte river within Colorado.

ARTICLE VIII.

Whenever any official of either state is designated herein to perform any duty under this contract, such designation shall be interpreted to include the state official or officials upon whom the duties now performed by such official may hereafter devolve, and it shall be the duty of the officials of the State of Colorado charged with the duty of the distribution of the waters of the South Platte river for irrigation purposes, to make deliveries of water at the Interstate Station in compliance with this compact without necessity of enactment of special statutes for such purposes by the General Assembly of the State of Colorado.

ARTICLE IX.

The physical and other conditions peculiar to the South Platte river and to the territory drained and served thereby constitute the basis for this compact and neither of the signatory states hereby concedes the establishment of any general principle or precedent with respect to other inter-state streams.

ARTICLE X.

This compact may be modified or terminated at any time by mutual consent of the signatory states, but, if so terminated and Nebraska or its citizens shall seek to enforce any claims of vested rights in the waters of the South Platte river, the statutes of limitation shall not run in favor of Colorado or its citizens with reference to claims of the Western Irrigation District to the water of the South Platte River from the sixteenth day of April, 1916, and as to all other present claims from the date of the approval of this compact to the date of such termination, and the State of Colorado and its citizens who may be made defendants in any action brought for such purpose shall not be permitted to plead the statutes of limitation for such periods of time.

ARTICLE XI.

This compact shall become operative when approved by the Legislature of each of the signatory states and by the Congress of the United States. Notice of approval by the Legislature shall be given by the Governor of each state to the Governor of the other state and to the President of the United States, and the President of the United States is requested to give notice to the Governors of the signatory states of the approval by the Congress of the United States.

IN WITNESS WHEREOF, the Commissioners have signed this compact in duplicate originals, one of which shall be deposited with the Secretary of State of each of the signatory states.

DONE at Lincoln, in the State of Nebraska, this 27th day of April, in the year of our Lord One Thousand Nine Hundred and Twenty-three.

DELPH E. CARPENTER,
ROBERT H. WILLIS.

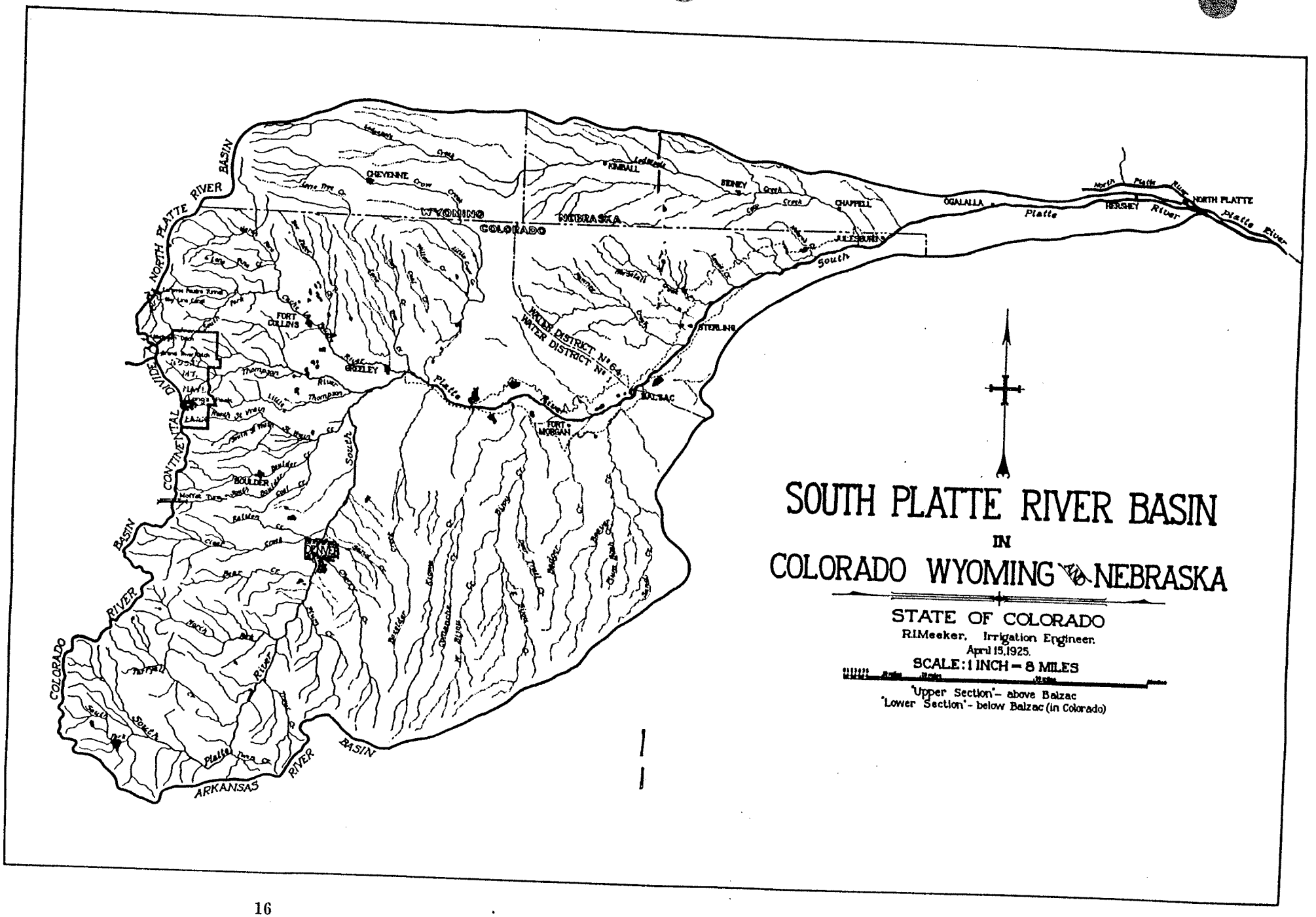
SOUTH PLATTE RIVER COMPACT
BETWEEN THE STATES
OF
COLORADO AND NEBRASKA

FILED in the office of the Secretary of State, of the State of Colorado, on the 14th day of July, A. D. 1923, at 11 o'clock a. m.

