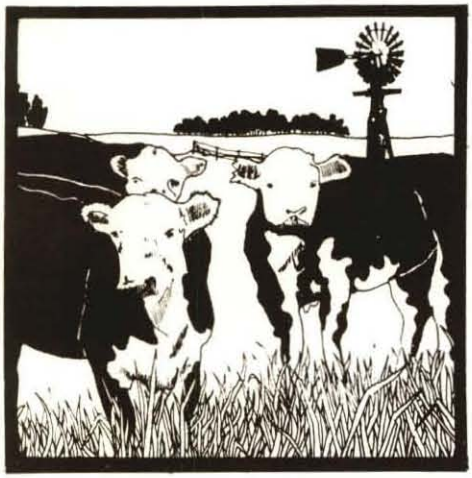

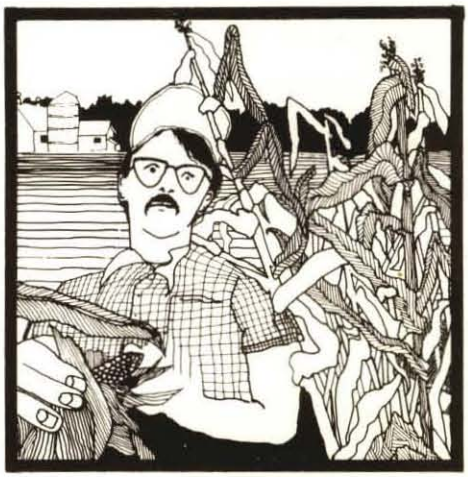

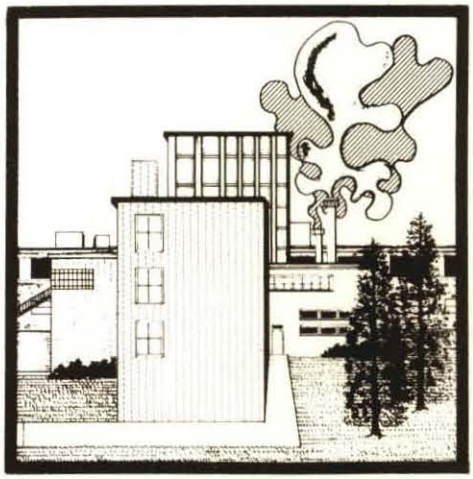

POLICY ISSUE STUDY
ON

GROUNDWATER RESERVOIR MANAGEMENT

State Water Planning and Review Process
Nebraska Natural Resources Commission

MARCH 1982

POLICY ISSUE STUDY
ON
GROUNDWATER RESERVOIR MANAGEMENT

STATE WATER PLANNING AND REVIEW PROCESS

GROUNDWATER RESERVOIR MANAGEMENT REPORT

REPORT
OF THE
NATURAL RESOURCES COMMISSION
TO
GOVERNOR CHARLES THONE
AND
THE MEMBERS OF THE NEBRASKA LEGISLATURE

MARCH 1982

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PROGRAMS:

SOIL & WATER CONSERVATION
WATERSHED PROTECTION
COMPREHENSIVE PLANNING
FLOOD PLAIN MANAGEMENT
DATA BANK
WATER CONSERVATION FUND
DEVELOPMENT FUND

STATE OF NEBRASKA

NATURAL RESOURCES COMMISSION

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January 15, 1982

The Honorable Charles Thone
Governor, State of Nebraska
State Capitol
Lincoln, Nebraska 68509

Members of the Nebraska Legislature
Eighty-Seventh Nebraska Legislature
First Session
State Capitol
Lincoln, Nebraska 68509

Governor Thone and Members of the Legislature:

This report entitled "Policy Issue Study on Groundwater Reservoir Management" has been reviewed and approved by the Natural Resources Commission. It is the final report of one of eleven Commission studies of water policy issues.

Numerous courses of action relating to groundwater reservoir management are analyzed in this report. The Commission's recommended course of action is also provided and can be found on the blue pages immediately preceding the summary. A separate appendix providing further information on groundwater management techniques is available upon request.

It is the hope of the Natural Resources Commission that this report will be helpful in making policy decisions and, if necessary, statutory changes. The Natural Resources Commission is prepared to answer any further questions you may have.

Sincerely,

Alvin Narjes

Alvin Narjes, Chairman
Natural Resources Commission

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Foreword

This is one of eleven water policy studies that are part of the State Water Planning and Review Process. It addresses alternative policies for the management of Nebraska's groundwater and is being forwarded to the Legislature and Governor for action as deemed appropriate. A separate Appendix, which provides further detail on management techniques contained in this report, is available.

This report is essentially the final task force report prepared by the Conservation and Survey Division of the University of Nebraska with the aid of an interagency task force. The Natural Resources Commission has added a transmittal letter, a summary, this foreword, small sections on the Public Hearing and the relationship to other studies, and made some changes in the wording of the Introduction. Two of the three Appendices to the Task Force Report were incorporated into this report. The major change is the addition of the policy recommendations contained in the following section of this report.

The interagency task force which helped the Conservation and Survey Division develop the data and alternatives used in the final task force report included the following individuals:

Jon Atkinson..... Department of Environmental Control
Tom Lamberson..... Department of Water Resources
Bob Burns..... Water Resources Center-UNL
Karen Langland..... Policy Research Office
Gerald Chaffin ..... Game and Parks Commission
Jerry Wallin..... Natural Resources Commission
John Alloway ..... Department of Agriculture

Dr. Marvin Carlson of the Conservation and Survey Division served as Task Force leader. Dennis Lawton of the Conservation and Survey Division also served as a task force member. The Conservation and Survey Division was responsible for leading the work of the task force and writing the final task force report.

Special credit should also be given to the Water Resources Center which was responsible for compiling most of the information now contained in Chapters 4, 5 and the separate appendix to this report. Chapter 4 serves as a summary of that appendix.

Non-task force members who contributed greatly to the report include Bob Kuzelka, Conservation and Survey Division; Dave Aiken, Department of Agricultural Economics, UN-L; Charles Deknatel, Department of Community and Regional Planning, UN-L; Ray Suppala, Department of Agricultural Economics, UN-L; and Tom Cech, Water Resources Center, UN-L.

Following initial consideration of the task force report the Commission released it for public review on November 18, 1981. The public comment period concluded January 15, 1982. A public hearing was held January 5, 1982 in Kearney. A summary of that hearing is available as a special section at the back of this report.

The Public Advisory Board devoted considerable time to discussion of the task force report and provided the Commission with a number of recommendations. Comments were also offered by the Interagency Water Coordinating Committee. In addition, a few written comments were received from members of the public representing either themselves or particular organizations. All such comments are on file at the office of the Commission and are available for review.

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(NOTE): A separate Appendix to this report is available upon request. "Potential Groundwater Reservoir Management Techniques and Associated Impacts: An Analysis" presents additional detail on material contained in Chapter 4.

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Photographs in this report
were provided by the Nebraska Natural Resources Commission

Comments and Recommendations of the Natural Resources Commission

The Commission believes the Groundwater Management and Protection Act has provided a very valuable tool for the management of ground water. However, we believe the time has come to move beyond the policy expressed in that act. We generally favor, in a modified form, six of the alternatives in the Groundwater Reservoir Management Report. They present opportunities for strengthening the ability of NRDs to manage groundwater use and development and are deserving of your support.

The main thrust of our recommendation is based on a combination and modification of three alternatives. Enactment of legislation based on these alternatives would result in a significant change in the Groundwater Management and Protection Act and the state's policy on groundwater management. Under the Groundwater Management and Protection Act, NRDs are given the authority, but are not required, to request the designation of a groundwater control area is groundwater problems occur or are foreseen. The Commission recommends this policy be modified to require the designation of control areas if groundwater "problem areas" develop.

To implement this policy the Commission recommends all natural resources districts be required to submit groundwater management plans to the Department of Water Resources by a certain date and update them periodically. The details of what would be required in such plans would need to be worked out in the process of drafting legislation. At a minimum they should include a statement of groundwater management goals and objectives, an identification of the principal aquifer(s) underlying the NRD, and a locally approved definition of what constitutes a groundwater problem area. Any other information required should be left fairly flexible but could include data on groundwater supplies and use, capability of the aquifers, recharge, and current or planned water conservation or augmentation (recharge) plans. Plans could be based on the best information currently available. Development of a groundwater model would not necessarily be required. Provision will have to be made for financing the preparation of these plans.

The identification of the principal aquifer(s) in a district and the adoption of a definition of what constitutes a problem area for each aquifer or portion thereof is essential to the implementation of our recommendation. The problem area definition would consist of a maximum average rate at which the groundwater in a principal aquifer can be depleted without the imposition of groundwater allocation and development restrictions. In other words, up to a certain point uncontrolled use and development could be permitted, although the NRD would be free to request a control area designation before the depletion rate reached the established maximum rate. However, once the established depletion rate for a principal aquifer was reached, the NRD would be required by law to request a control area designation by the Department of Water Resources for the land overlying that aquifer.

Because of the legitimate state interest in controlling the rate at which the state's groundwater supplies are exhausted, the Commission believes the legislature should establish the maximum allowable depletion rate that can be adopted by a NRD. We recommend that the maximum allowable depletion rate be no greater than 5 percent of the saturated thickness over a 5 year period. Any NRD would be free to establish a more restrictive rate than that established by the Legislature if they desired.

The role of the director of the Department of Water Resources in the control area designation process should be limited to a technical review of the plans, determining whether the maximum established depletion rate had been reached, and whether it appeared the controls proposed by a NRD would achieve the NRD's groundwater management goals. The director should not be given the authority to override the NRD board's

decisions on matters of policy - for example - the question of what depletion rate is appropriate, unless of course the board violates the guideline established by the Legislature.

To insure that the groundwater management plan is prepared, the Commission recommends that certain sanctions be imposed against NRDs that fail to carry out this responsibility. The Legislature should prohibit the transfer of state funds from the Resources Development Fund or the apportionment of funds from the Water Conservation Fund to a NRD which has not submitted its groundwater management plan as required. Other sanctions may be appropriate.

The solution proposed in the alternatives in the Groundwater Reservoir Management Report for the failure of a NRD to control groundwater use and development when problem areas develop is to authorize the Department of Water Resources to impose such restrictions. The Commission does not favor this approach. It would simply allow a NRD board that was reluctant to act to "pass the buck" to DWR. NRDs should not be allowed to evade their groundwater management responsibilities in this manner. Instead the Commission feels a NRD that fails to request a control area designation, once the established maximum depletion rate is reached, should be subject to suit either by an individual or by the Attorney General to compel the board to initiate the control area designation process.

The alternatives in the report that, in a modified form, would provide for the program outlined above and which therefore have our qualified support are: *Alternative 2g*: "Require comprehensive groundwater management program for control area designation"; *Alternative 8a*: "Require NRDs to restrict groundwater withdrawal in problem areas, and require DWR to restrict groundwater withdrawal in problem areas in the absence of NRD groundwater controls"; and *Alternative 9a*: "Require NRDs to restrict groundwater development in problem areas, and require DWR to restrict groundwater development in problem areas in the absence of NRD groundwater controls."

Three other alternatives also have merit and are deserving of legislative action.

The Commission believes strong research and educational programs in the area of improved irrigation practices are essential if we are to properly manage our groundwater resources. However, there is some concern that there may be duplication of the research or educational programs being conducted in other states or by different entities within the state. The Commission favors an initial effort to encourage the coordination of, and perhaps re-examine the emphasis of, the many research and educational programs being conducted at the present time. This should be followed by legislative action on *Alternative 5*: "Increase funding for research and educational programs." This increased funding would be devoted to those programs which have been shown to have merit.

Alternative 10: "Establish fee for withdrawing groundwater", also has our support if implemented in a substantially modified form. The Groundwater Management and Protection Act currently authorizes a NRD with a control area to establish groundwater allocations for water users in the area. However, the act does not explicitly authorize the imposition of a penalty on a water user who exceeds his or her allocation. The Commission recommends that the Legislature explicitly grant NRDs this authority. The assessment of a monetary penalty or fee on water users who exceed their allocation should be one option. In addition, NRDs should be authorized to reduce a water user's allocation for a subsequent allocation period by the excess amount used, or some multiple of that amount.

Without a doubt, the development of supplemental water supplies is an essential component of groundwater reservoir management. However, the Nebraska Constitution presently limits the ability of the state to finance needed projects. Therefore, the Commission supports the concept of *Alternative 11*: "Authorize increased state appropriations and issuance of bonds for development of supplemental water supplies." However, perhaps a more detailed analysis of what legislation is needed in this area should await completion of the Supplemental Water Supplies Study.

The members of the Commission have mixed emotions towards *Alternative 9b*: "Authorize purchase of control area pumping rights by NRDs" and we do not have a recommendation either for or against this alternative. Its implementation would provide NRDs with an additional tool to deal with groundwater declines and therefore has some merit. However, the expense could be prohibitive.

The Commission does not favor the remaining alternatives. With the exception of *Alternative 2g*, all the sub-alternatives under *Alternative 2* would severely restrict or eliminate a NRD's authority to manage groundwater development and use. The Commission feels to adopt any of these alternatives would be to take a step backwards and strongly opposes limiting the authority of NRDs to deal effectively with groundwater problems.

The Commission realizes many feel the imposition of a moratorium on new groundwater development would be inequitable but feels it is a necessary management option. Any moratorium could only be imposed for a period of one year at a time. Successive year long moratoriums would require action by both the locally elected NRD board and the Department of Water Resources. We do not feel this authority will be abused.

Adoption of either *Alternative 3*: "Irrigation development subsidy"; or *Alternative 4*: "Groundwater depletion payment", would also be a step backwards and the Commission opposes these two alternatives. A subsidy for irrigation development is not necessary or desirable. Providing the accurate localized data on groundwater declines necessary to implement *Alternative 4* would be difficult and expensive.

Alternative 6: "Financial incentives for irrigation efficiency"; and *Alternative 7*: "Require improved irrigation practices", should be considered together since they are different approaches to the same problem. That problem is how to get water users to adopt best management practices. The state currently offers an incentive for the adoption of some water conservation practices, including re-use pits, by cost-sharing on such practices through the Water Conservation Fund. Most other best management practices can be implemented by water users in the absence of incentives because it is in the user's economic interest to do so. Therefore, the Commission does not favor initiation of a new incentive program or requiring the adoption of specific practices. Establishing allocations and allowing water users to decide what practice or combination of practices to adopt so the allocation is not exceeded is preferable to requiring the adoption of specific practices.

Alternatives 8b and 8c deal with the controversial issue of whether groundwater allocations should be based on irrigated acres or irrigable acres. The Commission believes this issue should be resolved at the local level rather than by the Legislature and therefore opposes both alternatives. Each NRD should be able to decide for itself whether to base allocations on irrigated or irrigable acres.

Alternative 8c also deals with the issue of the sale of pumping rights. The Commission feels this issue should be put aside until completion of the Supplemental Water Supplies Study and perhaps the Marketability of Water Rights Study. One question that can be addressed at the time is whether the state wishes to authorize transfers of groundwater from one area in the state to another more suitable for irrigation.

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Summary

The Policy Issue Study on Groundwater Reservoir Management was conducted as part of the State Water Planning and Review Process. It is one of eleven studies that analyze Nebraska's water policy issues. The product of this study is a report which provides information to assist decision-makers in determining the appropriate rate of utilization of Nebraska's existing groundwater supplies. The report also presents a series of potential legislative alternatives which can be used as a basis for groundwater management.

Chapters of the report specifically address: constraints on groundwater development, potential of the principal aquifer, substate area analysis, potential techniques for groundwater management, and potential administrative-legislative actions. A separate appendix, providing further detail on management techniques is also available.

CONSTRAINTS ON GROUNDWATER DEVELOPMENT

There is a tremendous variability in the potential of Nebraska's sedimentary rocks to serve as aquifers. The thickness of the state's principal aquifer exceeds 1,000 feet in west-central Nebraska but is very thin or absent in many areas near the margin of the state. Within some of these areas, however, local or isolated aquifers are present which can provide for limited development. In eastern Nebraska considerable thickness of the principal aquifer is fine-grained material that yields water very slowly.

Groundwater in storage is a part of a dynamic recharge/discharge system. The groundwater is discharged from Nebraska's principal aquifer both by pumping and natural processes. The relative amounts of groundwater used for major purposes indicate that the overall rate of use would be most influenced by management of irrigation. Over 85 percent of groundwater use is for irrigation. Soil type and topography are important constraints on the use of groundwater for irrigation. Less than 2 percent of use is for rural domestic and livestock supplies. Approximately 12 percent of water use is for higher volume public and industrial supply.

From a regional perspective, groundwater in Nebraska moves slowly southeastward. The cone of withdrawal when caused by large withdrawals may influence the direction of movement. The rate of movement will range from several feet per day in continuous coarse gravel deposits to as little as a few inches per year in fine-grained material. The slow movement of groundwater common to most areas in Nebraska would not allow lateral groundwater flow to replace the amount withdrawn in a local area. Most recharge results from infiltration of part of the precipitation falling within the area.

Most groundwater in the principal aquifer is of good to excellent quality. However, portions of the principal aquifer have been affected by recharge from rivers that have been enriched in dissolved solids by evapotranspiration and irrigation return flows.

Although the concentration of dissolved solids serves to indicate the generally good quality of groundwater in the principal aquifer, this is only one aspect of the available data. Considerable variance from average quality could occur at any specific site. Certain constituents may be present in very low concentration that could create a health or environmental hazard.

Chapter 1 contains maps and information on the base of the principal aquifer, the configuration of the water table, thickness of the aquifer, the amount of groundwater in storage, transmissivity of the aquifer, and total dissolved solids. Environmental, technological, economic, social, and legal/institutional/administrative factors influence development of the groundwater resource.

POTENTIAL OF THE PRINCIPAL AQUIFER

Methods for efficient development of the groundwater resource will differ for various areas of the state because of variations in the amount of water available, the type of use desired and the local impacts that will be created. Another source of supply is annual recharge from precipitation. A map illustrating the average annual recharge to the aquifer from precipitation is included.

It is estimated that the state is underlain by 1.875 billion acre feet of recoverable groundwater of good quality. However, most of it is concentrated in the central one-third of the state. This fact, combined with the variation in the ability of underlying sediments to yield water and land suitability account for the differing potential for development of the principal aquifer across the state. Much of the eastern quarter of the state is composed of material that yields water very slowly and is suitable only for low volume rural-domestic supplies.

