SUMMARY OF FACTORS SUPPORTING

THE TWO PERCENT RELINQUISHMENT REQUIREMENT

COLORADO DIVISION OF WATER RESOURCES

OCTOBER 24, 1985

TECHNICAL APPENDIX E

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THE TWO PERCENT RELINQUISHMENT REQUIREMENT

Current Aquifer Conditions:

Significant portions of the Lower Dawson, Denver, Upper Arapahoe, Lower Arapahoe and Laramie-Fox Hills Aquifers are now under artesian pressure and will respond to pumping as a confined aquifer. These aquifers are in direct hydraulic connection with surface streams and the adjacent saturated alluvium. The withdrawal of ground water from those aquifers will deplete the flows in the surface streams as a result of the change in the ground water gradients where the stream alluvium is in contact with the bedrock aquifer. This change in gradient may either reduce the current ground water flow from the bedrock aquifer into the alluvium or it may reverse or steepen the gradient causing flow from the alluvium to enter the bedrock aquifers.

Studies Showing Impact of Pumping Confined Aquifer Wells on Streams:

A very comprehensive ground water modeling effort using historic and projected pumping rates in the Denver Basin aquifers was conducted by Mr. Stanley G. Robson of the U.S. Geological Survey and is described in the report entitled: "Bedrock Aquifers in the Denver Basin, Colorado, A Quantitative Water-Resource Appraisal," U.S. Geological Survey Open File Report 84-431. The report contains a series of maps showing the 1978 water table or piezometric head configuration for the Dawson, Denver, Arapahoe and Laramie-Fox Hills Aquifers. Mr. Robson first determined 1978 water table or piezometric head levels in the Denver Basin aquifers. Then the water table or piezometric head levels were computed for the year 2050 assuming the pumping of certain amounts of ground water. By comparing the difference in head levels between 1978 and 2050, the change in the gradient or direction of flow of ground water and resulting depletions to the surface stream system are predicted. The net recharge, or stream depletion is included in Table 7 of the report which summarizes the results of the model run.

Mr. Robson also provided the State Engineer the model results obtained when a satellite well field in Township 6 South, Range 65 West, 6th P.M. was pumped. Comparison of that data with the above referenced Table 7 allows quantification of the impact of the satellite well field on the net recharge to surface streams. The model runs indicate that as a result of the satellite well field pumping, the net recharge will increase. When expressed as a percentage of the water pumped for each aquifer, the net recharge can be summarized as follows:

Aquifer	Satellite Well Pumpage cfs (Q)	Net Recharge Impact cfs (q)	q/Q Percent
Dawson	10.70	0.36	3.4
Denver	10.23	0.18	1.8
Arapahoe	12.52	0.06	0.6
Laramie-Fox Hills	7.16	0.26	3.6

The increase in net recharge is either reduced natural discharge to streams or induced recharge from streams which will reduce natural stream flows in the modeled area. A more thorough analysis of the aquifer conditions shows that the impact of the satellite well field pumpage and projected full base development is due to confined aquifer pumping by wells that are at a significant distance from the outcrop of the Laramie-Fox Hills and Arapahoe aquifers. The low impact of pumping of the Arapahoe on the q/Q ratio above is due to the significant pumping from the Arapahoe aquifer in the near proximity of the satellite well field. If the satellite well field had been placed at a greater distance from existing development the impact would have been much greater.

In 1983, the staff of the State Engineer developed a two dimension finite difference model to evaluate pumping from the Lower Dawson formation. Three separate model runs were made. In each run, the aquifer was originally assumed to be confined and the distance from the streams where pumping was allowed was varied. The attached Illustrations 1, 2 and 3 summarize the model results. In the first model run, where pumping was allowed adjacent to the streams as depicted in Illustration No. 1, full aquifer development resulted in a depletion to the stream of 29 percent of the water pumped. In the second model run, where no puming was allowed within two miles of a stream as shown by Illustration No. 2, full aquifer development resulted in a 25 percent depletion to the stream. Finally, in the third model run, pumping was restricted to a zone at least three miles from a stream as depicted by Illustration No. 3. The stream depletion resulting from full aquifer development was 23 percent of the water pumped. These model results indicate the effect of pumping from deep within the aquifer will impact the stream in excess of two percent.

The State Engineer's staff has also used the Theis equation to calculate the shape and spread of the cone of depression due to pumping from a confined aquifer well from the four formations. For confined aquifer conditions the cone will expand beyond 25 miles and for a Laramie-Fox Hills well it would be in excess of 45 miles.