CARL S. MILLIKEN,
Secretary of State.

By CHARLES ARMSTRONG,
Deputy.

Filing Clerk, Leahy, Fees, Official.
Indorsed by M. S.


SOUTH PLATTE RIVER BASIN
IN
COLORADO WYOMING AND NEBRASKA
STATE OF COLORADO
R.I.Meeker, Irrigation Engineer.
April 15,1925.
SCALE: 1 INCH = 8 MILES
"Upper Section"- above Balzac
"Lower Section"- below Balzac (in Colorado)
WYOMING
NEBRASKA
COLORADO
CHEYENNE
KIMBALL
SIDNEY
CHAPPELL
OGALALLA
NORTH PLATTE
HERSHEY
JULESBURG
STERLING
FORT COLLINS
GREELEY
BOULDER
DENVER
BALZAC
FORT MORGAN
NORTH PLATTE RIVER BASIN
CONTINENTAL DIVIDE
SOUTH PLATTE RIVER BASIN
COLORADO RIVER BASIN
ARKANSAS RIVER BASIN
WATER DISTRICT No 64
WATER DISTRICT No 1

SOUTH PLATTE RIVER COMPACT
REPORT
OF
DELPH E. CARPENTER
COMMISSIONER FOR COLORADO

Governor William E. Sweet, Denver, Colorado.

Sir:

I have the honor to report that a compact was signed by Commissioners for the states of Colorado and Nebraska at Lincoln, Nebraska, April 27, 1923, providing for the permanent equitable distribution of the waters of the South Platte river. The compact was executed by me as Commissioner for the State of Colorado under authority of Chapter 243, Session Laws 1921 and Chapter 190, Session Laws of 1923, and by Hon. Robert H. Willis, Commissioner for the State of Nebraska, acting by appointment of the Governor. It was executed in duplicate originals, one of which has been deposited with the Secretary of State of each of the signatory states, and the compact will become operative when approved by the Legislature of each of the signatory states and by the Congress of the United States.

The compact generally provides as follows:

For purposes of administration, the South Platte river in Colorado is divided into two sections. The "Upper Section" includes that part of the South Platte river in Colorado above the intersection of the river with the west boundary of Washington County (east boundary of Morgan County). The "Lower Section" corresponds with Water District No. 64 and is that part of the South Platte river in Colorado between the west boundary of Washington County and the intersection of the river with the west boundary of Washington County (east boundary of Morgan County).

An interstate stream gauging station shall be located on the South Platte near Julesburg (at the joint expense and under the joint supervision of the two states) for the purpose of ascertaining and recording the amount of water flowing into Nebraska.

Present and future diversions and uses of water of the South Platte are grouped as follows: (1) Those to occur between April 1st and October 15th of each year and (2) those to occur between October 15th of each year and April 1st of the next succeeding year.

Article IV provides as follows:

(1) Colorado shall have the full and uninterrupted use and benefit of the waters of the South Platte at all times between October 15th of each year and April 1st of the next succeeding

year, except for diversions by the proposed Perkins County Canal as specifically permitted, limited and defined by Article VI.

Colorado shall have the full and uninterrupted use and benefit of the waters of the South Platte between April 1st and October 15th of each year, subject to the following limitations:

During said period of each year Colorado shall not permit diversions from the Lower Section of the river to supply Colorado appropriations having adjudicated dates of priority subsequent to June 14, 1897, to an extent that will diminish the flow of the river at the Interstate Station, on any day, below a mean flow of 120 cubic feet of water per second of time, provided, however, that Nebraska shall not be entitled to receive and Colorado shall not be required to deliver any part of such flow not immediately necessary for beneficial use by those entitled to divert water from the South Platte within Nebraska and the flow of the river at the Interstate Station shall be used by Nebraska to supply the needs of rights to the use of water, from the South Platte river in Nebraska, perfected prior to the date of the compact before permitting diversions from the South Platte by other claimants;

In deliveries of water by Colorado to Nebraska, at the Interstate Station, minor and compensating irregularities and discrepancies in flow shall be expected and permitted, but where any deficiency in the mean daily flow may have been occasioned by neglect, error or failure in the performance of duty by the Colorado water officials having charge of the administration of diversions from the Lower Section of the river in Colorado, any such differences shall be made up by the delivery of compensating quantities of water, within 72 hours; and

As a matter of intrastate protection of Colorado appropriations from the South Platte and the local control of deliveries of water by the officials, Paragraph 6 of Article IV provides that, whenever in the performance of Paragraph 2 of Article IV, senior appropriators in the Lower Section are deprived of water, such appropriators may call upon junior appropriators in the Upper Section for equivalent amounts according to the laws of Colorado.