A concern related to intensive utilization of an aquifer is lowering of the water table in areas where depths to water are relatively shallow. Environmental impacts could occur in these areas if an active groundwater to surface water interface was disrupted by a lowering of the water table. In some areas natural vegetation has expended significant amounts of water by evapotranspiration. Substitution of irrigated cropland may not alter that balance. A depth to water map is provided in the report.

The principal aquifer in portions of Nebraska has quantities of groundwater in storage that would appear to exceed use demands over a significant period. Thus for significant areas of Nebraska even maximum utilization for irrigation would not cause aquifer exhaustion. Groundwater withdrawal will result in some combination of decrease in storage, increase in recharge, and decrease in natural discharge. The relative values of recharge and discharge will determine both the changes in volume of water in storage and any resulting water level change. In areas conducive to rapid recharge, salvaged evapotranspiration can sustain a high rate of use. Withdrawals in such areas could occur without obvious effect upon regional streamflow.

In the remaining areas of the state there is a high potential for a decrease in groundwater in storage. Development is well underway in large parts of these remaining areas and management will need to be based upon detailed evaluations of the local hydrogeologic system. An analysis of the potential resource/development stress by sub-areas within the state is contained in Chapter 3.

POTENTIAL TECHNIQUES FOR GROUNDWATER MANAGEMENT

A variety of management techniques could be utilized to achieve a particular developmental goal or goals within an area. Chapter 4 discusses those techniques and the impacts they may have. The separate appendix to this report provides further detail on those management techniques.

Three general development strategies are examined in the report. They are: (1) encourage a rate of development which exceeds the current rate of development, (2) maintain the current rate of development, and (3) stabilize or reduce the rate of development.

The discussion in Chapter 4 focuses on methods of maintaining or reducing water use. The impacts of six management actions and their implementation methods are examined. The first three management actions examined involve reducing irrigation need. They do this through improving irrigation efficiency, improving crop water use efficiency and improving water conservation practices. Other actions include reducing development based on water supply criteria, reducing development based on geographic/environmental criteria, and reducing withdrawals to prolong groundwater supplies and reduce environmental impacts. A continuation of present state policy is also examined.

POTENTIAL ADMINISTRATIVE-LEGISLATIVE ACTIONS

In order to actually implement management techniques they must be placed within the context of the current system of laws and regulations. Eleven administrative-legislative alternatives were identified which would provide the mechanisms for groundwater reservoir management. For each alternative environmental, social, economic, technologic, and legal/institutional/administrative impacts were assessed. The legislative alternatives, not listed in priority, are:

To Maintain Current Rate of Development

1. No new legislation

. . . . . .

To Encourage a Rate of Development Which Exceeds Current Rate

2. Revise Groundwater Management and Protection Act
3. Establish irrigation development subsidy
4. Establish groundwater depletion payment

To Stabilize or Reduce the Rate of Development

5. Increase funding for research and educational programs
6. Financial incentives for irrigation efficiency

. . . . . .

7. Require improved irrigation practices
8. Restrict groundwater withdrawal in problem areas
9. Restrict groundwater development in problem areas
10. Establish fee for groundwater withdrawal
11. Authorize state appropriations or bonds for development of supplemental water supplies

---

A short explanation of each Legislative Administrative Alternative follows:

ALTERNATIVE 1: Enact no new groundwater management legislation and do not modify existing groundwater legislation.

. . . . . .

ALTERNATIVE 2: Enact legislation modifying the Groundwater Management and Protection Act (GMPA).

Enactment of this alternative would repeal or limit certain authorities granted in the GMPA. The authorities which could be modified include: well spacing, well drilling moratorium, and withdrawal limitations. Another option would be to totally repeal the GMPA. One sub-option provided by this alternative would be to require a statement of groundwater management goals, objectives, and implementation methods as a part of an NRD's request for a control area hearing designation.

ALTERNATIVE 3: Enact legislation establishing state income tax credit for irrigation equipment and development costs.

If it determined that more economic incentives to develop additional irrigation or to purchase more efficient irrigation equipment were needed, the Legislature could establish a state income tax credit for irrigation equipment and development costs.

ALTERNATIVE 4: Enach legislation establishing a Groundwater Depletion Payment.

If it determined that landowners should receive some economic assistance if groundwater supplies are being depleted, the legislature could establish a groundwater depletion payment. The program could be administered by making direct payments to those who develop irrigation for some proportion of their investment costs. Alternatively, the developer could be given a special deduction or tax credit which may or may not be limited to the developer's state income tax liability.

. . . . . .

ALTERNATIVE 5: Enact legislation increasing state funding for research and educational activities to improve irrigation practices.

If it determined that educational and research activities to improve irrigation practices should be expanded, the Legislature could appropriate greater funds for those purposes.

ALTERNATIVE 6: Enact legislation providing financial incentives for improved irrigation practices.

If it determined that irrigators should adopt improved irrigation practices, the Legislature could establish financial incentives to adopt such practices. For example, state income tax credits or state cost sharing could be provided for irrigation reuse pit installation, etc.

ALTERNATIVE 7: Enact legislation requiring irrigators to adopt improved irrigation practices.

If it determined that irrigators should adopt improved irrigation practices, the Legislature could require irrigators to adopt such practices. For example, irrigators could be required to install irrigation water reuse pits, or to implement irrigation scheduling.

ALTERNATIVE 8: Enact legislation requiring groundwater withdrawals to be restricted in problem areas.

(a) **Enact legislation requiring NRDs to restrict groundwater withdrawals in problem areas, and requiring the DWR to restrict groundwater withdrawals in problem areas in the absence of NRD groundwater controls.**

The GMPA makes the establishment of groundwater controls an NRD option. If it determined that groundwater withdrawals should be restricted in problem areas, the Legislature could enact legislation requiring groundwater withdrawals to be restricted in problem areas.

(b) Enact legislation requiring that groundwater withdrawals be reduced in problem areas (including control areas) by allocating groundwater on a per irrigated acre basis.

Under this alternative, groundwater allocations for irrigation purposes would be based on

the number of acres irrigated. The quantity of the allocation would depend on what depletion rate (if any) is established for the problem area. An important part of this alternative is the legislative definition of what constitutes a problem area: when groundwater depletion exceeds, e.g., one percent per year; when groundwater withdrawals deplete streamflow; etc. A second issue is if and how a groundwater depletion rate is established.

(c) Enact legislation requiring that groundwater withdrawals be reduced in problem areas (including control areas) by allocating groundwater on a per irrigable acre basis and permitting the local sale of groundwater pumping rights.

This alternative could go the farthest in recognizing the "correlative" or coequal rights of landowners to use a common groundwater supply if the groundwater allocation were low enough to require irrigators to purchase groundwater allocations from owners of local irrigable land that is not irrigated. In other words, irrigators would be required to pay non-irrigators for the irrigator's disproportionate use of the common groundwater supplies.

ALTERNATIVE 9: Enact legislation requiring groundwater development to be restricted in problem areas.

(a) Enact legislation requiring NRDs to restrict groundwater development in problem areas, and requiring the DWR to restrict groundwater development in problem areas in the absence of NRD groundwater controls.

The GMPA makes the establishment of groundwater controls an NRD option. If it determined that groundwater development should be restricted in problem areas, the Legislature could enact legislation requiring groundwater development to be restricted in those areas.

(b) Enact legislation: (1) requiring compensation as a prerequisite to restricting or prohibiting groundwater development, and (2) authorizing NRDs or the State to purchase groundwater development rights in groundwater control areas.

The GMPA authorizes NRDs to limit groundwater development in control areas through well spacing requirements and well drilling moratoria. If it determined that landowners should be compensated for the imposition of such restrictions, the Legislature could enact legislation requiring compensation as a prerequisite for restricting or prohibiting groundwater development. Alternatively, NRDs or the State could be authorized to purchase a landowner's rights to drill an irrigation well as another means of restricting future groundwater development.

ALTERNATIVE 10: Enact legislation establishing a fee for withdrawing groundwater.

ALTERNATIVE 11: Enact legislation authorizing increased state appropriations or issuance of bonds for development of supplemental water supplies.

If it determined that additional state support should be given to develop supplemental water supplies, principally by the construction of surface water storage reservoirs, the Legislature could authorize increased appropriations or the issuance of bonds.

IMPACTS OF ALTERNATIVE #1 - NO NEW LEGISLATION

All impacts of Legislative-Administrative Alternatives cannot be included in a summary. However, an understanding of the Baseline Condition is vital to understanding the impacts of all other alternatives. It was projected that the status quo or baseline situation described by Alternative 1 would probably result in the following key water user responses:

1. A doubling of groundwater irrigated acres over the next 40 years accompanied by changes in the proportion of irrigated acres devoted to various crops.
2. Reduction in the average amount of water pumped per acre of about 30 percent in the case of gravity irrigation systems by the 2000, and about 10 percent for sprinkler systems by the year 1990.
3. Growth in the profitability of irrigated agriculture over the next 40 years. Average returns to land and management in irrigated agriculture were projected to increase four-fold over the next 40 years when measured in constant 1977 dollars. If this phenomenon occurs, it will be reflected in steadily rising land values.

Economic impacts were projected in conjunction with work being done on the High Plains-Ogallala Aquifer Study. The procedures used in that analysis are explained in the separate appendix to this report. The following economic impacts are projected through the year 2020 if Alternative 1 is followed:

1. The value of total crop production is projected to increase by 278 percent.
2. Total returns to land and management are projected to increase by 446 percent.

3. The state's economy is projected to improve throughout the period, but net economic declines could begin to occur sometime after the year 2020. Further analysis is needed to determine exactly what would happen.
4. After the year 2000 the rate of improvement is projected to slow down reflecting the expectation that land will revert to dryland at an increasing rate.
5. While the statewide outlook is projected as positive through 2020, localized regions may face economic difficulties under the status quo.
6. Under the status quo, approximately 1,850,000 acres are projected to revert to dryland production due to aquifer exhaustion.
7. It is estimated that landowners who can no longer irrigate will be harmed economically with net returns falling by more than $100 per acre.

The following environmental impacts are projected if Alternative 1 is followed:

1. Declines in groundwater levels are projected to continue in many areas.
2. Impacts are projected to occur in areas of high water table including seasonal and possibly permanent declines in sandhills wetlands, wet meadows and shallow wells.
3. Evapotranspiration salvage is projected to rise.
4. Increased leaching of nitrates and other chemicals is possible in susceptible and unmanaged areas.
5. Streamflows are projected to be impacted in relation to declines in areas of high water table.
6. Increased soil erosion are projected to occur in some areas.

IMPACTS OF OTHER ADMINISTRATIVE-LEGISLATIVE ALTERNATIVES

For reasons of space only a brief synopsis of economic and environmental impacts of other alternatives will be given. Other impacts are described in the text.

Impacts of *Alternative 2 - Revise the Groundwater Management and Protection Act* depend on the response of water users to the action. The authority to use a moratorium on well drilling may not be used by NRD's. Therefore, the impacts may be similar to the status quo. In the case of well spacing authorities and withdrawal limitations there may be significant use by NRDs. The degree of impacts depend upon one's assumptions on the degree to which the authority would have been used.

Potential economic impacts of *Alternative 3 - Establish Irrigation Development Subsidy* include: transfer of wealth from the non-farm to the farm sector, higher farm incomes in initial years and lower farm incomes in later years due to aquifer depletion. Under one estimate the cost to the state would be about 11 million dollars a year. Environmental impacts could include accelerated groundwater declines and related effects on wetlands, streamflow, and habitat in areas of high water table. Groundwater quality problems or erosion problems could also occur under some circumstances.

Potential economic impacts of *Alternative 4 - Establish Groundwater Depletion Payments* include increased farm income and transfer of income from other people to irrigators. Unless payments are or exceed about $20 per acre the development response is likely to be nominal. Environmental impacts are dependent upon the degree to which the rate of water use is encouraged. Potential environmental impacts include: groundwater declines, increased leaching of nitrates, erosion (dependent on management decisions), and in areas of high water table, streamflow and wetland reduction and changes in evapotranspiration salvage.

Potential economic impacts of *Alternative 5 - Increase Funding for Research and Educational Programs* depend upon the success of the program. Education may help reduce the amount of water used. Less water pumped does not necessarily mean significantly less water consumed. Research offers more potential. However most research programs do not lead to less water used per acre but rather increased production per unit of water used. Environmental impacts depend upon the success in reducing withdrawals. Potential impacts could include: reduction in nitrates, lengthened aquifer life, less erosion in some cases, and variable effects on streamflow. In some cases streamflow may be reduced due to less runoff. In other cases it may rise due to less groundwater pumping.

Potential econimic impacts of *Alternative 6 - Financial Incentives for Irrigation Efficiency* include increased net incomes for irrigators and transfer of wealth from non-irrigators to irrigators. There may also be a short term overall economic benefit. However, to the degree that development is encouraged, there may be a shorter aquifer life and an eventural decrease in income. Although the alternative may slow the rate of aquifer decline slightly, this effect may be more than compensated for by an increased rate of aquifer development. Environmental impacts

would be much like those of the previous alternative if there were net reductions in withdrawals. Otherwise impacts are likely to be similar to those of Alternative 1.

Potential economic impacts of *Alternative 7 - Require Improved Irrigation Practices* will be positive in most cases because these practices lower irrigation costs in most instances. The non-irrigation economy will probably not be affected unless enforcing the regulation becomes especially expensive. Total pumpage would decrease although, in some cases, net withdrawals will not change significantly. Environmental effects of this alternative would depend upon the hydrology of the individual area and the degree to which net withdrawals are affected.

Potential economic impacts of *Alternative 8 - Restrict Groundwater Withdrawal in Problem Areas* are negative for the next 40 year period. For example, a statewide 80 percent allocation program (80% of expected pumpage) would decrease returns to land and management by 3 percent to 6 percent over 40 years and result in 675,000 more acres in production as of 2020 than otherwise would be. In terms of off-farm economic impacts, the results are similar, meaning reduced income during the next few decades in return for having more economic activity a half a century or more into the future. It was estimated that as of 2000 a 80 percent allocation would reduce the total value of goods and services in Nebraska by 0.9 percent. Other economic effects would depend upon the water user response. Allocations would potentially result in cropping pattern shifts.

Potential environmental impacts of Alternative 8 include: reduced rates of groundwater decline, streamflow maintenance on some streams, reduced evapotranspiration salvage potential, and maintained water levels in impoundments and Sandhill's lakes. Reduced erosion and leaching of nitrates are also possible, but would depend somewhat on the concentration of water use allowed.

Potential economic impacts of *Alternative 9 - Restrict Groundwater Development in Problem Areas* were calculated for the years 1990, 2000, and 2020. A statewide well moratorium implemented in 1985 would reduce net returns to crop agriculture by 21 percent by 2020. In return 788,520 fewer acres would have reverted to dryland. It is projected that by 2020 the moratorium would have reduced the total annual value of good and services produced by the Nebraska economy by $2,882,383,000. Current owners of irrigable but undeveloped land would be precluded from developing it and accordingly improving their income, while current irrigators would gain from the extended aquifer life. This equity problem could be mitigated by State or NRD purchase of pumping rights in areas where development is precluded.

Potential environmental impacts include reduction of the rate of groundwater decline. There is also potential for reductions of leaching of nitrates and other chemicals. Overall impacts will depend on criteria used and the areas to which they are targeted.

Potential economic impacts of *Alternativer 10 - Establish Fee for Groundwater Withdrawal* depend primarily on what the fund is used for. If the money is used for economically efficient water development projects, a water charge would mean less net income for irrigators in early years, but compensating increases in later years when the surface development projects come on line. However, if all irrigators were charged for such withdrawals, some irrigators essentially would be subsidizing others. Potential environmental impacts include slightly reduced rates of groundwater decline, reduced nitrate leaching, varying effects on streamflow, and possible reduction in well and lake decline.

Potential economic impacts of *Alternative 11 - Authorize State Appropriations or Bonds for the Development of Supplemental Water Supplies* depend on how economically efficient the projects are. In cases where surface water is obtainable by those who have available groundwater supplies, irrigators probably would be unwilling to pay more for surface water than the cost of groundwater extraction. Potential environmental impacts from continued or expanded use of groundwater could include nitrate leaching, soil loss, sedimentation of surface water and degradation of aquatic habitat.

Introduction

The purpose of this study is to determine the appropriate rate of utilization of the existing groundwater supplies in Nebraska. A particular goal was the formulation of a series of potential legislative alternatives as a basis for groundwater management. The limitations of time and funding restricted the study to a broad perspective based upon analysis of available data.

The first major objective was to determine those criteria which affect or are affected by the rate of utilization of groundwater. These factors can act as constraints or specific limitations on any management process. The first constraint, the capabilities of the principal aquifer, is summarized in Capter 1. Another constraint considered in Chapter 1 is type of utilization. Irrigation development is the dominant form of groundwater use in Nebraska. A third constraint was the impacts related to external factors. Chapter 1 includes a discussion of these factors including environmental, technological, economic, social, and legal/institutional/administrative.

The second major objective was to determine the need for establishment of additional goals for use of existing groundwater supplies. Chapter 2 discusses the potential of the principal aquifer; particularly the groundwater in storage, the annual recharge from precipitation and the potential salvage from evapotranspiration. These statewide perspectives and the data from Chapter 1 were utilized in Chapter 3 to briefly examine the developmental potential of substate areas which were delineated for this study. Quantitative projections for local areas are not possible without more specific data and more definitive techniques for analysis.

The third major objective was to determine the appropriate management techniques to implement the potential development goals. A series of potential management techniques are summarised in Chapter 4 and are more fully discussed in the separate appendix to this report. A number of components of groundwater management techniques are examined in detail as well as the potential impacts and relationships with the constraints defined in Chapter 1.

The final major objective was to determine alternative and recommended administrative and legislative actions to provide the management process. A series of administrative - legislative actions are detailed in Chapter 5. Both the relationships to management procedures and the impacts of implementation are examined. Eleven legislative alternatives are identified that could establish an appropriate management process.

This study is one of a series of policy issue studies designed to address the major priority questions identified by the State Water Planning and Review Process (November, 1978). Some of the findings of this *Groundwater Reservoir Management Study* will provide direct response to a major policy concern. Other findings will need to be integrated with the results of other issue studies to provide sufficient input for policy analysis and recommendation. This integration procedure will be particularly required for major policy concerns such as surface water and groundwater interrelationships, allocation of water supplies to competing users and augmentation of available supplies. Analysis of these broader concerns may require data beyond the current series of studies and/or site-specific research. An examination of the relationship of this report to other policy studies is included as a special section following Chapter 5.