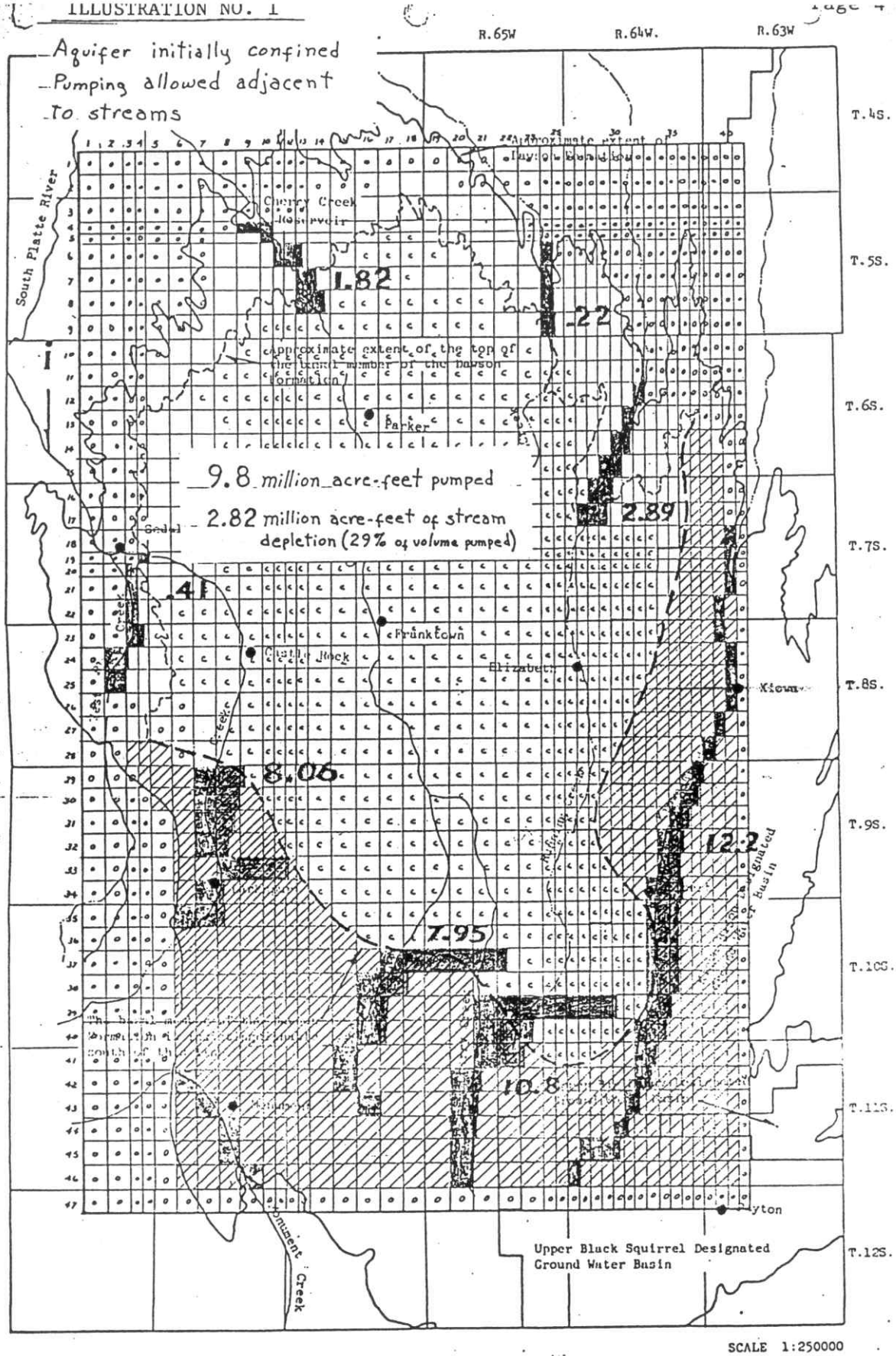
The data from Robson's modeling, the Lower Dawson model of the State Engineer and the Theis equation calculations indicate the change in the piezometeic head resulting from withdrawal of nontributary ground water from each of the four aquifers will reach out in excess of 25 miles and that the impact on surface flow would exceed two percent.

Thus, the requirement that two percent of the nontributary water pumped be relinquished is needed to offset the impact on natural streams resulting from the pumping of nontributary wells. Absent this relinquishment requirement, injury will result to vested tributary water rights.