Article VI permits Nebraska to construct a new "Perkins County Canal" to divert water from the South Platte river in Colorado for the irrigation of arid lands in Nebraska, upon the conditions, limitations and reservations specifically set forth in the article, inter alia:

Nebraska is permitted to divert not to exceed 500 cubic feet of water per second of time, but only between October 15 of any year and April 1 of the next succeeding year (as of priority of date December 17, 1921), from the net flow of water in the Lower Section which may remain after supplying all present and future appropriations in the Upper Section and all present appropriations in the Lower Section, and, also after supplying additional future appropriations in the Lower Section for the benefit of

which a superior, preferred and dominant right of use of 35,000 acre feet annually is specifically reserved to Colorado by subparagraph (a) of Paragraph 2 of said Article. The reservation of 35,000 acre feet of water, to be annually diverted and stored in the future for the use and benefit of future development in the Lower Section of Colorado, shall apply without regard to the time or manner of making such future use. Diversions by the Nebraska canal shall in no manner impair or interfere with the exercise by Colorado of the right of future use to the extent of such reservation. The construction and operation of the canal and the use of water thereby shall not vest in Nebraska any right or claim to a prior, preferred or superior servitude upon or claim or right to the use of any water of the South Platte river in Colorado from April 1 to October 15, and Nebraska specifically waives any such claims and agrees that the same will never be made nor asserted. The canal may intercept any surplus waters which would otherwise flow into Nebraska and not necessary for use in either state, but such diversion shall not give rise to a claim of prior appropriation as against any present or future Colorado user and shall not diminish the supply necessary to pass the Interstate Station to satisfy superior claims of users of water from the river in Nebraska. No appropriations of water from the South Platte river perfected by use through any other canal within Colorado shall be transferred to said canal or be claimed or asserted for diversion or carriage for use on lands in Nebraska. While Nebraska shall have the right to regulate diversions of water by said canal for the purpose of protecting other diversions from the South Platte river within Nebraska, Colorado reserves the right at all times to regulate and control the diversions by said canal to the extent necessary for the protection of all appropriations and diversions within Colorado or necessary to maintain the flow at the Interstate Station as required by Article IV.

Article III deals with the waters of Lodgepole Creek, a tributary of the South Platte flowing through Nebraska and entering the river within Colorado. This stream is treated separately. A point of division of the waters of the stream is fixed at two miles north of the interstate boundary. Nebraska shall have the use of all waters flowing in the creek above and Colorado the use of all waters flowing at or below that point. Nebraska is permitted to use the channel of the creek, below the point of division and the channel of the South Platte between the mouth of Lodgepole Creek and the Interstate Station, for the carriage of waters stored from the creek in Nebraska and to be used by ditches diverting from the South Platte in Nebraska, under certain definite provisions respecting quantity and periods of flow.

By Article V, Colorado is granted the right to maintain, operate and extend, within Nebraska, the Peterson and other canals of the Julesburg Irrigation District now or hereafter used

for the carriage of water from the South Platte for irrigation of lands in both states, Colorado to continue to exercise control and jurisdiction over said canals and the carriage and delivery of water thereby. Nebraska users shall be given the same recognition and protection as are afforded the interests of similar land owners served by said canals within Colorado, but Colorado reserves the right for those in control of said canals to enforce the collection of charges and assessments against Nebraska users, by withholding delivery of water until payment of such charges or assessments. Nebraska grants to Colorado the right to acquire rights of way and other properties necessary to the construction, operation and protection of said canals, by purchase, prescription or the exercise of eminent domain.

By Article VII, Nebraska agrees that compliance with the provisions of the compact and delivery of water in accordance with its terms shall relieve Colorado from any other, further or additional demand or claim by Nebraska upon the waters of the South Platte river within Colorado.

By Article VIII it is made the duty of the Colorado water officials, and their successors in authority, to deliver water at the Interstate Station in compliance with the compact, without the necessity of enactment of special statutes for such purposes.

By Article IX it is specifically provided that the physical and other conditions peculiar to the South Platte river and the territory drained and served thereby constitute the basis for the compact and neither of the signatory states concedes the establishment of any general principle or precedent with respect to other interstate streams.

By Article X it is provided that the compact may be modified or terminated at any time by mutual consent of the signatories and that if so terminated the statutes of limitation shall not be in favor of Colorado or its citizens with reference to the claims of the Western Irrigation District in Nebraska from the 16th day of April, 1916 (the date of commencement of the suit of the Western Irrigation District vs. the Riverside Irrigation District, et al., U. S. District Court, Denver), or, as to other present claims in Nebraska, from the date of the approval of the compact to the date of such termination, and Colorado and any of its citizens who may be made defendants in any action brought for such purpose (after termination of the compact) shall not be permitted to plead the statutes of limitation for such periods of time.

By Article XI the compact shall become operative when approved by the Legislature of each of the signatory states and by Congress of the United States, and provision is made for the giving of notice of legislative approval to the Governors and to the President.

By Paragraph 2 of Article I, the provisions of the compact respecting each signatory state, shall include and bind its citizens and corporations and all others engaged or interested in the

diversion and use of the waters of the South Platte river in that state.

Pursuant to the understanding between the Commissioners for Colorado and Nebraska and the attorneys for the litigants, the suit entitled "The Western Irrigation District vs. The Riverside Irrigation District, et al.," pending before the Federal District Court at Denver, and involving the use and disposition of the waters of the South Platte river by Colorado and its citizens, was dismissed and there is no other pending or threatened litigation on this important river.

MEMORANDUM

The compact concludes negotiations and continuous studies of water supply, engineering and other problems since 1916. It is the successful result of probably the first effort to use the treaty powers of the states in the settlement of interstate controversies respecting the waters of western streams.

The changed river conditions, due to development in Colorado since 1859, make possible the conclusion of a compact between the two states which will protect the water users in Nebraska, without injury to present and future users in Colorado, and will permit practically unlimited expansion and development in Colorado.

A review of the facts and of the history of the stream is essential to an understanding of the compact.