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Chapter 1

Constraints on Groundwater Development

INTRODUCTION

Prior to determination of alternatives for management of a resource, limitations of the resource as well as the range of impacts of the process of utilization must be defined. Only then can a realistic analysis be made of the available alternatives. The factors that constrain this analysis procedure are the physical characteristics of the resource, the potential levels of utilization and the stresses created by the process of utilization. Definition of these factors is particularly difficult for a resource such as groundwater since it is only one part of the dynamic hydrologic system. However in order to properly evaluate and recommend alternatives, limits must be understood and potential impacts judged acceptable.

Since the process of utilization also is dynamic, the impact analysis must be a continuing procedure. New interactions will be created by changes in the resource system, in the level of development, in the choice of technique of management, and in the manner of administrative-legislative control. This chapter will discuss those factors in Nebraska that will act as constraints upon development of the groundwater resource. The availability of the basic data will determine the extent to which the capability of the aquifer can be defined. Data also are available to delineate the characteristics of the various types of utilization. Other constraints are less subject to definition. Thus a range of impacts have to be considered for related external factors such as environmental, economic, social, technological and legal/institutional/administrative constraints.

CAPABILITIES OF THE PRINCIPAL AQUIFER

Nebraska is underlain by up to ten thousand feet of sedimentary rock, all of which contains differing amounts of groundwater (Figure 1 - oversize)*. There is however a tremendous variability in the potential of these rocks to serve as aquifers. These variations are due to the physical characteristics that affect water yield, the chemical characteristics that affect quality and the technology and economics of obtaining the resource.

Limited amounts of water currently are being utilized from the Paleozoic rocks in extreme eastern Nebraska. Water supplies are obtained from the Dakota sandstone (Cretaceous) in several areas in the eastern portion of the state and from the Niobrara Formation (Cretaceous) in northeastern Nebraska. However, most of the groundwater utilized in Nebraska is derived from rocks of Tertiary and Quaternary age. This hydrogeologic unit is commonly referred to as the principal aquifer.

To properly evaluate the alternatives for development and management of this groundwater resource, data must be compiled relevant to its capabilities. By definition based on utilization, the principal aquifer consists of the Arikaree and Ogallala deposits of Tertiary age in western Nebraska, the Ogallala and overlying Quaternary deposits in central Nebraska and only the Quaternary rocks in eastern Nebraska.

A configuration map of the base of these hydrogeologic units was drawn to define the lower limit of the principal aquifer (Figure 2 - oversize).* Another contour map was constructed illustrating the configuration of the water table in 1979 (Figure 3 - oversize).* The water table reflects the top of the zone of saturation and thus defines the upper surface of the primary aquifer. By combining the two configuration maps, a thickness map of the principal aquifer was constructed (Figure 4 - oversize).* Maximum thickness exceeds 1,000 feet in the west central portion of the state. There are numberous areas near the margin of Nebraska where the principal aquifer is very thin or absent.

The thickness values plus a general knowledge of the pore space in the rocks allow estimates to be made of the amount of groundwater in storage in the principal aquifer (Figure 5). A

*Oversize Figures are presented at the back of the report.

transmissivity map was prepared (Figure 6) illustrating the capacity of the aquifer to transmit water, a function of the permeability of the reservoir. These maps provide an indication of the well yield potential from the principal aquifer at any point within the state.

Figure 5 illustrates the amount of mobile water contained in the pore space of the principal aquifer. It is based on the assumption that the aquifer will have a specific yield of two-tenths of its thickness. The actual yield within a period of time is a function of the rock's permeability. For instance, the water stored in the fine-grained rocks in eastern Nebraska moves very slowly and should not be expected to support high pumping rates.

This groundwater in storage is a part of a dynamic recharge/discharge system. Nearly all of the recharge in a local area is provided by precipitation. Development of the aquifer will result in decreasing the amount of water in storage and lowering the water table. Recharge by seepage from surface water and precipitation can be important and may counteract this decline in local areas where the water supply and characteristics are favorable. It has been estimated that the principal aquifer in Nebraska contains 1.875 billion acre-feet of groundwater (Bentall and Shaffer, 1979). That estimate is conservative in that it primarily considers the more readily available water in the permeable rocks.

The transmissivity values illustrated in Figure 6 provide an indication of the capacity of an aquifer to transmit water. These values are a function of aquifer permeability and saturated thickness. The transmissivity values may be used to make estimates of well yield in any particular area.

The areas of lower trasmissivity in large part reflect thinning of the principal aquifer. However, even some relatively thick portions of the aquifer, particularly in eastern Nebraska, have low transmissivity values and would support only low-yield wells. Those areas with values exceeding 20,000 gallons per day per foot are generally capable of well yields sufficient for irrigation. Although the values are not absolute well yield values, this map does provide a perspective on the groundwater potential for irrigation development in any particular area of the state or for other large withdrawal.

The chemical quality of groundwater in Nebraska was described by Engberg and Spalding (1979). In that publication a series of maps illustrated the concentration ranges of the major chemical constituents (Figure 7). Maps zones of concentration of dissolved solids and illustrates their interpretation of the data available for the major source of groundwater utilized in various areas of the state. Except for quality information from older aquifers in eastern and northwestern Nebraska, these data represent one aspect of the water quality of the principal aquifer.

Most groundwater in the principal aquifer is of good to excellent quality. The major dissolved solids are calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and silica. Only in a few areas of the major river valleys do concentrations of dissolved solids exceed 500 milligrams per liter (mg/1) in the principal aquifer. These portions of the principal aquifer have been affected by recharge from the rivers that have been enriched in dissolved solids by evapotranspiration and irrigation return flows.

Although the concentration of dissolved solids serves to indicate the generally good quality of groundwater in the principal aquifer, this is only one aspect of the available data. Considerable variance from average quality could occur at any specific site. Certain constituents may be present in very low concentration that could create a health or environmental hazard. Detailed analysis should be obtained if any potential of negative effects exists. However, this map does illustrate that Nebraska has the benefit of good quality groundwater in its principal aquifer.

A final characteristic considered to be important in defining the capabilities of the principal aquifer is the depth to water. This aspect is important both for an economic evaluation of extracting the water as well as for any environmental impacts of changing the water level. The water table contour map and surface topographic maps were used to prepare a

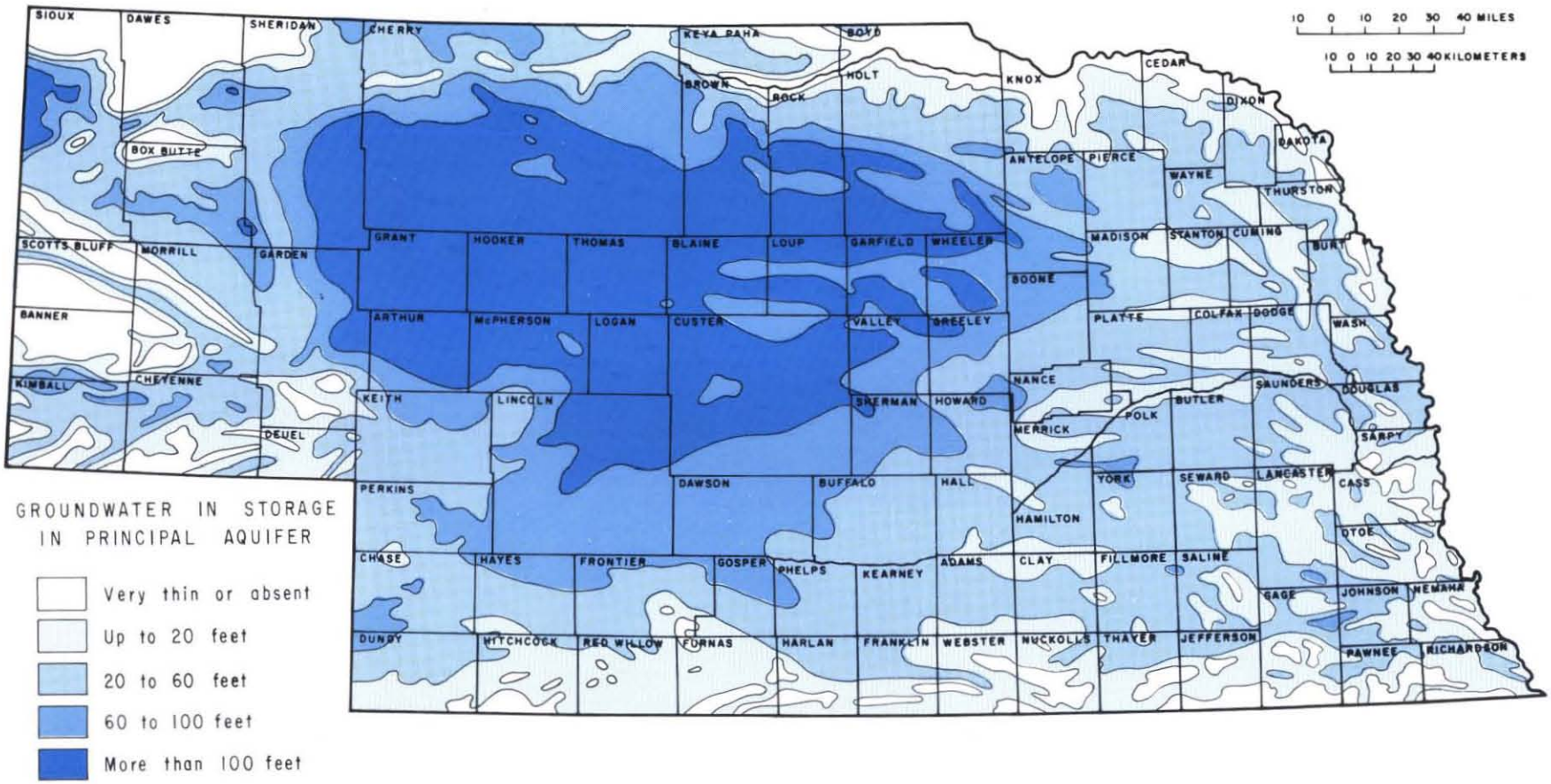

Figure 5 - Groundwater in Storage in the Principal Aquifer

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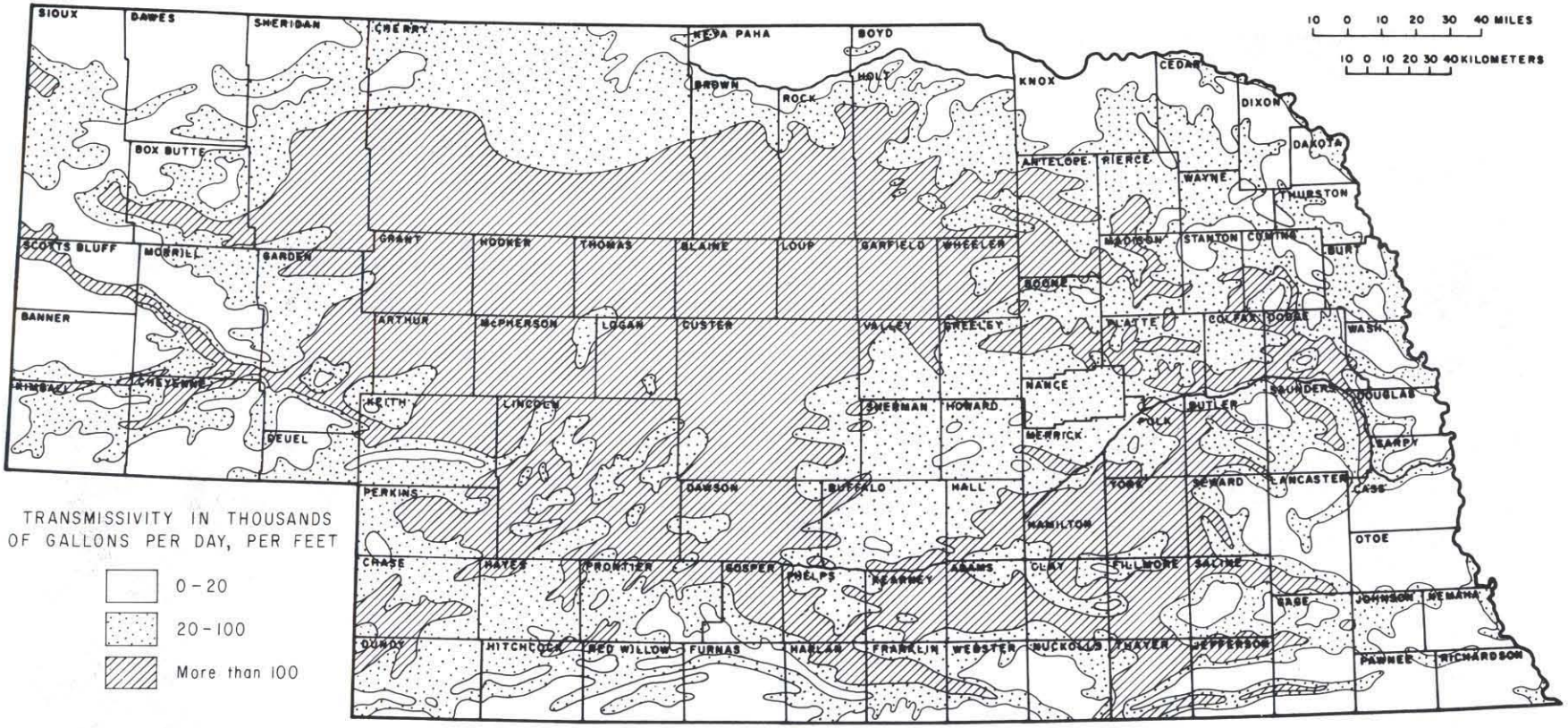


Figure 6 - Transmissivity of the Principal Aquifer

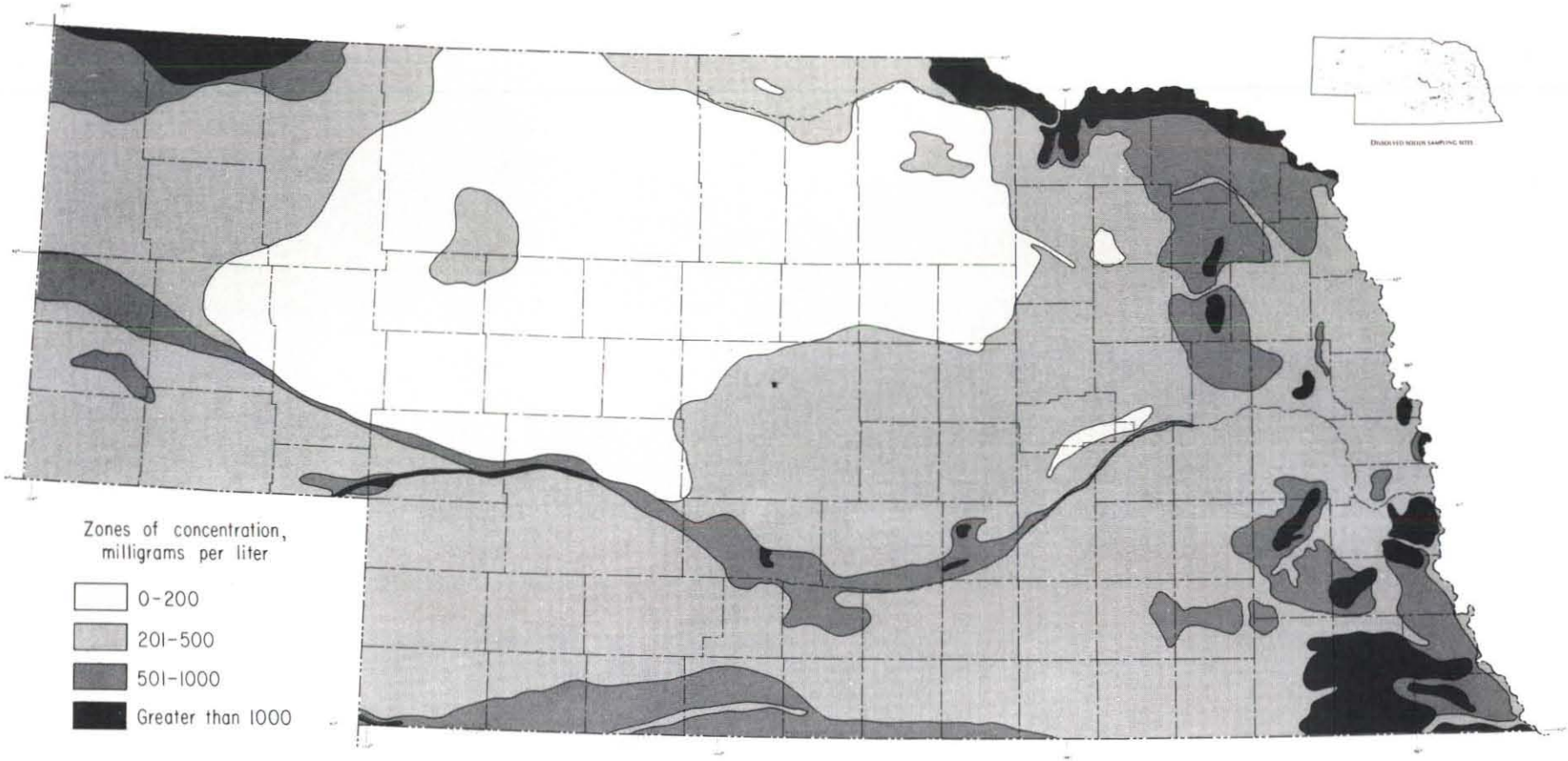
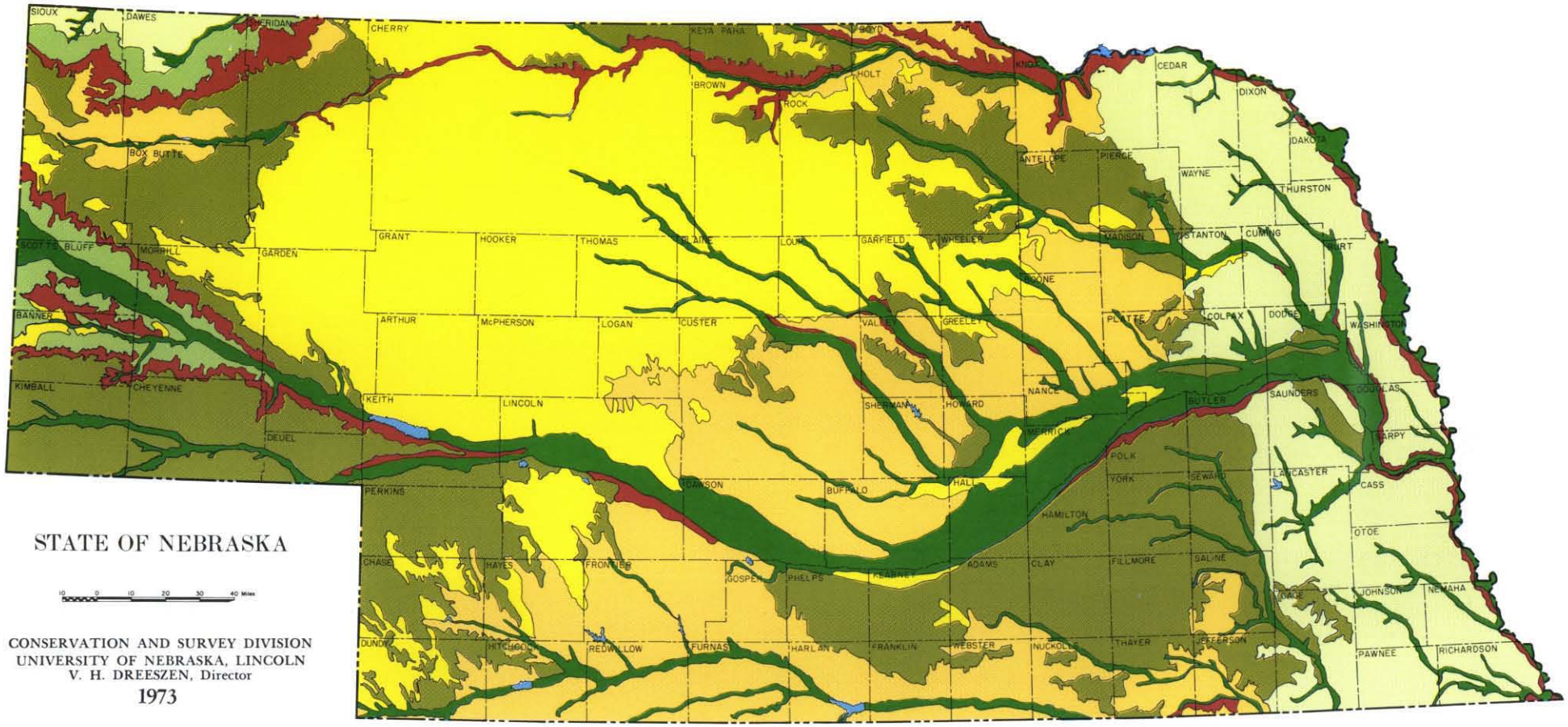


Figure 7 - Concentration of Dissolved Solids in the Significant Aquifers of Nebraska



EXPLANATION

Valleys—flat-lying land along the major streams. The materials of the valleys are stream-deposited silt, clay, sand, and gravel.