Demonstration of Relinquishment:

The State Engineer will require an applicant for the use of nontributrary ground water to demonstrate how he will not consumptively use more than 98 percent of the water pumped and how the relinquished amount will enter the uppermost aquifer or be delivered directly to a nearby stream. Should a permittee's uses change in the future, the State Engineer will need to have data available to him to demonstrate that two percent of the water is still being relinquished. The rules, as drafted, will allow the State Engineer to require a permittee to demonstrate he is not consumptively using more than 98 percent and the non-consumed amount is entering the uppermost aquifer or a nearby stream.

ILLUSTRATION NO. 1



GRID MAP
SHOWING BOUNDARY CONDITIONS

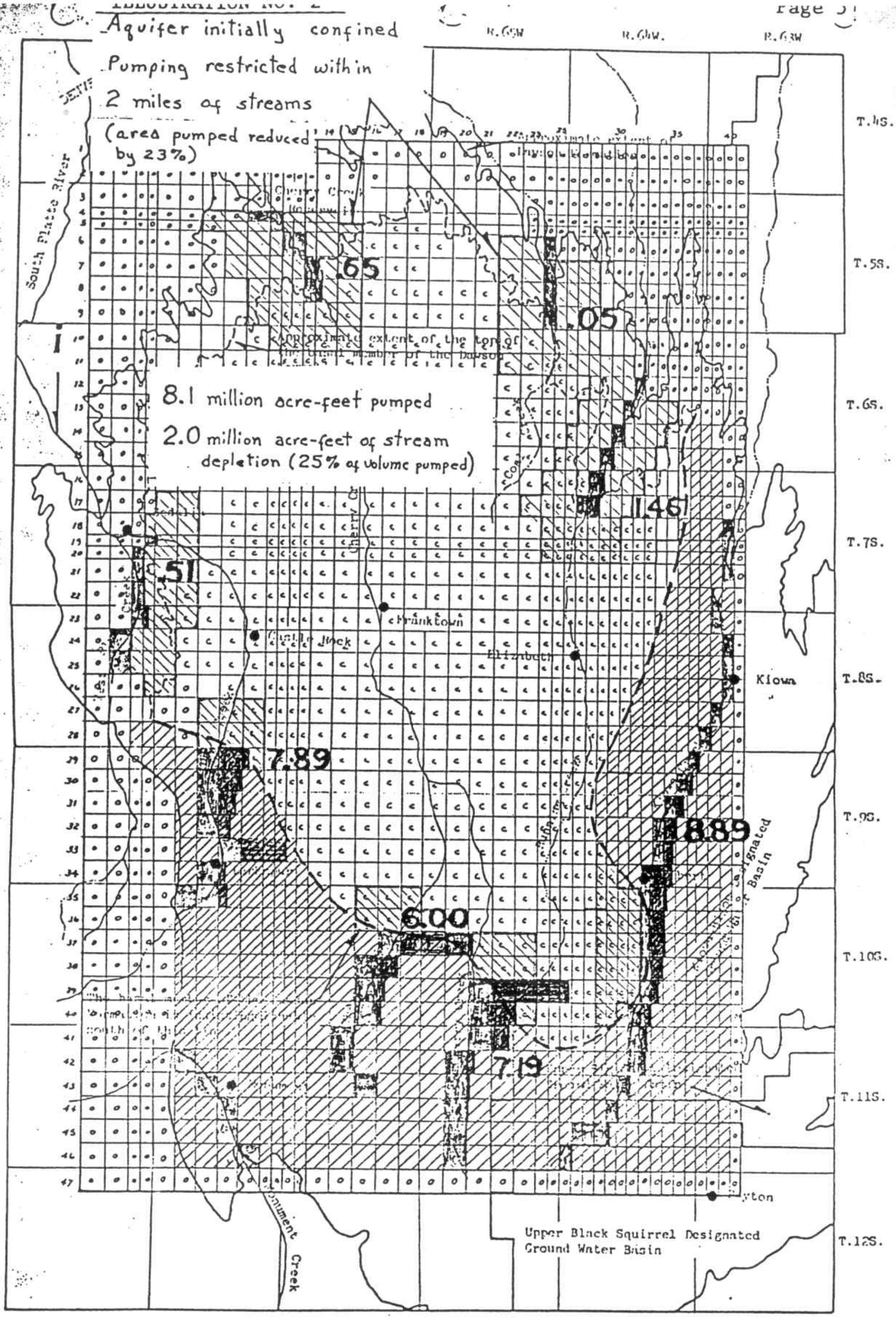
Depletion to streams (Run 7)

Bars indicate depletion to each node
1" = 5 cfs

Large Numerals indicate max. depletion to stream in cfs

EXPLANATION:

- Constant Head
- o — No Flow (K=0)
- a — Initially confined
- Unconfined
- Entire Thickness of Dawson Aquifer Modeled