Development in Colorado, fortunately, commenced near the headwaters of the South Platte with resultant "land-storage" of water over an immense acreage long prior to June 14, 1897, the alleged date of commencement of the canal of the Western Irrigation District, the principal claimant in Nebraska. The flow of return and seepage waters coming back to the river from irrigation of Colorado lands, has resulted in a constant supply at the interstate line. This flow is increasing and will soon be sufficient to care for the full demands of Nebraska as determined by the compact, while great quantities of water annually flow to waste across the interstate line, during the flood season and the winter months, which are available for diversion by the proposed Perkins County canal without injury to present or future development in Colorado, principally by reason of the fact that most of said waters return to the river below available points of diversion by Colorado constructors. The once "disappearing" flood stream has been converted into one of constant flow making possible the development in both states.

The South Platte river rises wholly within the State of Colorado, with the exception of Lone Tree, Crow and Lodgpole Creeks, tributaries which enter the stream from the north and have their rise in Wyoming. From its source at the Continental Divide, the stream flows northeasterly through South Park, emerging from the mountains at Platte Canon, and thence flows northerly to the mouth of the Cache la Poudre, receiving contributions from various large tributaries below the canon. It then flows easterly and

northeasterly, to the boundary line between Colorado and Nebraska, and thence easterly to join the North Platte river at North Platte, Nebraska.

The area drained and served by the South Platte is quite extensive in the upper portion and gradually contracts as the river proceeds easterly. From Julesburg, Colorado, to North Platte, Nebraska, the river flows through a narrow valley bounded by high plateaus and the irrigable lands are quite limited, except for the possible irrigation of a large tract of land in Perkins County, Nebraska, at the headwaters of certain tributaries of the Republican river. These lands may be served by the proposed Perkins County canal described in Article VI of the compact.

In addition to its natural supplies, the river receives limited contributions from the headwaters of the Colorado and of the North Platte, by means of trans-mountain canals and tunnels across or through the intervening divides. Most of these structures are of long standing. The most recent is the tunnel of the Greeley-Poudre Irrigation District between the headwaters of the Laramie (a tributary of the North Platte) and the Cache la Poudre (a tributary of the South Platte), recently approved by the United States Supreme Court by its decision in the case of Wyoming vs. Colorado.

The South Platte irrigates about 1,500,000 acres in Colorado, and furnishes the domestic, municipal and industrial supplies for Denver and the other cities, towns and villages in northeastern Colorado. The extensive irrigation development in the South Platte drainage has been made without government aid. The irrigation works are owned and operated by the water users through mutual ditch corporations and, to a limited degree, through irrigation districts.

More than half of our people are dependent upon the waters of this stream system. More than half the present taxable wealth of the state is located in the South Platte drainage. The use of the waters of this river is the basis of the agricultural, manufacturing and all other activities in the entire northeastern portion of the state.

Irrigation, municipal, industrial and other uses of the waters of this stream have been in the process of development since 1859, by means of numerous canals, conduits, reservoirs and other structures. The development has reached an advanced stage. Water is extremely valuable. The duty of water is high. Great economy is practiced and the demands upon the stream are constantly increasing. The whole supply of the river must ultimately be put to use and any interference with complete control constitutes a menace to the future prosperity and general welfare of the state. Future development cannot proceed until there is a definite determination of the interstate rights to the use of the waters of this stream between Colorado and Nebraska. Colorado appropriators and users cannot finance the construction necessary to a more complete use of the waters in the face of adverse claims by Ne-

braska and her citizens. Nebraska cannot reclaim the arid lands in Perkins County without obtaining the privilege of constructing and operating the Perkins County canal, with its diversion and a considerable portion of its canal line in the State of Colorado.

The South Platte development is an outstanding proof of the fundamental principle of economic development of any river system, viz., that of commencing at the headwaters and proceeding gradually down-stream, thereby to prevent waste and to permit the use and repeated re-use of the return and seepage waters which re-enter the stream after serving the upper lands and cities.

Of nature, the flow of the stream was similar to that of the Arkansas and many other rivers of arid regions. It had its source in the high mountains and in the region of heavy precipitation. It then flowed out across arid plains to disappear into the sands during the heat of summer. The flow was excessive in May and June and disappeared entirely during the summer. The river frequently became dry for months of each year to points as far west as the present city of Fort Morgan. At such times freighters and travelers were compelled to dig into the sands of the river to obtain water for their animals.

Irrigation development commenced near the foothills and progressed gradually eastward. The dependable flow was over-appriated before 1880. Thereafter numerous reservoirs were constructed for the conservation of winter flows and a great portion of the flood waters of the early summer. The application of water to the lands and in municipal and industrial uses, in conjunction with the artificial storage provided by reservoirs, has so conserved and regulated the flow of the stream that it has been changed from intermittent to perennial and the area served is many times greater than would have been served if the waters had first been applied along the lower reaches of the stream.

The flow of the river at the interstate line was intermittent until about the year 1909. Since hitherto it has been perennial with increasing quantities passing over the interstate line, notwithstanding extensive new development along the lower reaches of the stream in Colorado.

This flow is permanent. It will improve with time. Each new structure in Colorado will tend to further equalize the flow of the stream at the interstate line. The extensive development between Greeley and Julesburg, completed since 1909, has resulted in great benefit to the flow in Nebraska and there is every reassurance of a gradual and cumulative increase as the full effect of increased irrigation becomes manifest in the form of ever-increasing return flows from the lands served.