Large Reservoirs—constructed for purposes such as water storage for irrigation, generation of electricity, flood control, or recreation.

Dissected Plains—hilly land with moderate to steep slopes, sharp ridge crests, and remnants of the old, nearly level plain. The Dissected Plains are old plains eroded by water and wind.

Rolling Hills—hilly land with moderate to steep slopes and rounded ridge crests. In eastern Nebraska, the Rolling Hills are mostly glacial till that has been eroded and mantled by loess, while in northwestern Nebraska the hills were produced by the erosion of clay and clay-shale beds.

Valley-Side Slopes—moderately sloping land which occurs between the escarpments and the major stream valleys in western Nebraska. These areas are mostly siltstone bedrock covered by a few feet to a few tens of feet of sand, gravel, or silt.

Plains—flat-lying land which lies above the valley. The materials of the plains are sandstone or stream-deposited silt, clay, sand, and gravel overlain by wind-deposited silt (loess).

Sand Hills—hilly land composed of low to high dunes of sand stabilized by a grass cover. The sand dunes mantle stream-deposited silt, sand and gravel, and sandstone.

Bluffs and Escarpments—rugged land with very steep and irregular slopes. Bedrock materials, such as sandstone, shale, and limestone, are often exposed in these areas.

Figure 9 - Topographic Regions Map

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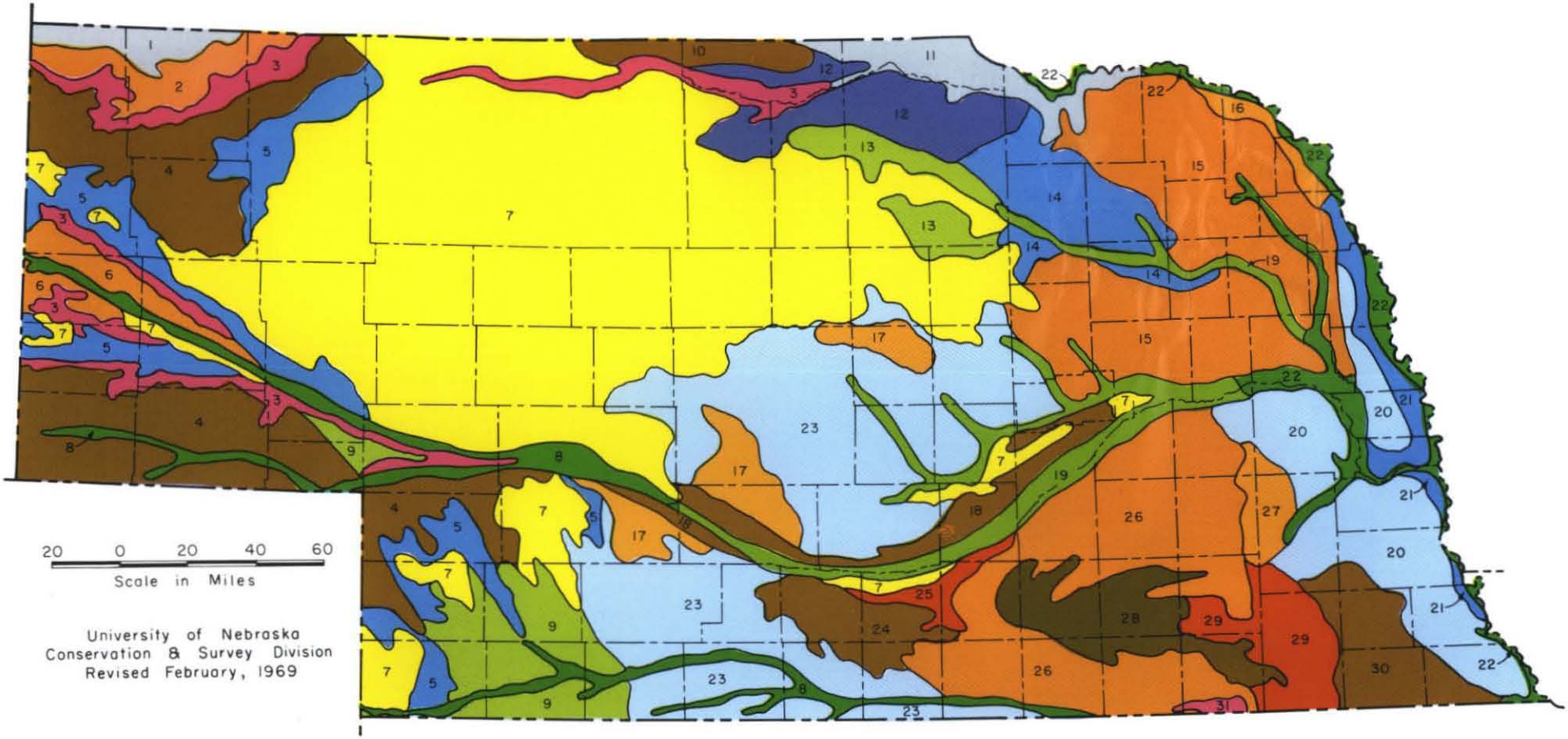

1. – Pierre – Samsil
2. – Bridgeport – Keith
3. – Rough broken land
4. – Keith – Rosebud
5. – Anselmo – Keith
6. – Mitchell – Tripp
7. – Valentine – Dunday
8. – McCook – Las
9. – Keith – Colby
10. – Holt – Valentine
11. – Reliance – Boyd
12. – Thurman – Jansen
13. – Loup – Valentine
14. – Thurman – Valentine
15. – Moody – Crofton
16. – Crofton – Nora
17. – Colby – Ulysses
18. – Hall – Wood River
19. – Leshara – Platte
20. – Sharpsburg – Marshall
21. – Marshall – Monona
22. – Luton – Haynie
23. – Holdrege – Colby
24. – Holdrege – Hastings
25. – Kenesaw – Holdrege
26. – Hastings – Crete
27. – Sharpsburg – Shelby
28. – Crete – Fillmore
29. – Crete – Wymore
30. – Wymore – Pawnee
31. – Lancaster – Hedville

Figure 10 - Nebraska Soil Association Map

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general depth to water map for the principal aquifer (Figure 8 - oversize).* These values represent the depth at which water would be present in a well completed in the principal aquifer. The map does not indicate the depth to the groundwater reservoir nor does it reflect the variation that might occur during pumping. Of particular interest for this study are those areas with depths to water fifty feet or less.

UTILIZATION OF GROUNDWATER

The groundwater in Nebraska's principal aquifer is discharged both by pumping and by natural processes. Some natural discharge will occur in areas where the water table intersects the land surface. Lakes may form allowing significant amounts of evaporation or streams may transport the released groundwater. Another form of natural discharge occurs from groundwater which lies within the root zone. Although highly variable, significant amounts of water can be extracted and transpired by natural vegetation.

Man's utilization of groundwater is a function of both the availability of the resource and the potential for effective use. Thus in a state where nearly 90 percent of groundwater utilization is for irrigation, land suitability is an important consideration. The nature of the land resource, as defined by topography (Figure 9) and soil type (Figure 10), is a constraint upon the degree of utilization of groundwater for irrigation. Estimates can be made of the land suitability for irrigation of various areas in the state and thus establish a maximum level of groundwater use under current technology.

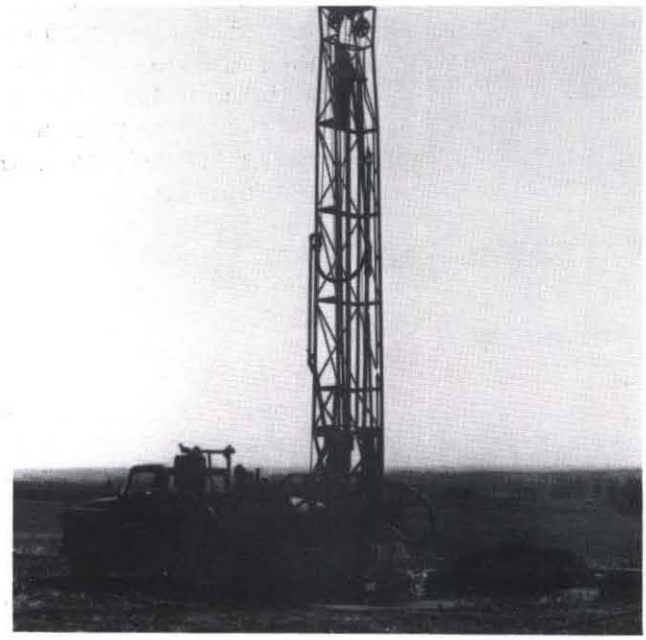
Figure 9 illustrates the physical features at the land surface. Except for the surface water reservoirs, these features are the result of geologic processes operating over long periods of time. Some areas have undergone significant erosion; in other areas unconsolidated materials have been deposited and completely mantle the bedrock surface. Both the slope and the near-surface material strongly influence the local topography. The topographic regions are a unique combination of a series of processes that have acted upon the available materials to create the current landscape. The patterns thus formed at the surface and near surface are a major influence upon soil type, land capability, and the utilization of the groundwater resources.

Figure 10 illustrates the major soil associations of Nebraska. The soil associations are strongly influenced by parent material and slope of the land surface. As would be expected, the patterns on this map are very similar to those on the topographic region map. In some areas the parent material, either bedrock or unconsolidated material, influence soil type without significant change in topography. Detail for each of the major associations was provided by Elder (1969).

Each soil association contains a number of individual soils that have been described and their distribution mapped on a county basis. These county soil survey reports are the best available summary of land capability. Based upon land suitability, projections can be made of the potential utilization of the groundwater resource for irrigated agriculture.

The relative amounts of groundwater utilized for major purposes indicates that the overall rate of use would be most influenced by management of irrigation. Less than two percent of annual use is for rural domestic and livestock supplies. Approximately twelve percent is for higher volume public and industrial supply which have a very local impact. The volume of use and statewide impact of irrigation indicates that, if necessary, controls on irrigated agriculture would effectively manage the rate of groundwater utilization.

Figure 11 presents a compilation of data from historical surveys and irrigation well registrations from the Nebraska Department of Water Resources. Climatic trends, technology, and economics control the rate of well installation.



Annual installations increased slowly into the 1950s. Periods of accelerated development occurred during the middle years of the 1950s, 1960s, and 1970s. A major influence on rate of development has been the annual variation in precipitation. However, the advent of center-pivot irrigation systems created a high rate of installation during the 1970s.

Figure 12 presents the location of registered irrigation wells and significant changes in Nebraska groundwater level. The upper map shows the location of the 65,775 irrigation wells that had been registered in Nebraska through 1980. The distribution of wells has been most influenced by economics, land characteristics and groundwater availability. It is estimated (Johnson and Pederson, 1981) that in 1980 these wells pumped about 7.5 million acre-feet and irrigated about 5.1 million acres. Groundwater is estimated to provide more than 72 percent of the water supply for irrigation in Nebraska and to serve about 85 percent of the irrigated land.

The lower map shows the significant changes that have occurred from pre-development through 1980 in the groundwater levels in Nebraska. These data are collected as part of the cooperative program between the Conservation and Survey Division and the U.S. Geological Survey. An annual report is published containing a summary of the data collected (Johnson and Pederson, 1981).

In most areas there are natural variations in water level caused by seasonal changes in recharge/discharge. However, most changes noted on this map can be related to some alteration in the groundwater system by man. The areas of significant declines coincide with areas of intensive groundwater irrigation. Most of the water level rises have been created by importation and seepage of surface water into the aquifers. The available data does not demonstrate that the declines are indicative of aquifer exhaustion or that these declines will expand beyond the areas of large withdrawal.

EXTERNAL FACTORS

Introduction

Environmental, technological, economic, social, and legal/institutional/ administrative factors can act as constraints and have diverse impacts on development. The degree of constraint imposed by such impacts can be presented within a definite range for each interrelationship. Analysis and determination of levels of specific impacts depends upon a choice of management techniques and administrative/ legislative action alternatives. Prior to implementing development programs, management techniques, administrative structures and legislation; the interrelationship between these actions and the external factors should be considered. The following discussion indicates how each of these external factors can affect and/or be affected by the utilization of groundwater. A more detailed discussion on this subject is included in the separate Appendix to this report.

Environmental

Environmental factors that affect the utilization of groundwater for irrigation include climate, soil type, slope, soil moisture conditions, quality of groundwater, vegetation and depth to groundwater. Quality can limit the availability of groundwater for certain uses, such as a high content of nitrogen prohibiting certain domestic uses or a high salt content prohibiting agricultural use. Vegetation, specifically phreatophytes, can significantly consume shallow groundwater through a natural process. Streams, lakes and wetlands that are directly connected to an aquifer also can consume great quantities of groundwater by evaporation that might otherwise be available for irrigation, domestic or other man-induced purposes. Vegetation and surface water impacts on utilization are significant in areas of shallow water table.

The impact of utilization of groundwater on environmental factors can be significant in areas of shallow water table. The impact may be limited by site-specific conditions such as soil type or depth. Quantity impacts such as reduced streamflows and loss of wetlands can occur when water levels decline. Water quality impacts may be the result of over application of groundwater and leaching of dissolved solids back into the aquifer. Improper well construction can allow site specific contamination. Soils may be impacted through secondary effects that allow increased erosion by wind or water. Impacts to vegetation and wildlife habitats also may result from changes in the water levels. This can be direct causal relationship such as a loss of phreatophytes in areas of declining water levels or the creation of wetlands from croplands in areas of rising water tables. The relationship can be indirect such as removal of shelter belts to allow for more productive irrigation practices. Utilization of groundwater can both directly and indirectly affect factors such as recreation and aesthetics, which may be dependent on environmental characteristics.

Technological

Technological factors that affect the utilization of groundwater are considered to be primarily on-the-farm technical changes that fall into four categories: (1) the reduction of evapotranspiration without a loss per unit of grain yield; (2) cultural practices such as runoff control, weed

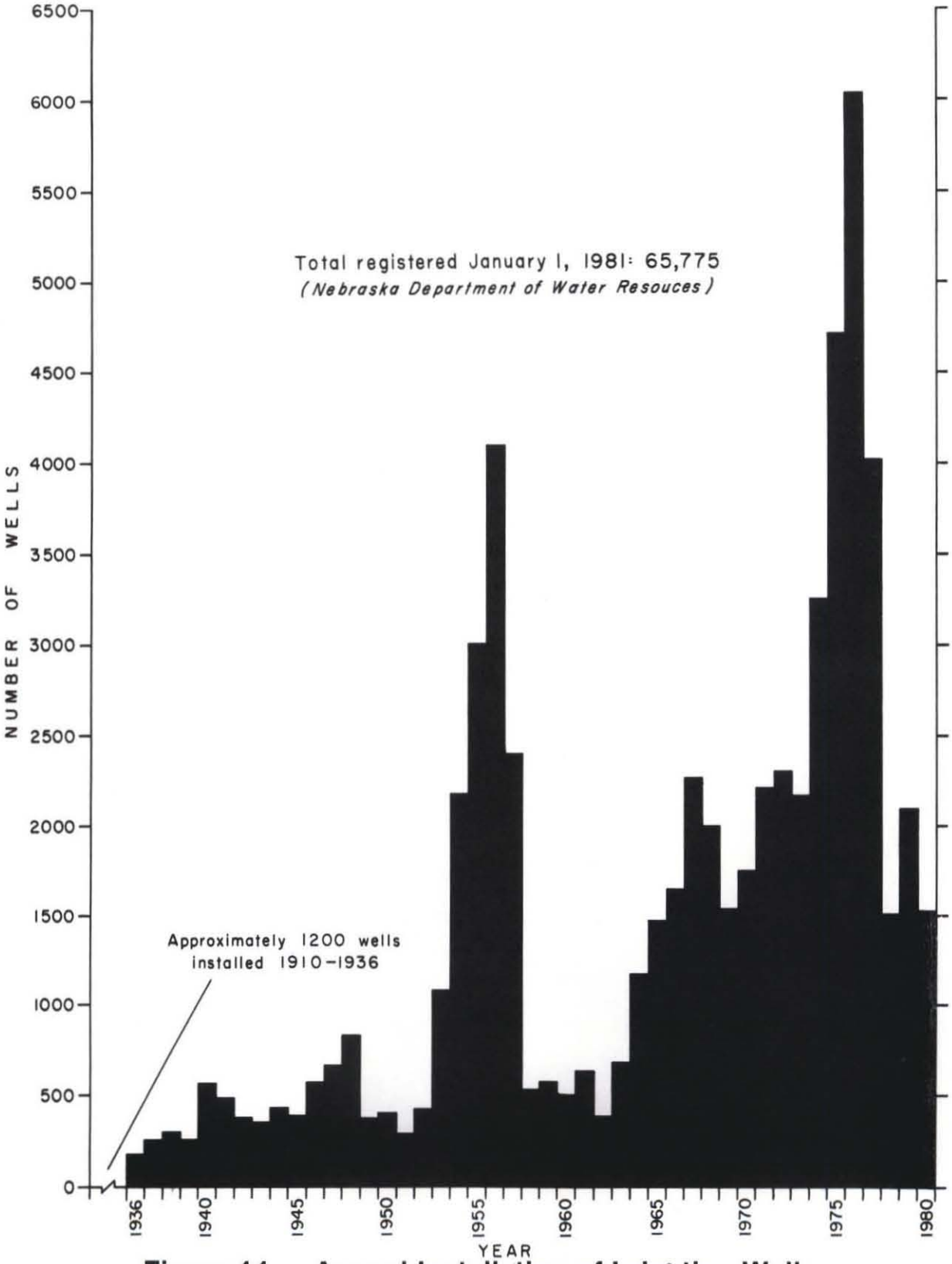


Figure 11 - Annual Installation of Irrigation Wells
Annual installation of irrigation wells in Nebraska through 1980
(estimated from historical surveys and irrigation well registration data)

suppression or tillage techniques; (3) improved efficienty of the irrigation conveyance system; and (4) application efficiency.