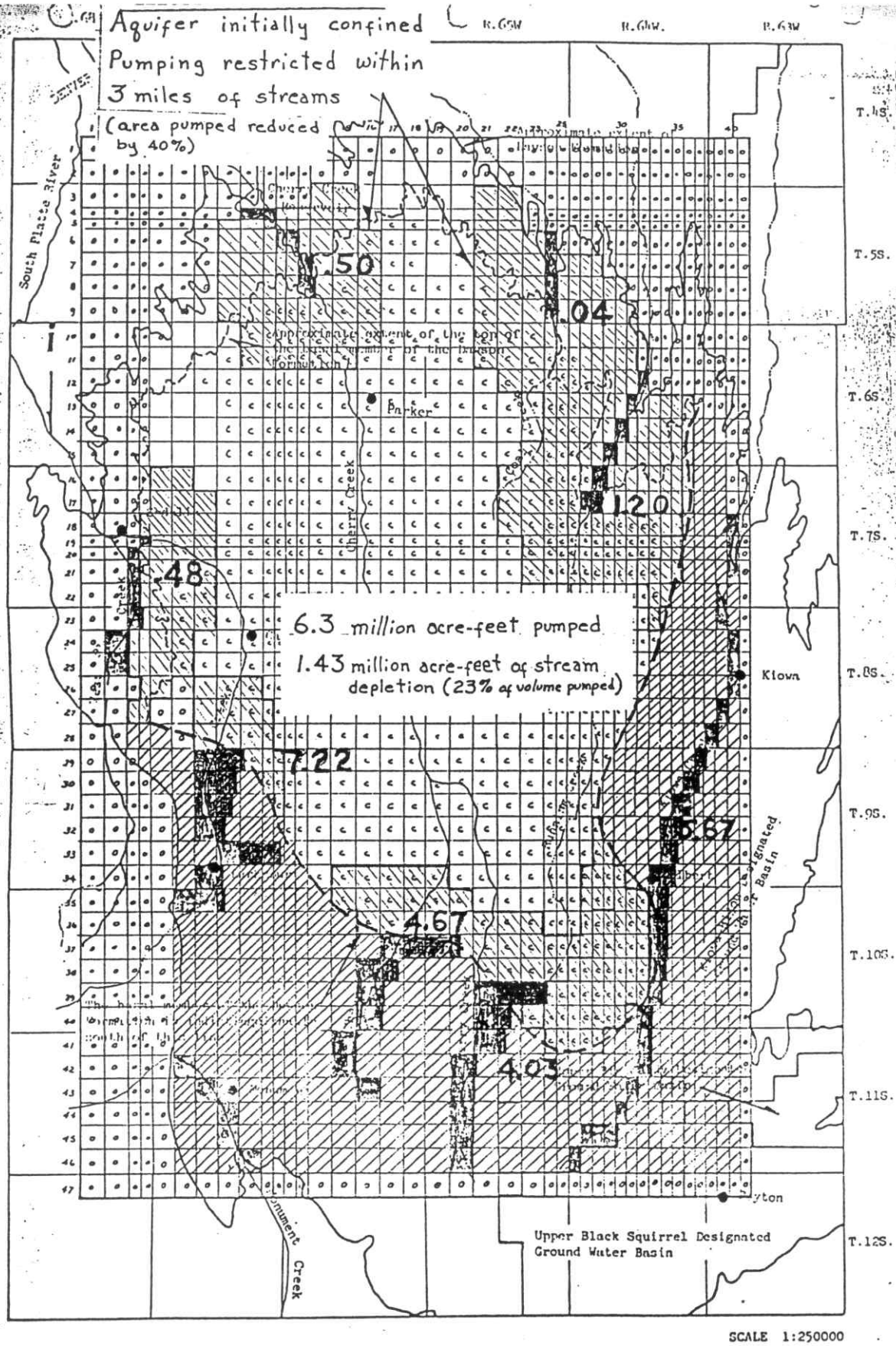


SCALE 1:250000

GRID MAP
SHOWING BOUNDARY CONDITIONS
DEPLETION TO STREAMS (RUN 15)
Bars indicate depletion to each node
1" = 5 cfs
Large Numerals indicate max depletion
To stream in cfs.

EXPLANATION:

- 10 Constant Head
- o No Flow (K=0)
- c Initially confined
- Unconfined
- Entire Thickness of Dawson Aquifer Modeled



GRID MAP
SHOWING BOUNDARY CONDITIONS
DEPLETION TO STREAMS (RUN 16)

Bars indicate depletion to each node
1" = 5 cfs
Large Numerals indicate max depletion to stream in cfs.