Nebraska claims that on June 14, 1897, the Western Irrigation District commenced the construction of a canal for the irrigation of about 15,000 acres of land lying south of and parallel with the river in the vicinity of Big Springs, Brule and Ogallala. A canal with upwards of 180 cubic feet of water per second capacity was constructed and thereafter used for irrigation. The head works

of the canal are located on the south bank of the river just below the interstate line and are so situated that all of the water flowing into Nebraska may be first diverted by the canal (to the extent of its capacity) and thereby applied to the lands of the district. These lands are immediately adjacent to the stream with heavy return flows and replenishment of the river supply. These sources furnish a constant flow available for diversion by several smaller canals located between the interstate line and North Platte. At the time of the construction of the canal there was no visible flow of water in the river except for a brief period during the late spring and early summer and during the winter months. The river was dry during the times of greatest need. Practically all of the extensive canal development in Colorado, for direct application of waters without storage, occurred prior to June 14, 1897, including the canals in the vicinity of Sterling and Julesburg. The annual irrigation of the lands under these canals resulted in an equalization of the stream flow which caused an improvement in the water supply at the interstate line.

The extensive reservoir development for the diversion, storage and use of the waters of the South Platte in Colorado, below the mouth of the Cache la Poudre, occurred subsequent to 1897. By these projects large areas of new lands were brought under irrigation. While the return flows from these areas have been gradually increasing, during and shortly prior to the year 1916, the water users under the Western canal in Nebraska complained that the increased diversions in Colorado had worked great detriment to the supply of the river available for the Nebraska users. The condition became acute and in 1916 a suit was brought by the Attorney General of Nebraska, in the name of the Western Irrigation District, against a large number of canal and reservoir companies in Colorado, together with the State Engineer and other water officials. In this suit, filed in the United States District Court, it was sought to establish a prior and preferred claim to 180 cubic feet of water per second of time of priority date June 14, 1897, and to enforce the delivery of that amount at the headgate of the Nebraska canal at the expense of Colorado water users. It was a test case not brought for the sole benefit of the complainant irrigation district. A number of large enterprises, which divert water from the Platte river below North Platte, and a number of small enterprises diverting from the South Platte between Julesburg and North Platte would have profited by a favorable decision. The suit was financed by appropriations made by Nebraska Legislature and, while brought in the name of a private appropriator, in effect, it was a suit by the State of Nebraska against the State of Colorado.

The irrigation enterprises in Colorado formed an association for defensive purposes. Funds were raised by assessments upon the members of the association. These were combined with state funds made available through appropriations by the Colorado Legislature. Intensive studies of the legal, engineering and

other problems involved were undertaken and continued until the conclusion of the compact in 1923.

Early in the proceedings the attorney for the Colorado water users suggested to the Nebraska officials that the suit should be settled by interstate compact and that the compact should constitute a complete settlement of all the problems which might arise between the states and their citizens respecting the use of the waters of the river. Nebraska officials viewed the proposal with favor and, throughout the investigations, the problems to be determined by compact between the states were unofficially discussed and analyzed.

In 1921 the General Assembly of the State of Colorado passed an Act authorizing the appointment of a Commissioner for the purpose of negotiating and concluding a compact between the states of Colorado and Nebraska respecting the use and disposition of the waters of the South Platte and tributaries. A Commissioner was appointed pursuant to the Act. The Governor of Nebraska thereafter appointed Robert H. Willis to be the Commissioner for that state without prior legislative authority. The results of the engineering investigations from 1916 to 1921, ably conducted by R. G. Hosea, engineering and water supply expert for Colorado, and his assistants, were made available to the Commission. This data, together with the information obtained throughout the general investigation since the commencement of the suit, facilitated the labors of the commission and became the basis of a joint investigation of the river problems.

It became evident that, with the more complete reclamation of the lands served by the large irrigation works along the South Platte in Colorado, the flow at the interstate line would soon become adequate to take care of all demands upon the South Platte in Nebraska and that the large quantities of water now available (during winter months) for diversion by the proposed canal of the Perkins County enterprise will be increased. It was also found that the enormous quantities of water returning from the irrigation of lands along the North Platte river in Nebraska are adequate to supply all legitimate senior claims from the main river below North Platte and also sufficient to furnish ample supply for extensive new development along the main river.

The entire ordinary summer flow of the river and its tributaries in Colorado was many times over-appropriated long prior to the commencement of any canals in Nebraska. This condition generally obtains above Sterling, Colorado, and to a great extent down to Julesburg. This fact justified the exclusion of all that part of the river above the east line of Morgan County from detail administration necessary to carry out any interstate compact. Water District No. 64 of the State of Colorado comprises that part of the South Platte river and its tributaries between the east line of Morgan County (west line of Washington County) and the interstate line and is a complete unit for state administration

and control of diversions and uses of water for irrigation and other beneficial purposes.

In view of these conditions the compact agreed upon was limited in its immediate operation to Water District 64, which is designated in the compact as the "Lower Section" of the river, with provision for local readjustments of diversions by the Colorado authorities wherever necessary.

The season of direct irrigation of lands from the South Platte in Colorado and Nebraska commences about April 1 and ends about October 15. During this season all of the waters of the stream are utilized for direct application to the soil, except during flood periods when waters are both applied to the soil and stored in the reservoirs for future use.

From October 15, of each year, to April 1 of the next succeeding year, the waters of the river are diverted and stored in the reservoirs, excepting that part of the flow composed of return waters entering the stream below the head of the Harmony canal, the last reservoir inlet in Colorado. This canal fills the reservoir of the Julesburg Irrigation District and completes the filling by midwinter. During the remainder of the winter there are no diversions for storage in Water District 64 and all the water flows into Nebraska, there to waste.