The impact of the utilization of groundwater on technological factors can be significant. These impacts generally are observed in areas where the quantity or cost-effective withdrawal of groundwater has experienced sudden negative changes and encouraged innovation. An example is the development of low pressure irrigation systems to reduce energy costs.

Figure 13 shows the location of center-pivot systems that had been active prior to December 1980. These systems have allowed development to expand into areas where soil typed and/or topography had previously limited irrigation. The first inventory of center-pivots in 1972 noted 2,735 systems. The inventory in 1980 reported 1,580 new systems and a total of 18,785.

The location of these systems is, of course, controlled by the availability of water. The center-pivot system is an example of advances in technology that have brought land under irrigation which formerly may not have been feasible. Technological advance is a consideration in both the potential for development and its management.

Economic

Economic impacts associated with groundwater use range from farm income change to effects on municipal water supply costs and industrial development. Nearly all significant economic impacts from groundwater utilization stem from irrigation, the state's major consumer of groundwater. Principal farm level economic factors that are impacted are irrigated acres, yield and net income. Capabilities of the land for production when coupled with water availability determine irrigation development potential. When groundwater is easily accessible, the influence on the economic factors is positive. When the quantity of groundwater is limited or costly to obtain the influence on one or more farm level economic factors will be negative. Tradeoffs between factors may occur such as a reduction in irrigated acres coupled with partial conversion to a crop of higher market value.

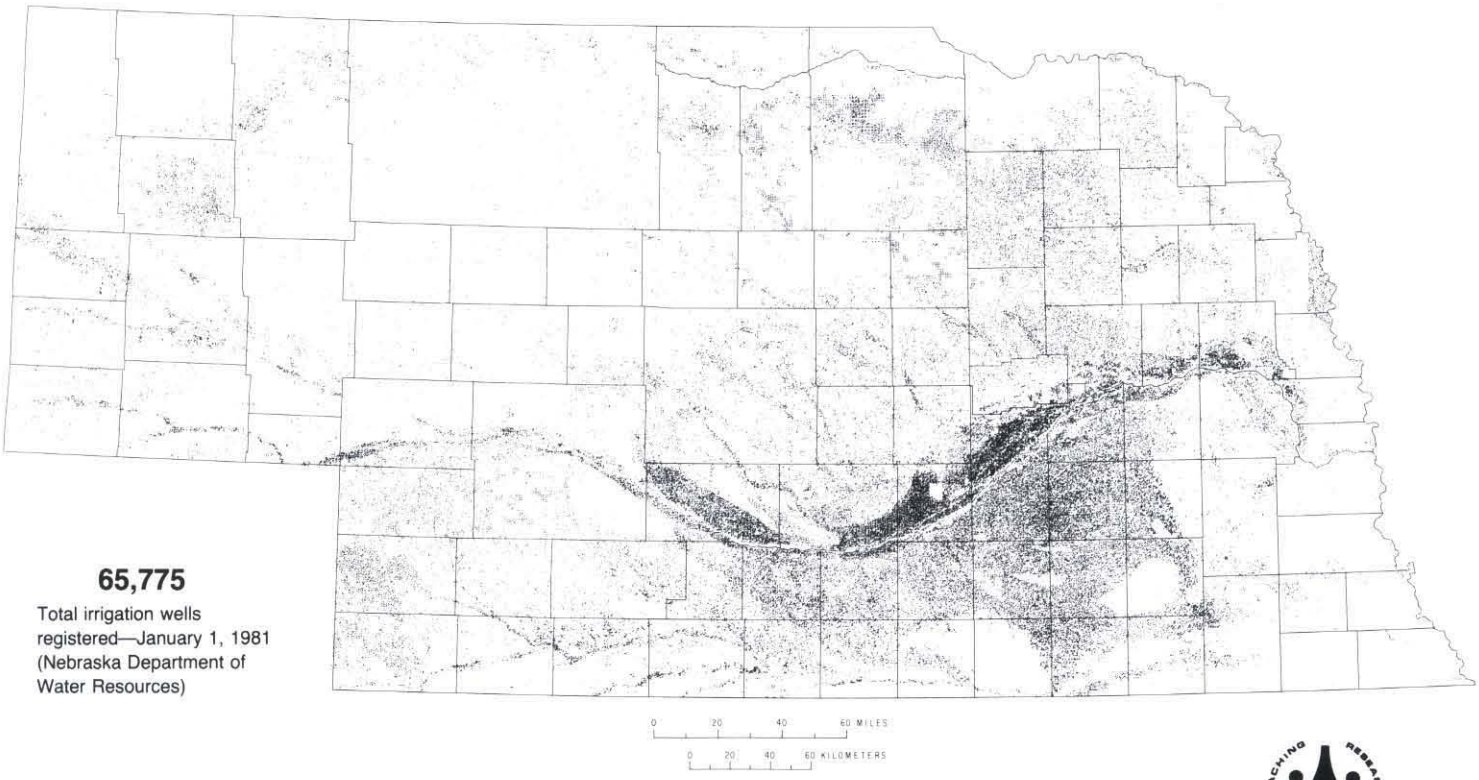
There also is an impact of economic factors on the utilization of groundwater. This relationship probably is broader and more clearly observed than the reverse effect of impact of groundwater utilization on economics. Major farm level economic factors that may have a positive or negative impact on utilization of groundwater include commodity prices, energy prices, crop yields, irrigation system costs and other input costs. These factors are highly variable. The marginal farm operation is especially vulnerable to the variances of these factors.

Social

Five social factors can be identified as having a relationship with changes in rate, amount and location of groundwater withdrawals for irrigation: attitudes, farm structure, community structure, quality of life and equity. These factors can both affect and be affected by the utilization of groundwater.

The rate of depletion of an area's groundwater supply can be influenced by attitudes toward the resource. People who perceive the supply as limited may desire to curtail the rate of utilization, while those who feel the groundwater supply is infinite may call for no controls. In turn, attitudinal changes can result when groundwater quantities are declining. These attitude adjustments may occur through increased awareness of problems or from alterations in economic returns due to limitations on water availability and/or increased pumping costs.

The size and ownership patterns of farms may affect the utilization of groundwater. Large farms and corporate ownership may lead to increased investments in irrigation. Smaller farms and family ownership could result in a more restricted development of irrigation. Under conditions where groundwater declines result in modifications in agriculture with related changes in profitability of the irrigator, "response" to declining groundwater levels or increased groundwater management could have a profound effect on the farm structure of an area. This could

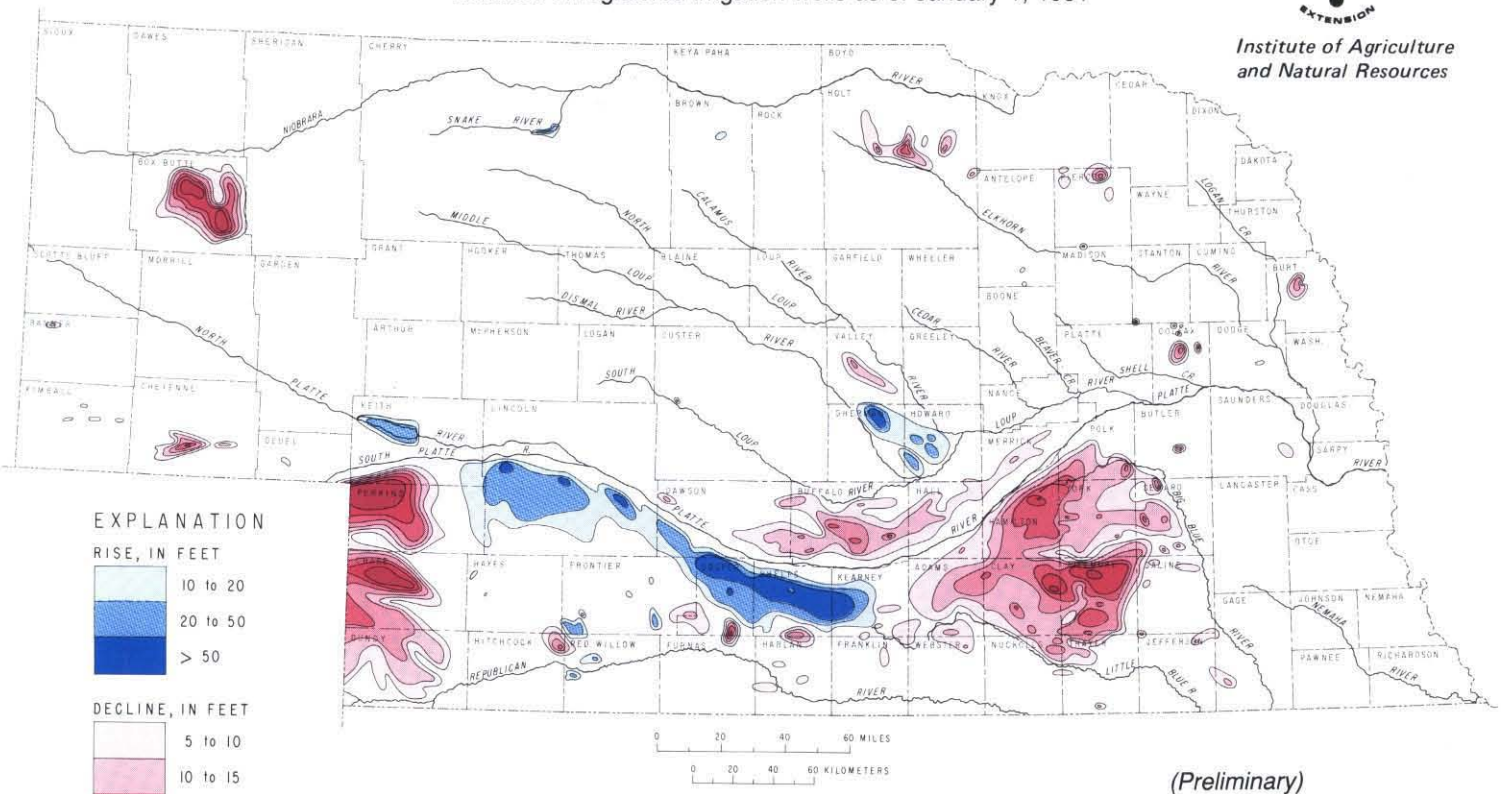


65,775

Total irrigation wells registered—January 1, 1981 (Nebraska Department of Water Resources)

Location of registered irrigation wells as of January 1, 1981

Institute of Agriculture and Natural Resources



(Preliminary)

Significant rises and declines in Nebraska groundwater levels from predevelopment as of fall 1980

Prepared cooperatively by
U.S. Geological Survey and
Conservation and Survey Div., IANR,
The University of Nebraska–Lincoln

Figure 12 - Groundwater Maps, 1980

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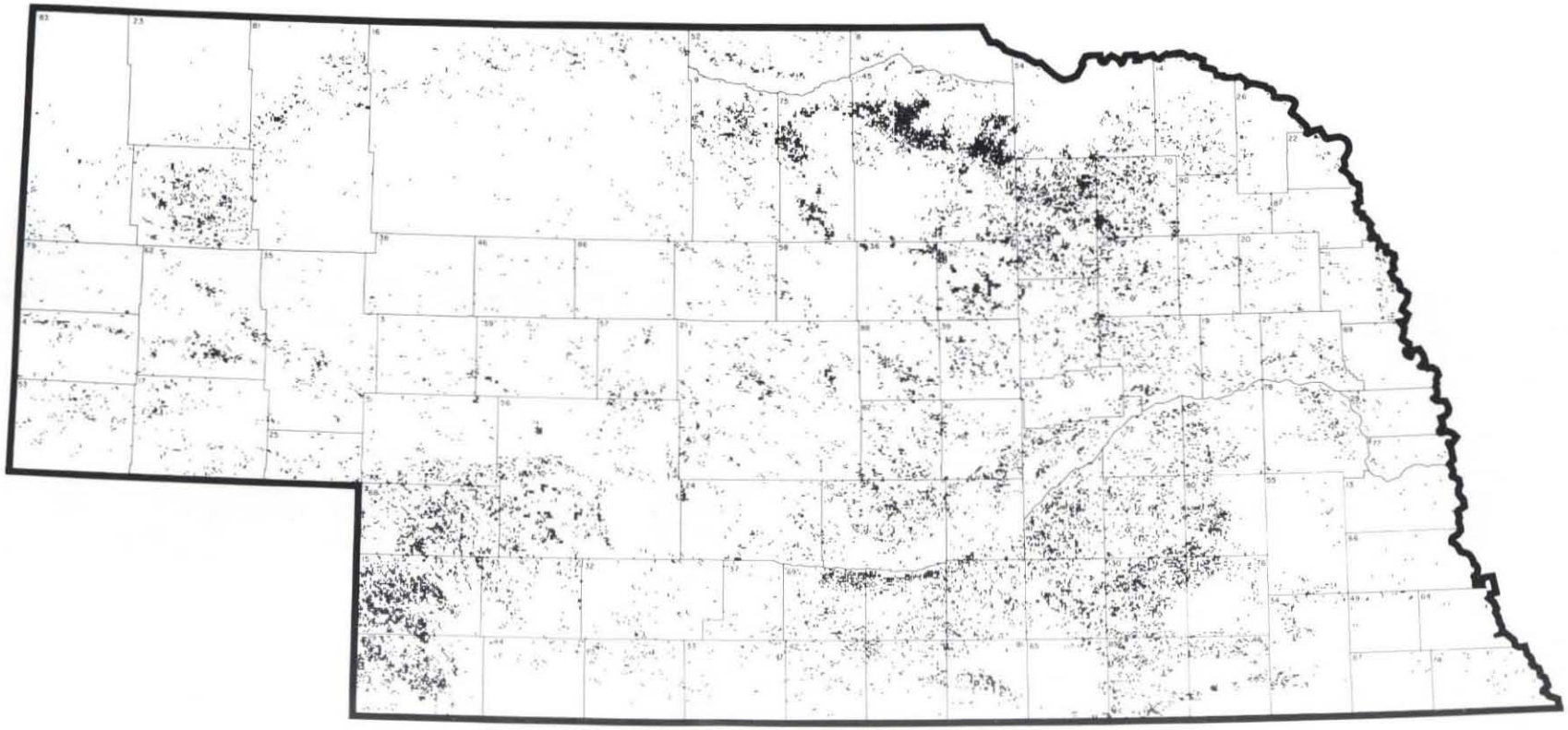


Figure 13 - Location of Center-Pivot Irrigation Systems in 1980

include increased farm size and shifts in farm ownership patterns and management techniques.

The relationship between community structure and utilization of groundwater is widely debated. However, there are relationships such as changes in a community's business types and levels due to the impact of irrigation development. Impacts of groundwater utilization on farm incomes also will impact on the community structure. It is unclear to what degree these changes and impacts can be attributed to groundwater utilization practices.

As groundwater utilization interacts with social factors such as farm and community structures it will in turn affect the quality of life of area residents. Quality of life, which consists of several intangible elements such as personal security, opportunities, well-being, happiness, contentment, etc., will be altered by changes in income, community services, health, and attitudes.

Aspects of equity include attitudes and beliefs regarding the type and distribution of opportunities for income, wealth, employment, etc., and also the nature of these opportunities as they actually exist. Equity will be a significant social factor with respect to intervention or change in groundwater utilization. It will be associated with attitudes and also with farm and community structure as related to income distribution.

LEGAL/INSTITUTIONAL/ ADMINISTRATIVE

There is a clear cause-effect relationship between groundwater utilization and legal/institutional/administrative factors. As groundwater is located and used, laws relating to its use are considered and may be adopted. Existing legislation may promote, retard or prohibit groundwater utilization. Some of this legislation may indirectly affect groundwater utilization through tax or land use provisions. In the same manner administrative practices continually interact with groundwater utilization.

One of the major factors that impacts on groundwater utilization is institutional structure, which exists at all government levels and has widely varying types and degrees of impact. Another factor is existing groundwater law that deals with rights, transfers, conflicts, mining and surface water-groundwater conflicts. A factor of growing importance is the developing institutional and legal mechanisms to address water quality. Additional factors include financial programs directly related to water and land treatment, education programs and research programs in conjunction with data collection. The multi-government level of involvement in all of the above factors is in itself a factor. Finally, the judicial system which is founded both on legislative and institutional principles is a factor which affects and is affected by groundwater utilization. This spectrum of factors is so broad that examples of impacts can be best supplied as specific alternatives are considered elsewhere in this report.

Chapter 2

Potential Of The Principal Aquifer

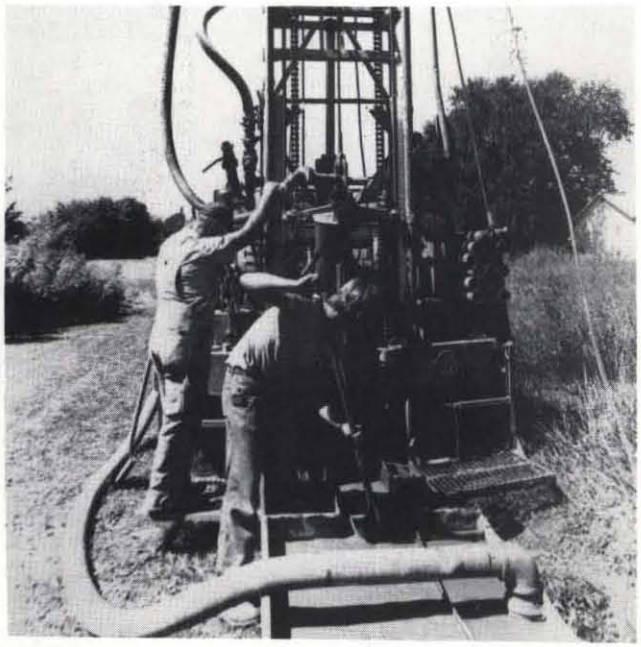
INTRODUCTION AND ASSUMPTIONS

The methods for efficient development of the groundwater resource will differ for various areas of the state. This is due to variations in the amount of water available, the type of use desired and the kinds of local impacts that will be created. An understanding of these variables is necessary prior to implementing any long range planning mechanism.

A series of maps illustrating the characteristics of groundwater in Nebraska were developed from available data and are presented in Figures throughout this report. Figure 14 subdivides the state into 13 regions with similar groundwater conditions (Reed, 1968). The original publication contains a general description of each region and includes information on land resources as well as water resources. As is apparent in the region titles, the boundaries were strongly influenced by topographic and land resource characteristics. In addition to providing regional descriptions of the principal aquifer, the publication also notes the capabilities of various local or secondary aquifers. The regions, as defined, do not necessarily denote significant differences in the capability or potential utilization of the principal aquifer. These characteristics require more detailed analysis and can be strongly influenced by local hydrologic or use factors.

Other maps indicate the thickness of saturated rocks in the principal aquifer (Figure 4) and the amount of groundwater stored in the rocks (Figure 5) assuming an average of twenty percent pore space. These maps illustrate the amount of groundwater in the principal aquifer in any particular area within the state. Data were derived from both testhole drilling and registered irrigation wells (Figure 12) as well as any other miscellaneous drilling considered reliable. Figure 15 shows the location of test holes which are the major source of detailed information about the groundwater resource. Most of these tests resulted from a program of systematic drilling carried out as a cooperative project between the Conservation and Survey Division and the U.S. Geological Survey. Other drilling has been supported by specific hydrogeologic research projects and stratigraphic investigations.

Data from these test holes have been carefully collected, interpreted and filed. This framework of carefully documented information has been supplemented by drilling records of private contractors and other state and federal agencies. The general hydrogeologic characteristics of the groundwater reservoir in Nebraska have been described in a number of publications. Although detailed research has been done in specific areas, there is still much to be learned about the aquifer systems, particularly as they are subjected to the stress of utilization.



A statewide water-level monitoring project was begun in 1930 as a part of the cooperative groundwater program between the Conservation and Survey Division and the U.S. Geological Survey. Figure 16 illustrates the location of those wells measured during 1980. Over thirty agencies currently contribute data related to this project. The cooperative program serves a co-

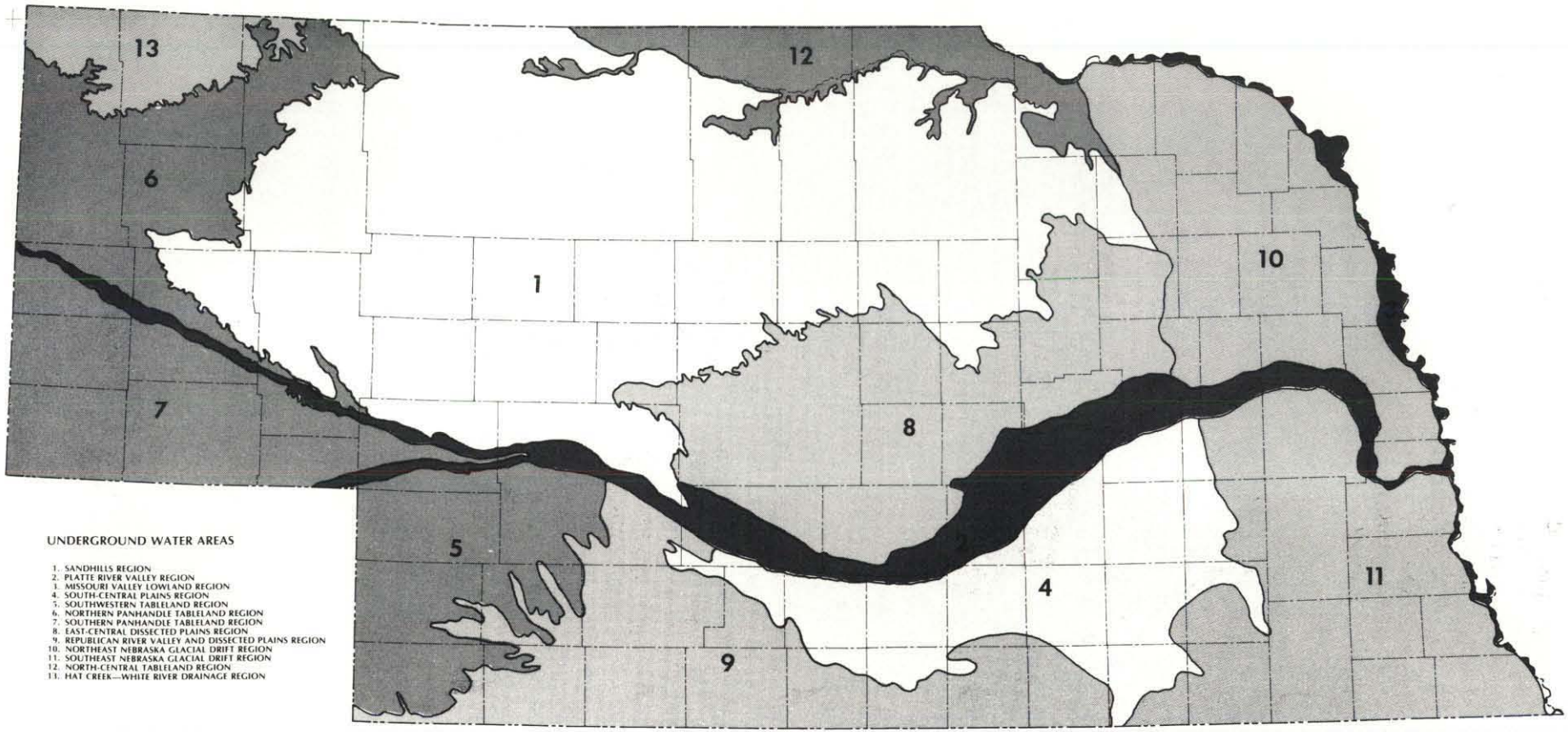


Figure 14 - Groundwater Areas of Nebraska

ordinating role and also operates a computer storage-retrieval system for the data.

The statewide network has provided long-term data on changes in water in storage and indicates where local significant water-level fluctuations are occurring. The original generalized appraisal of the state's groundwater resources now includes detailed local data for planning and evaluating development in specific areas. As a part of the cooperative program, and annual report is compiled summarizing the observation well data (Johnson and Pederson, 1981).

Both the coarse-grained and fine-grained rocks in the principal aquifer contain significant amounts of stored groundwater. However, the amount of water available for use is controlled by the rate at which it can move through the rocks and be extracted by wells. The transmissivity map (Figure 6) can be used to obtain an estimate of well yield.

In addition to current groundwater in storage, another source of supply is the annual recharge to the aquifer from precipitation. Although highly variable from season to season and year to year, an average annual rate of precipitation map can be constructed for the state. These rates vary from 16 inches per year in the northwest to 34 inches in the southeast. A part of this precipitation will percolate downward and recharge the groundwater supply. The rate at which this process occurs in any given area is dependent upon the amount and timing of precipitation, the intensity of evapotranspiration, the slope of the land surface and the thickness and permeability of material overlying the water table. Using these considerations, a map was constructed (Reed, 1967) illustrating an average annual amount of water added to the groundwater supply from precipitation (Figure 17). These values plus the groundwater in storage values provide an estimate of the potential total supply within the groundwater reservoir in each area in the state. In local areas, this supply is further enhanced by seepage from imported surface water.

A review was made of the current utilization of groundwater in Nebraska (Bentall and Shaffer, 1979). Significant amounts are extracted on a local basis for public supply, industry and power generation. Large numbers of rural-domestic wells are scattered across the state. These users have little impact on total water availability and are best managed by local consideration of alternatives. By contrast, irrigation has the characteristics of significant consumptive use and broad distribution which would allow state or substate level management plans to be effective.

Soil association maps at a scale of 1:250,000 were used to estimate, on a township basis, land suitability for irrigation. A map was prepared (Figure 18) illustrating projected maximum irrigation development from groundwater based only upon land suitability. This map illustrates one aspect of the maximum level of stress that could be placed upon the principal aquifer by utilization of groundwater.

Another significant variable in use is the amount of water extracted by each well or for any unit area. For purposes of analysis, a well equivalent was defined as the installation(s) necessary to irrigate one quarter of a section (160 acres). This well equivalent is similar to the average current center-pivot system as related to the area irrigated. All of the evaluations for maximum utilization are based upon this well equivalent definition.

There can be significant variation in the amount of water consumptively utilized by irrigation. This variation is created by factors such as type of crop, efficiency of operation, land capability and local climatic conditions. Thus for each well equivalent, a range of consumptive water use values were incorporated into the analysis. 150 acre feet per year for each well equivalent was considered as a value approaching average consumptive use of historic irrigation practices. 120 acre feet per year for each well equivalent was considered as a value for the consumptive use that could be achieved through efficient irrigation techniques without significantly affecting economics or cropping practices. 90 acre feet per year for each well equivalent was considered as a value for consumptive use which could only be achieved by significant changes in irrigation techniques and cropping practices. All of these values are for consumptive use--water that permanently is removed from the groundwater supply in any particular area.

AVAILABLE WATER IN STORAGE

Nebraska's groundwater resource is not uniformly distributed throughout the state. It has been estimated (Bentall and Shaffer, 1979) that the state is underlain by 1.875 billion acre feet of recoverable groundwater of good quality. Most of this resource is contained in the principal aquifer. However, as indicated on the Groundwater in Storage map (Figure 5), the majority of the groundwater is concentrated in the central one-third of the state. This map assists in identifying areas that have an adequate supply for potential use and areas where the potential use exceeds aquifer capability.

As has been demonstrated, control of irrigation development is the most obvious mechanism to be considered in creating state or regional management procedures for effective utilization of

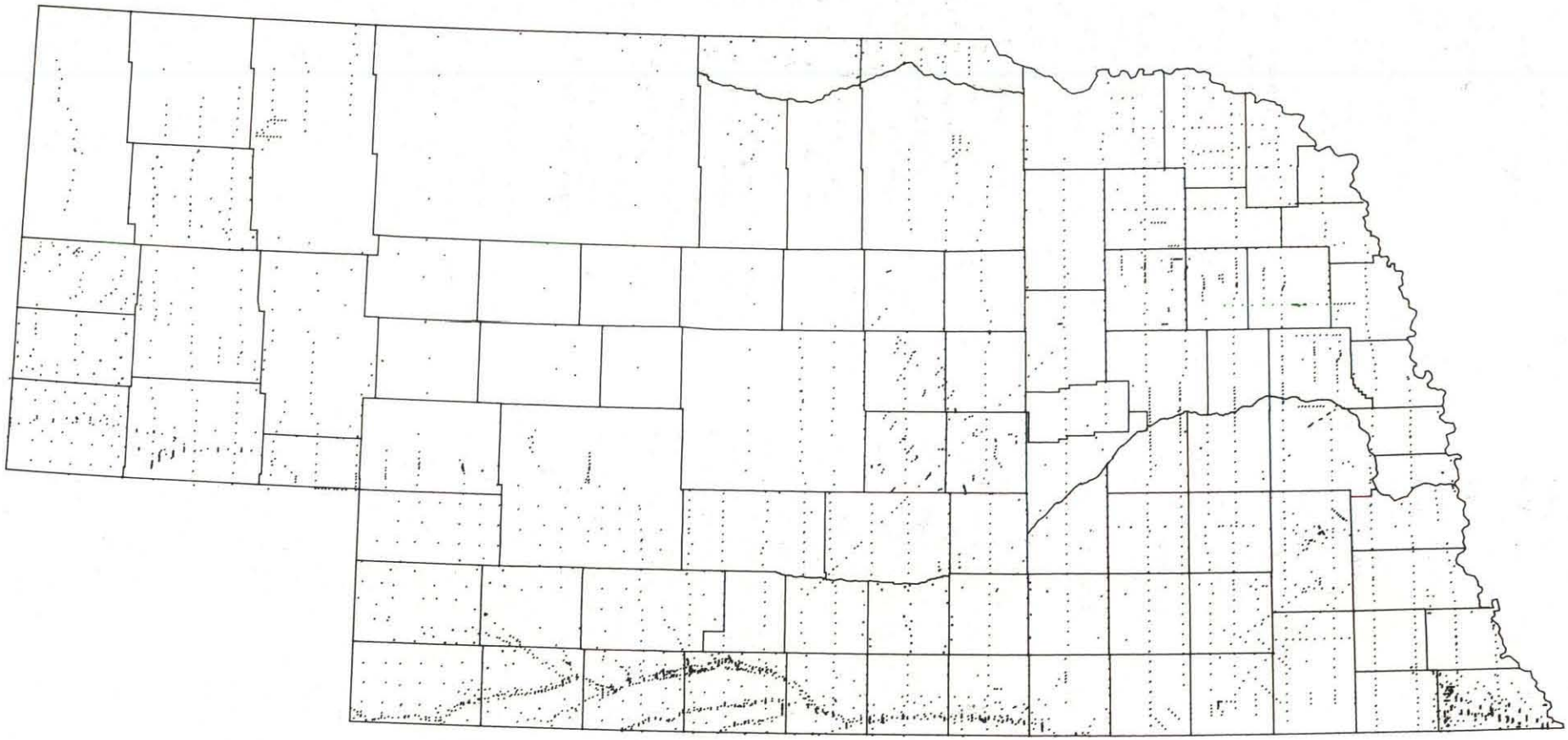


Figure 15 - Location of Test Drilling for Hydrogeologic Investigations

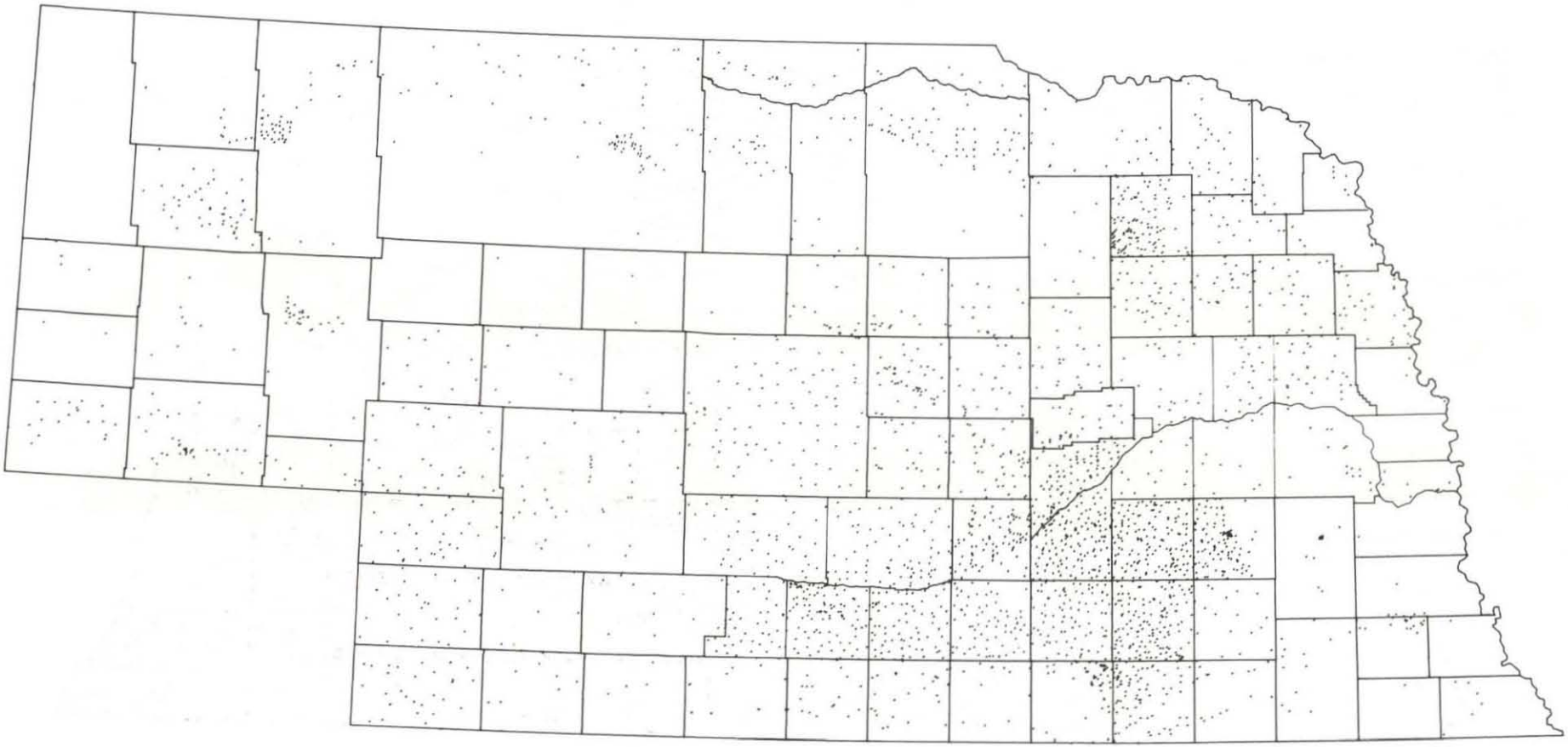


Figure 16 - Location of Observation Wells for the Groundwater Level Monitoring Program