A thorough investigation was made respecting future irrigation expansion by new reservoir development to divert in Water District 64. Such opportunities were found to be limited by topography and by reason of the fact that the greater part of the available lands located in Water District 64 are served by canals and reservoirs diverting in the Upper Section of the river. It was ascertained that an additional annual storage and application of 25,000 to 35,000 acre feet of water would be adequate to care for all probable future expansion of irrigation in Water District 64, by diversions made from that portion of the river.

During the months of low flow the Colorado canals are justly entitled to practically all of the water available for diversion in both sections of the stream. During periods of high flow there is water enough for all appropriators in both states. During the interval intervening between the high flow and the extreme low flow some regulation of diversions by canals in Water District 64 will be required to pass 120 second feet of water across the interstate line for use in Nebraska. But this interval is of short duration and the adjustment of diversions by the water officials will have little effect upon diversions in Colorado. The increase of flow at the state line will ultimately remove all necessity for regulation.

The compact was prepared during the winter of 1922-23. Several drafts were made and submitted for suggestion and criticism by the Attorney General of each state and by the engineers, water supply experts and attorneys for the canal companies in both states. After final approval, the compact was signed at Lincoln, Nebraska, April 27, 1923, by the Commissioners. It was

then submitted to the Nebraska Legislature by special message of Governor Bryan and was approved. It will become effective upon approval by the General Assembly of the State of Colorado and the Congress of the United States.

The compact is satisfactory to water users in both states. It affords a permanent solution. Its provisions are simple and its operation will require no additional employes in either state. In the course of time and with improvement of flow at the interstate line, it will become self-executing. Its ratification will permanently remove opportunity for interstate litigation, similar to that obtaining with respect to the Arkansas river. Under it, new development may proceed with assurance of title to uses of water and with benefit to both states. It assures permanent peace with our neighboring state and directly benefits the majority of our people in the security of their possessions and in their opportunities to use the natural resources most essential to their prosperity and the general welfare of our state.

I take pleasure in calling attention to the valued services of R. G. Hosea, irrigation expert for Colorado from 1916 to 1923, who served as my associate and advisor throughout the prolonged negotiations. His studies of the water supply problems of the South Platte river are recognized to be among the most thorough and comprehensive ever conducted upon any river system of like magnitude. His data became the basis of the compact.

I respectfully suggest that the compact be submitted to the General Assembly of the State of Colorado and recommend its approval.

Respectfully submitted,

DELPH E. CARPENTER,
Commissioner for Colorado.

Denver, Colorado, January 7, 1925.

COLORADO LEGISLATION

"AN ACT TO APPROVE THE SOUTH PLATTE RIVER COMPACT.

"Be It Enacted by the General Assembly of the State of Colorado:

"SECTION 1. The General Assembly hereby approves the compact, designated as the "South Platte River Compact," between the states of Colorado and Nebraska, signed at the City of Lincoln, State of Nebraska, on the 27th day of April, A. D. 1923, by Delph E. Carpenter as the Commissioner for the State of Colorado, under authority of Chapter 243, Session Laws of Colorado, 1921, and Chapter 190, Session Laws of Colorado, 1923, and by Robert H. Willis as the Commissioner for the State of Nebraska, thereunto duly authorized, which said compact is as follows:"

[HERE FOLLOWS THE COMPACT IN FULL]

Safety and emergency clauses contained in Sections 2 and 3.

Approved February 26, 1925.

For the Colorado Act directing the Governor of Colorado to appoint a Commissioner for Colorado to serve on the South Platte Commission—See Chapter 243, page 799, Session Laws, Colorado, 1921.

MEMORANDUM OF LAW—INTERSTATE COMPACTS

"No state shall, without consent of Congress, * * * enter into any agreement or compact with another state." (U. S. Const. Art. I., Sec. 10, Par. 3).

"Consent of Congress" may be obtained either before or after conclusion of the compact and may be either express or implied. The adoption or approval of proceedings taken under the compact indicate consent. "The Constitution makes no provision respecting the mode or form in which the consent of Congress is to be signified, very properly leaving that matter to the wisdom of that body, to be decided upon according to the ordinary rules of law and of right reason." (Green vs. Biddle, 8 Wheat. 85; Va. v. W. Va., 11 Wall, 39; Va. v. Tenn., 148 U. S. 503; Wharton v. Wise, 153 U. S. 173; Holmes v. Hennison, 14 Pet. 571. Story on Const., 4th ed., Vol. 2, Chap. XXXV.)

When consent is given "then the States were in this respect restored to their original inherent sovereignty; such consent, being the sole limitation imposed by the Constitution, when given, left the States as they were before, as held by this court in Poole v. Fleeger, 11 Pet., 209; whereby their compacts became

of binding force, and finally settled the boundary between them; operating with the same effect as a treaty between sovereign powers. That is, that the boundaries so established and fixed by compact between nations, become conclusive upon all the subjects and citizens thereof, and bind their rights, and are to be treated to all intents and purposes, as the true, real boundaries. * * * The construction of such a compact is a judicial question." (R. I. v. Mass., 12 Pet. 657, 725, 731). "The compact is a law to the sovereigns who enter into it, and is equally a law to the citizens. It regulates the rights and remedies of all who are affected by it." (Fleeger v. Poole, 1 McLean, 191. See also Bennett v. Boggs, Baldw. 60; Spooner v. McConnell, 1 McLean 337; Green v. Biddle, 8 Wheat 1; Va. v. Tenn., 148 U. S. 503, 517-528; Wharton v. Wise, 153 U. S., 155.) See above cases for general discussion of the right of States to enter into compacts.