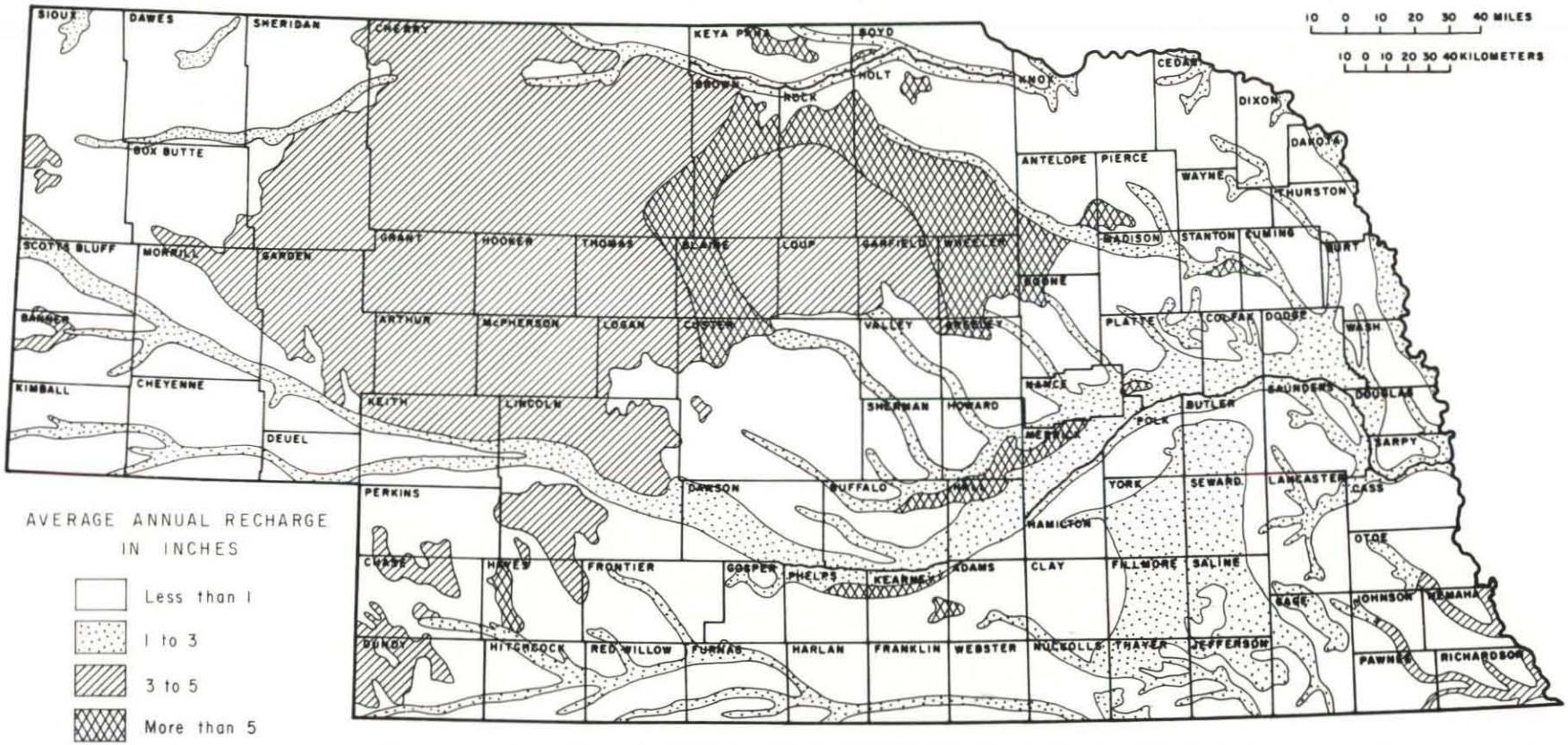


Figure 17 - Average Annual Recharge to Groundwater from Precipitation Sources

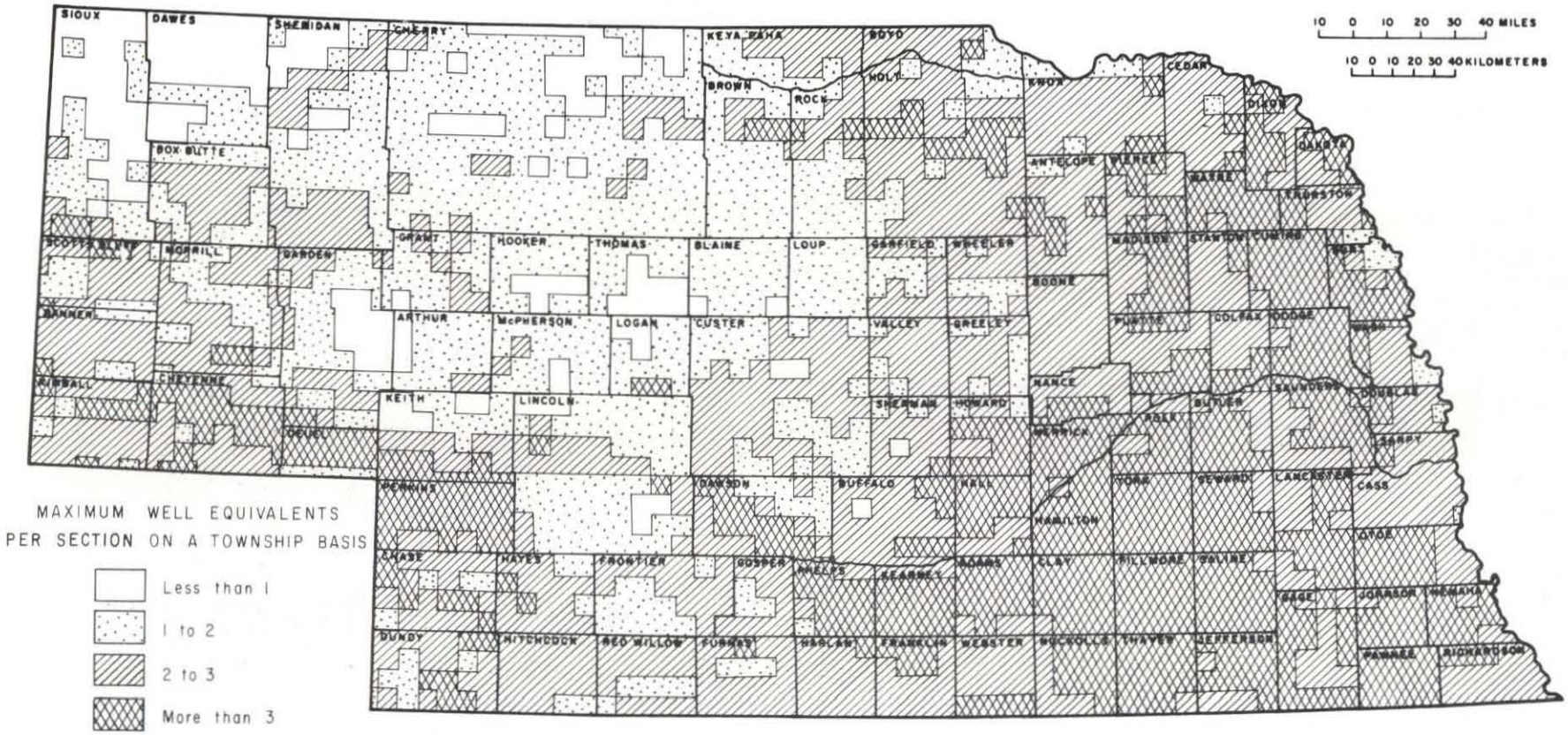


Figure 18 - Maximum Irrigation Development from Groundwater Based on Land Suitability

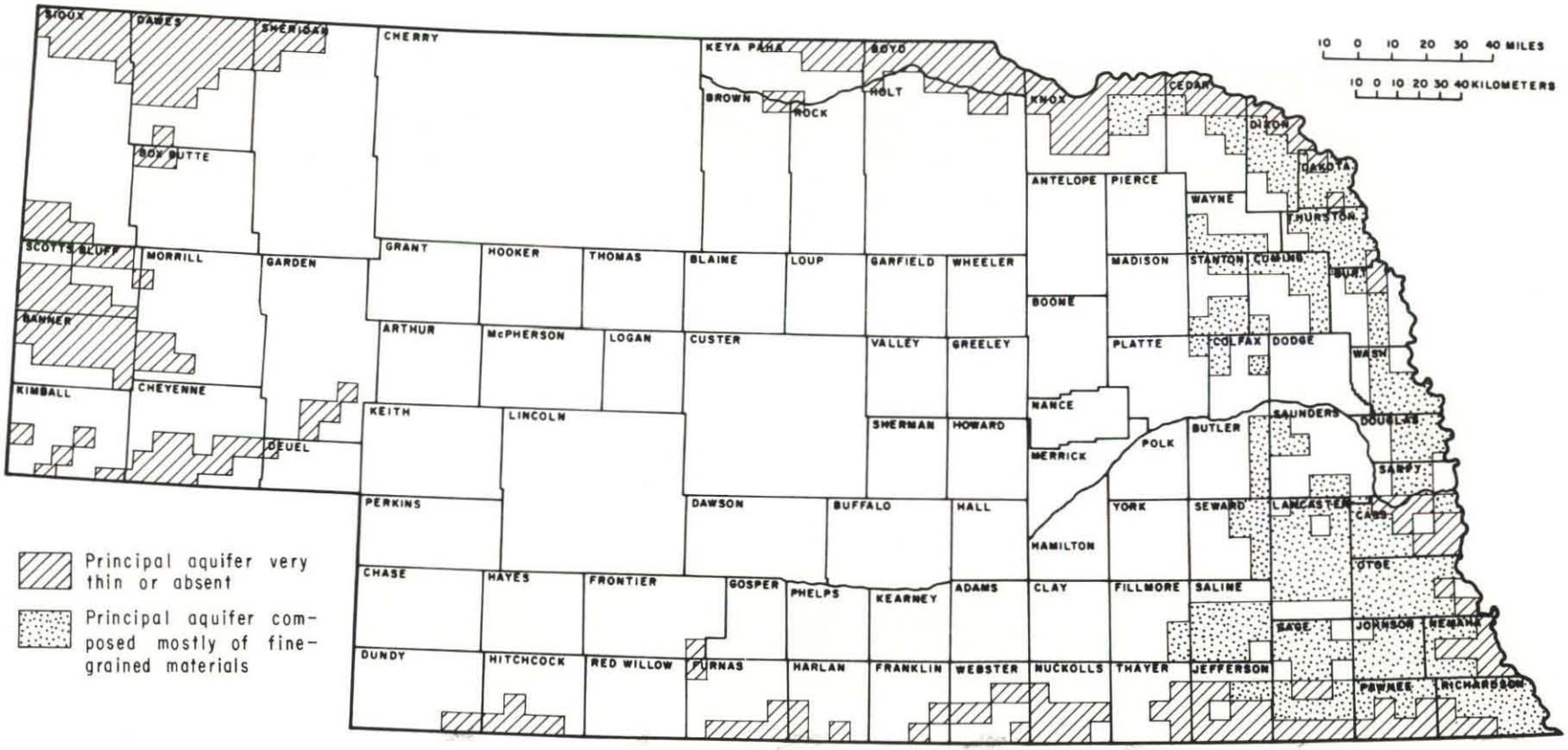


Figure 19 **Townships Containing Areas of Low Potential for Groundwater Utilization from the Principal Aquifer**

groundwater. Many areas near the margins of the state lack sufficient groundwater in storage to sustain significant irrigation development (Figure 19). In these areas the principal aquifer is very thin or absent. In other areas, the principal aquifer is composed mostly of fine-grained material that yields water very slowly and is suitable only for low volume rural-domestic supplies. Much of the eastern one-fourth of the state (Figure 19) has these low yield characteristics. Thus for considerable areas of Nebraska, development of groundwater is a local concern and management techniques will be dependent upon site specific conditions. In most areas efficient utilization will require detailed local studies of the hydrogeologic system.

Local aquifer systems that are essentially isolated from the principal aquifer also would not be susceptible to state or regional management procedures. These groundwater reservoirs consist of channel deposits in restricted bedrock valleys, either modern or ancient, and permeable zones present within the upper portion of the bedrock. These local aquifers also will require site-specific analysis and formulation of unique development procedures.

The principal aquifer in portions of Nebraska has quantities of groundwater in storage that would appear to exceed use-demands over any forseeable period. These areas were identified by the following procedures. For each township, the quantity of groundwater (Figure 5) was compared to the maximum irrigation utilization based upon land capability from Figure 18. A series of these comparisons was generated by varying the consumptive use per well equivalent. It was assumed, for maximum stress, that these well equivalents were installed rather than progressively developed.

Figure 20 illustrates those townships where the current amount of groundwater in storage exceeds the 200 year demand at a rate of 150 acre feet/year. The 200 year projection is assumed to exceed the time-frame for any anticipated management strategy. Thus for significant areas of Nebraska even maximum utilization would not cause aquifer exhaustion.

A similar resource/utilization comparison was made on the basis of a consumptive use per well equivalent of 120 acre feet/year. Figure 21 outlines those areas not depleted over the 200 year period. Figure 22 illustrates the effects of a 90 acre feet/year rate of consumptive use per well equivalent. The implementation of more efficient and innovative irrigation techniques would obviously expand the area of 200 year aquifer capability. However, even historic irrigation practices and maximum development would not exceed current aquifer storage for a large portion of Nebraska (Figure 20).

AVAILABLE RECHARGE AND POTENTIAL SALVAGE

Groundwater stored in the principal aquifer in Nebraska is a part of an active hydrologic system. Lateral flow within the aquifer is too slow in most areas to have a significant effect upon withdrawal and thus most recharge to the aquifer is

derived from precipitation in the local area. Under natural conditions, the recharge and discharge values of an aquifer are in balance. Groundwater withdrawal by pumping will result in some combination of decrease in storage, increase in recharge and decrease in discharge. The relative values of recharge and discharge will determine both the change in volume of water in storage and any resulting water level change. Optimum conditions would be those that allow maximum groundwater utilization with only minimal change in the water table. The resulting changes in recharge and discharge could be minimized in shallow water table areas by salvage of streamflow and evapotranspiration.

Figure 17 is a map illustrating the average annual recharge to groundwater from precipitation sources under natural conditions (Reed, 1967). A number of factors can influence this rate of recharge. The two most significant variables are the amount of precipitation and the rate at which the water can move through the material overlying the aquifer. The average increase of 18 inches in annual precipitation across the state from west to east contributes a general parallel increase in the regional recharge rate. More

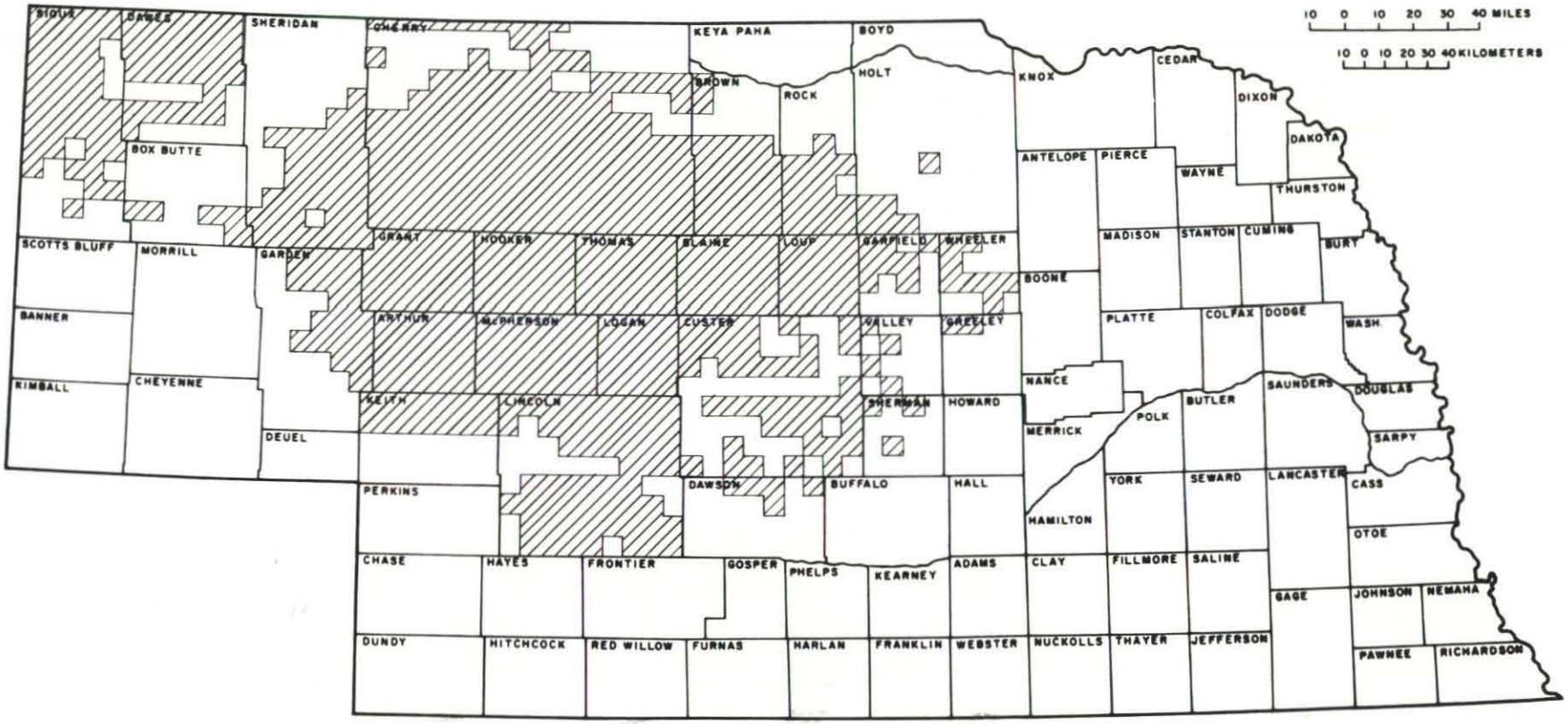


Figure 20 - Townships Where Groundwater in Storage Exceeds 200 Year Requirements of Maximum Projected Irrigation Development (Demand Rate Equals 150 Acre Feet/Year Per Well Equivalent)