Among compacts approved by U. S. Sup. Ct., in boundary cases, see Va. and Penn., 1780 (11 Pet. 20); Va. and Penn., 1784 (3 Dall. 425); Ky. v. Tenn., 1820 (11 Pet. 207); Va. and Tenn., 1802 and 1856 (148 U. S. 503, 511, 516); Va. and Md., 1785 (153 U. S. 155, 162). Respecting boundary rivers, see Wash. and Ore., Columbia River; Md. and Va., Potomac River (153 U. S. 155). See also recent harbor control compact, N. Y., and N. J.

New states are admitted into the Union upon an equality and with all the powers of sovereignty and jurisdiction which pertain to the original states and such powers may not be constitutionally diminished, impaired or shorn away by any conditions, compacts or stipulations embraced in the act under which a new state was admitted. Coyle v. Smith, 221 U. S. 559; U. S. v. Sandoval, 231 U. S. 28; Tex. v. White, 7 Wall, 700; Pollard v. Hagan, 3 How. 223; Scott v. Sandford, 19 How. 612; Ill. C. R. Co., v. Ill., 146 U. S., 434; Ward v. Race Horse, 163 U. S. 514; Ks. v. Colo., 206 U. S. 46.

Consent of Congress restores states to full sovereignty of independent nations. Principles of international law are applicable to interstate streams. (Kas. v. Colo., 185 U. S., 125; 206 U. S. 46) and of interstate compacts "the rule of decision is not to be collected from the decisions of either state, but is one * * * of an international character." (Marlett v. Silk., 11 Pet. 1, 23).

INTERNATIONAL RIVERS

For international law respecting claims of lower nation to waters having their origin in upper nation, see 21 Ops. U. S. Atty. Genl. 274, 282; also Op. U. S. Atty. Gen. Aug. 20, 1919, in re Colo. River.

Controversies respecting international rivers are settled (1) by treaty or (2) by war. See Convention for Equitable Distribution Waters Rio Grande, Malloy, Treaties, Vol. 1, p. 1202 and above cited cases. Interstate controversies are settled (1) by

interstate compacts or agreements or (2) by decision of the U. S. Sup. Ct. (a substitute for war), Kas. v. Colo., 185 U. S., 125; 206 U. S. 46; R. I. v. Mass., 12 Pet. 657.

Compacts may be made in full accord with physical and other conditions without regard to strict legal rules. If conflict is allowed to become acute and litigation follows an equitable apportionment of waters of interstate rivers will be made by the Supreme Court, having due consideration to natural conditions, local laws, etc. See Kas. v. Colo. 206 U. S., 46 and Wyo. v. Colo., 259 U. S. 410.

COMPACTS BETWEEN STATES AND UNITED STATES

Compacts between two or more states are usually formulated by joint commissions. Commissioners are appointed with previous legislative authority or by the executives subject to subsequent legislative approval of compact. Right to negotiate compacts is founded upon sovereignties of states or of States and the United States "each sovereign with respect to the objects committed to it, and neither sovereign with respect to the objects committed to the other." (McCulloch v. Maryland, 4 Wheat, 316, 400, 410. See also U. S. v. Texas, 143 U. S. 621, 646; 162 U. S. 13; U. S. v. La. 127 U. S., 182, 189. Sturges v. Crowninshield, 4 Wheat, 122, 192; Gibbons v. Ogden, 9 Wheat, 1,187; Chrisholm v. Ga., 2 Dall., 419, 425. Tex. v. White, 7 Wall., 700, 725; Collector v. Day, 11 Wall, 113, 124; So. Car. v. U. S., 199 U. S. 437, 448, 454. Kans. v. Colo., 206 U. S., 46, 87, 97, 117.)

14.0 ECONOMIC LIFE OF THE DENVER BASIN AQUIFERS

This Chapter is a study of the economic life of the Denver Basin aquifers. This project was funded by the Colorado Legislature through the Colorado Water Conservation Board and in cooperation with the Office of the Colorado State Engineer. HRS Water Consultants, Inc. (HRS) was awarded the contract to perform the work.

14.1 BACKGROUND AND INTRODUCTION

Discussions concerning the economic life of the Denver Basin aquifers have occurred for more than 20 years. Denver Basin aquifer hydrogeologists realized that production from the Denver Basin aquifer wells will decline over time due to a reduction of the aquifers' saturated thickness caused by pumping. What is not known is how water well production rates will decline and how the cost of Denver Basin aquifer groundwater production will increase over time. The work in S.B. 96-153 is meant to address these two very important questions.

Determining the economic life of the Denver Basin aquifers is a complicated problem. Analysis of the problem involves, groundwater hydrology, hydrogeology, geology, water well hydraulics, analytical and numerical groundwater flow modeling, borehole geophysics, current and future Denver Basin aquifer groundwater demands, population projections, economic analysis, Colorado Water law, and knowledge of water well installation and equipping. The analysis of production and drawdown in a Denver Basin aquifer well is complicated by the fact that aquifers are composed of inter bedded layers of sandstone, siltstone and shale. Denver Basin aquifer water wells are constructed such that wells screens are placed adjacent to the saturated sandstone/siltstone layers.

Phase 1 of the study concluded that the problem should be analyzed as an aquifer drawdown problem where the relationships among aquifer drawdown, the pumping water level in a well, and production from a Denver Basin aquifer well is understood. The problem can be stated as follows: How does well production from the Denver Basin aquifers change in response to reduced saturated thickness and lower pumping water levels? Well production is important because it is the measure of an aquifer's production. Additionally, the costs of well installation, operation and maintenance over time to maintain aquifer production will be the basis of the economic analysis.

This Phase 2 study is intended to provide insight into the costs of ground-water production from the Dawson, Denver, and Arapahoe aquifers which supply water in the Denver Basin of Colorado. This initial effort is meant to develop the methods to analyze Denver Basin aquifer wells and to calculate the cost of ground-water production at some well locations. The results of the well analyses cannot be applied basin wide. The study results show significantly different results for wells located in different areas of the Denver and Arapahoe aquifers. However, the results have some

applicability to other wells located within the same aquifer area. Additional work should be performed on more wells in each aquifer to determine the production costs in additional aquifer areas.

Development of the ground water stored in the Denver Basin aquifers has resulted in regional declines in water level and increased pumping costs within some areas of the aquifers. In some aquifer areas water levels have risen. At some time, costs to produce the ground water may exceed the costs of other possible water supplies, making the other supplies more attractive. Our goal is to estimate the relationship between ground water production and cost over the next 50 years at several well sites in the Denver Basin.

Previous work has provided estimates of regional water levels in the Denver Basin under several possible development scenarios. These modeling studies provide a description of the probable future water levels in the aquifers but do not address the problem of water levels in the pumping wells. Methods to estimate pumping water levels based on simulated regional water levels exist for certain aquifer conditions, but do not properly account for changing aquifer thickness as the aquifers are drained. HRS has developed a method of simulating pumping water levels in the type of wells found in the Denver Basin and applied this methodology to this problem.

14.2 CONCLUSIONS

For long term simulations, the Trescott approximation gives a very good estimate of expected pumping water level in a well under confined conditions.

For situations where the aquifer converts from confined to unconfined conditions, the Trescott approximation gives usable results when more than half of the original saturated thickness remains at the pumping well. Though an approximation exists for unconfined conditions, it is not clear how this would be applied in a situation where the aquifer changes from confined to unconfined conditions in the course of the simulation.

At Denver and Arapahoe aquifer sites toward the edges of the basin, we would expect to need additional wells to meet demand within the next 30 to 40 years. Well sites in the central portion of the basin may be able to operate at high pumping rates for many years without requiring additional wells to meet projected pumping rates.

As saturated thickness decreases, the pumping water level in the well becomes very sensitive to regional water levels and pumping rate. In the simulations at site 3 (Woodmen 7), a single well was required in 2015, but two wells were required in 2025. An increase in steady pumping rate of 11 gpm (5%) together with a drop in regional water level of 29 feet (23 feet of artesian head and 6 feet or a mere 1% reduction saturated thickness) caused water level in the well to drop to the bottom of the screen indicating that another well would be required to meet demand. This extreme

sensitivity to pumping rate with decreasing saturated thickness has been observed in the Denver Basin aquifers and is supported by anecdotal evidence.

Pumping water levels are based in part on regional water levels. The comparison of observed and simulated water levels at the Castle Pines A3 well (Site 1, Figure 7.7) indicates that if the regional water level is incorrect, the pumping water level will be incorrect. However, if we know or can project the regional water level, the radial flow modeling methodology should allow us to calculate the pumping water level for a given discharge rate. If, as at this site, we can develop a time lag relationship between observed and calculated water levels, this may be useful for planning, even when the original simulations do not provide a correct hydrograph. We should recall, however, that the simulations of regional water levels are based on a particular pumping scenario, and if actual pumping differs significantly from this, future projections will also be inaccurate.

The ability of the Multi-Completion Well module to closely match observed water levels in pumping wells, monitoring wells, and individual layers during simulation of aquifer tests indicates that the module is working correctly.

The future cost of ground-water production in the Denver and Arapahoe aquifers is closely related to the number of additional wells required to meet a demand schedule.

14.3 RECOMMENDATIONS

Since pumping water levels are a strong function of regional water levels, one of the best ways to derive better pumping water levels is to develop a better future estimate of regional water levels in the aquifers. Additional modeling studies incorporating more accurate estimates for historic and present withdrawals and better projections for future water demand should give a better estimate of future conditions in the aquifer.

The Trescott approximation for pumping water level in a well appears to be remarkably accurate for long term pumping under confined conditions and also works quite well as the aquifers start to convert to unconfined conditions over large areas. As saturated thickness drops, the accuracy of this approximation decreases. It is not clear how an approximation for calculation of pumping water level in a well would work for an aquifer which changes from confined to unconfined conditions during pumping. By using the MCW program module, it is possible that a relationship could be developed for the Denver Basin aquifers allowing much easier estimation of pumping water levels as saturated thickness decreases in the aquifers.

Results of the Trescott approximation were compared to results from the radial flow model for conditions where the aquifer started under confined conditions and converted to unconfined conditions near the well during pumping. This comparison indicated that the approximation is quite good for confined conditions. A similar approximation specific to conditions where the aquifer is initially unconfined has been applied to wells

at sites 4 and 7. It would be interesting to compare these results to a radial flow model to see if the approximation is also good for the initially unconfined conditions.

Results of the Trescott approximation for the Denver aquifer in the North Metro area indicate quite low production rates from individual wells due to the low transmissivity in the cell. A review of well records, aquifer test data, and production history from existing wells may allow a determination of whether these results are reasonable.

One of this study's results is that the Trescott confined and unconfined approximations for pumping water level in a well appear to work well. As discussed above additional work should be performed on the unconfined approximation to confirm this result. The next analysis should address the cost of production from the Denver Basin aquifers over the entire area of the aquifers. This could be done by using the Trescott unconfined and confined approximations and by developing a new approximation for a well during the transition from confined to unconfined conditions using the multi-completion well module. The three approximations could then each be applied to their appropriate aquifer areas. More than one unconfined-confined approximation per aquifer may be necessary. These approximations would be applied to regional water levels developed from a regional ground water model. The State Engineer's new model of the Denver Basin aquifers may be appropriate for this purpose. The results of this analysis would then be used to determine the cost of ground water production for each aquifer over the entire basin.