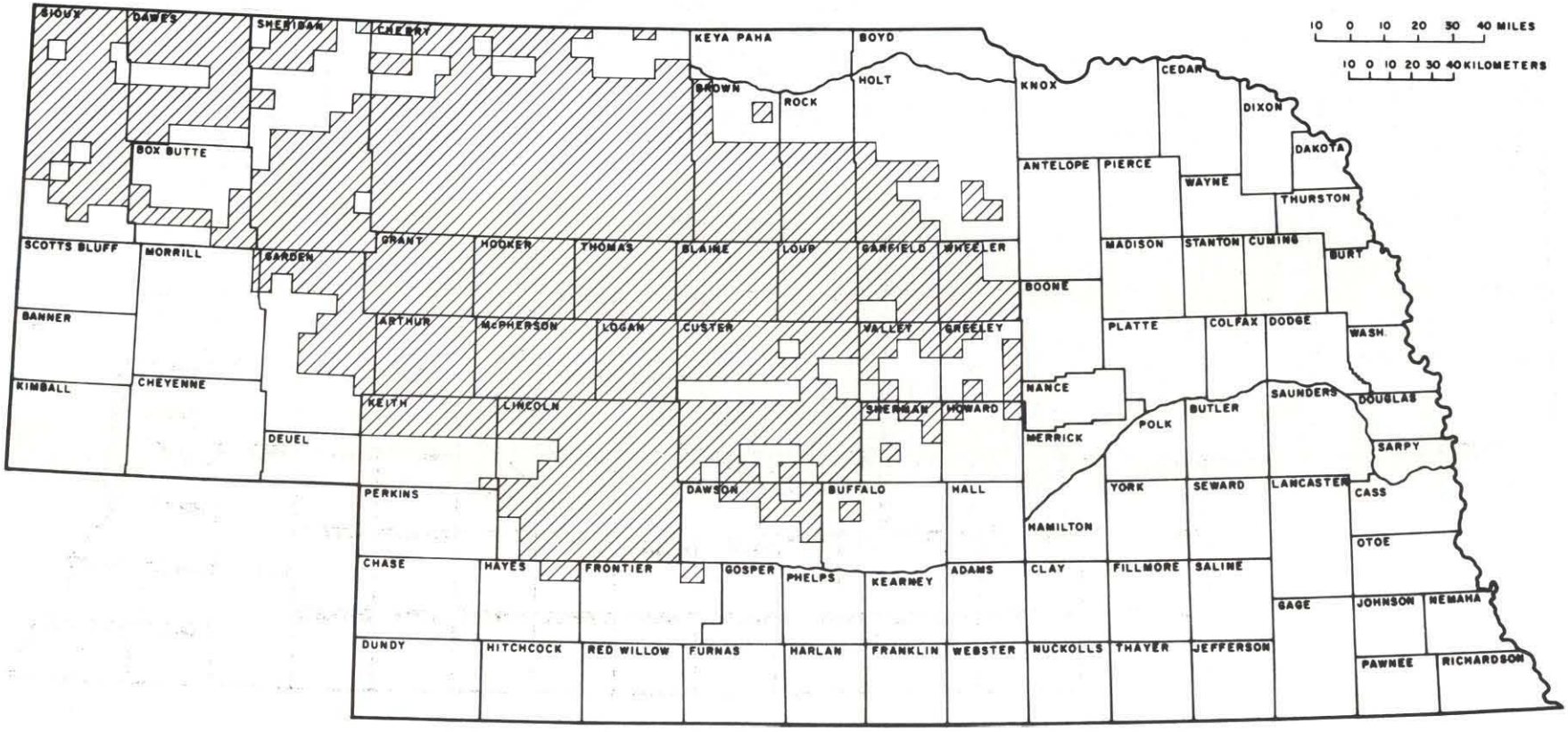


Figure 21 - Townships Where Groundwater in Storage Exceeds 200 Year Requirements of Maximum Projected Irrigation Development (Demand Rate Equals 120 Acre Feet/Year Per Well Equivalent)

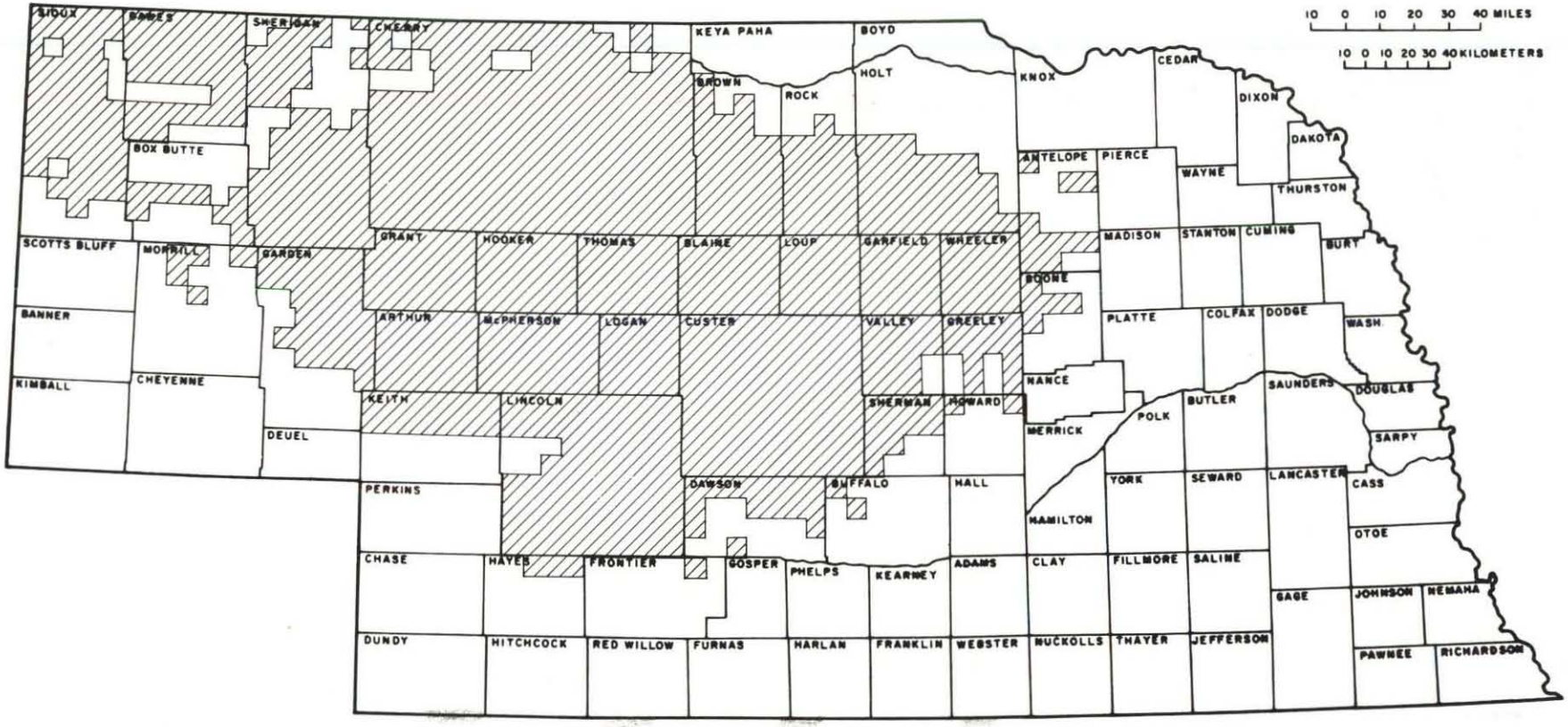


Figure 22 - Townships Where Groundwater in Storage Exceeds 200 Year Requirements of Maximum Projected Irrigation Development (Demand Rate Equals 90 Acre Feet/Year Per Well Equivalent)

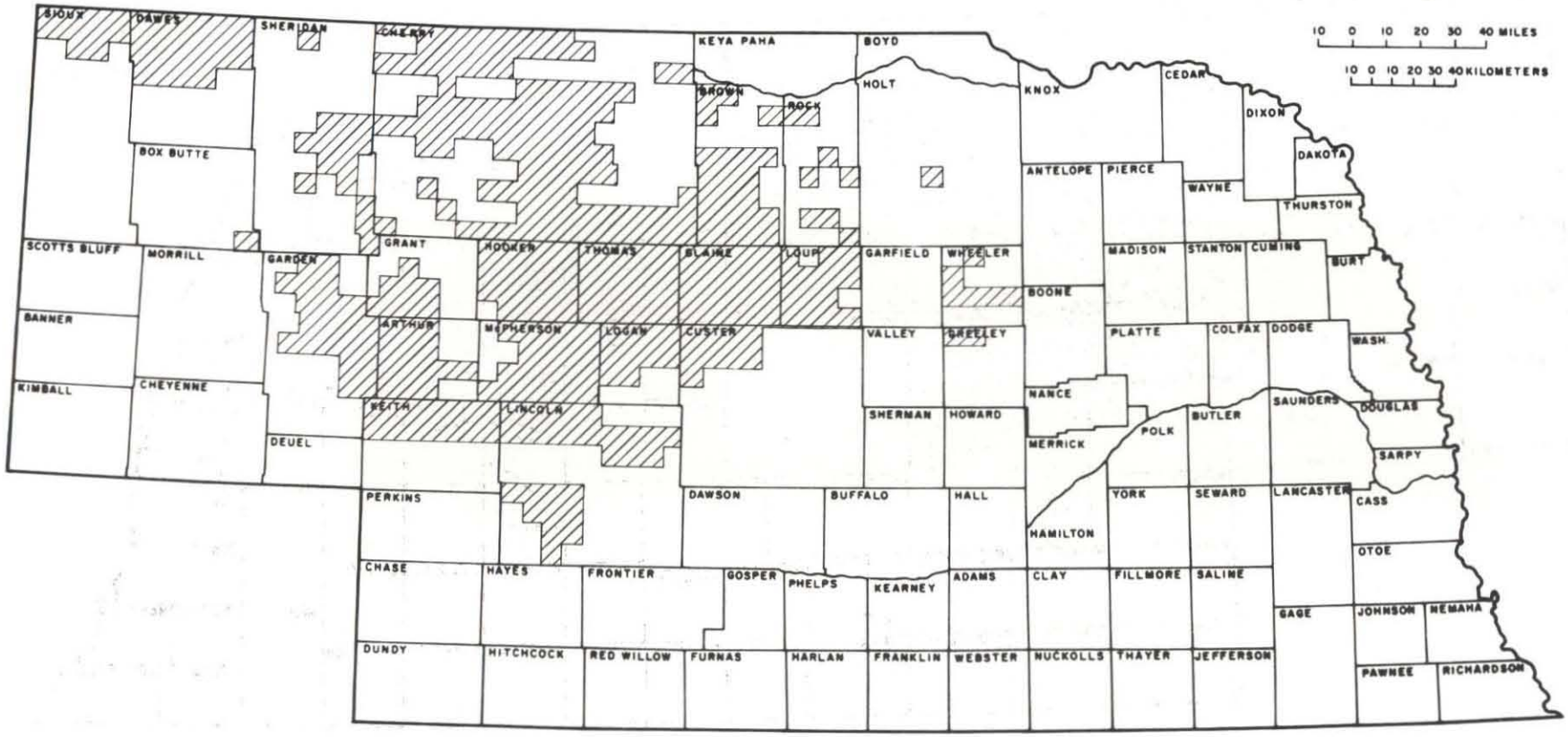


Figure 23 - Townships Where Annual Recharge From Precipitation Exceeds Maximum Projected Irrigation Development (Demand Rate Equals 150 Acre Feet/Year Per Well Equivalent)

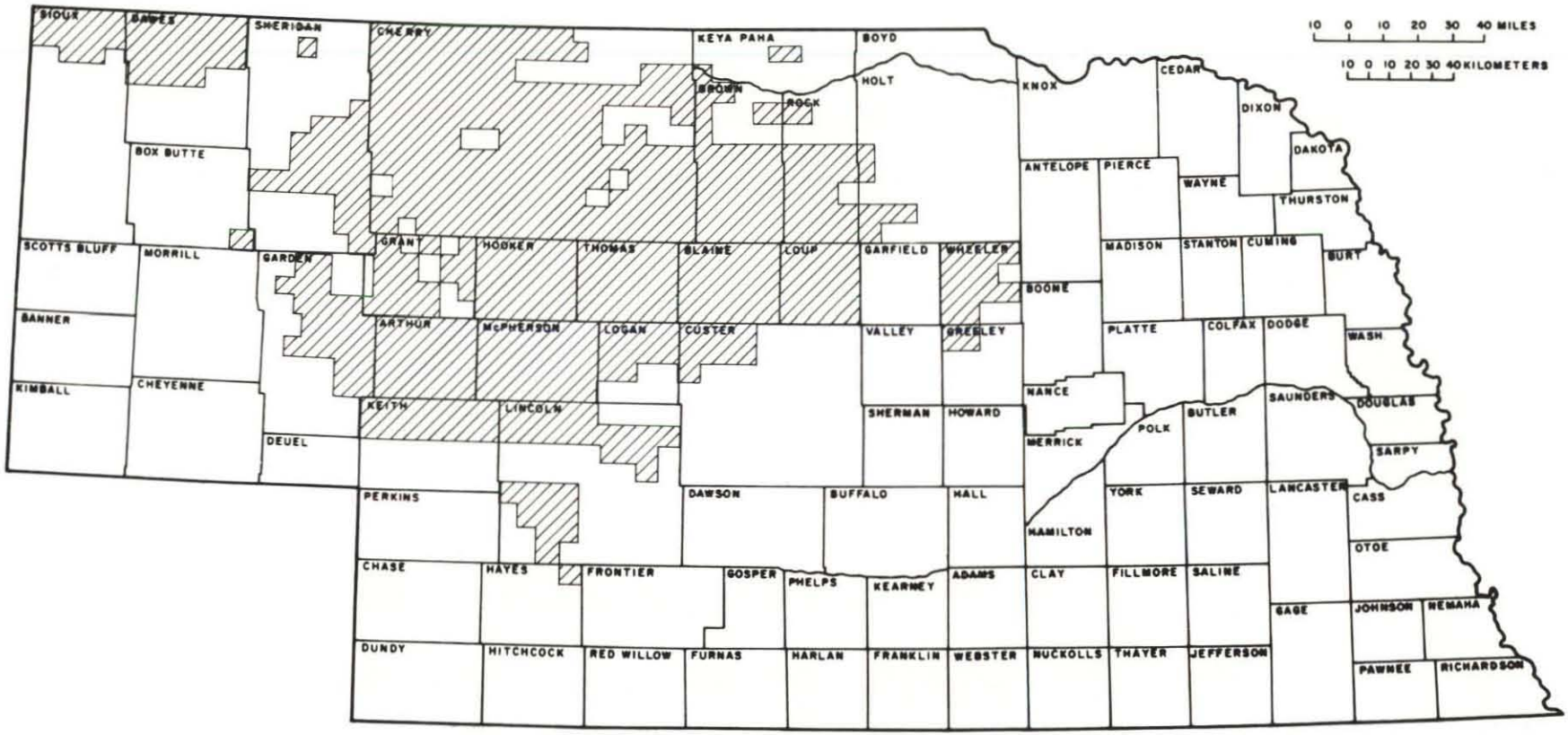


Figure 24 - Townships Where Annual Recharge From Precipitation Exceeds Maximum Projected Irrigation Development (Demand Rate Equals 120 Acre Feet/Year Per Well Equivalent)

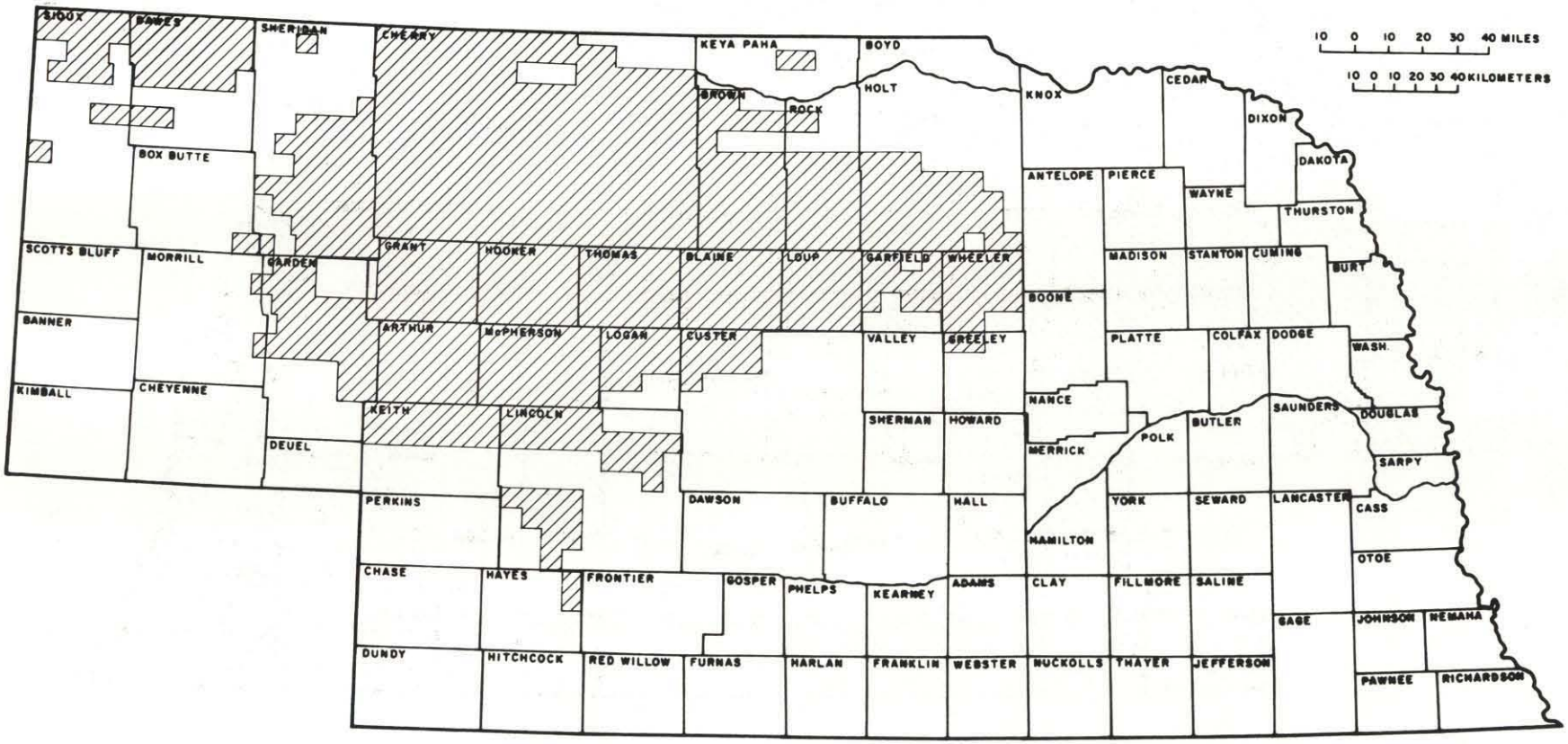


Figure 25 - Townships Where Annual Recharge From Precipitation Exceeds Maximum Projected Irrigation Development (Demand Rate Equals 90 Acre Feet/Year Per Well Equivalent)

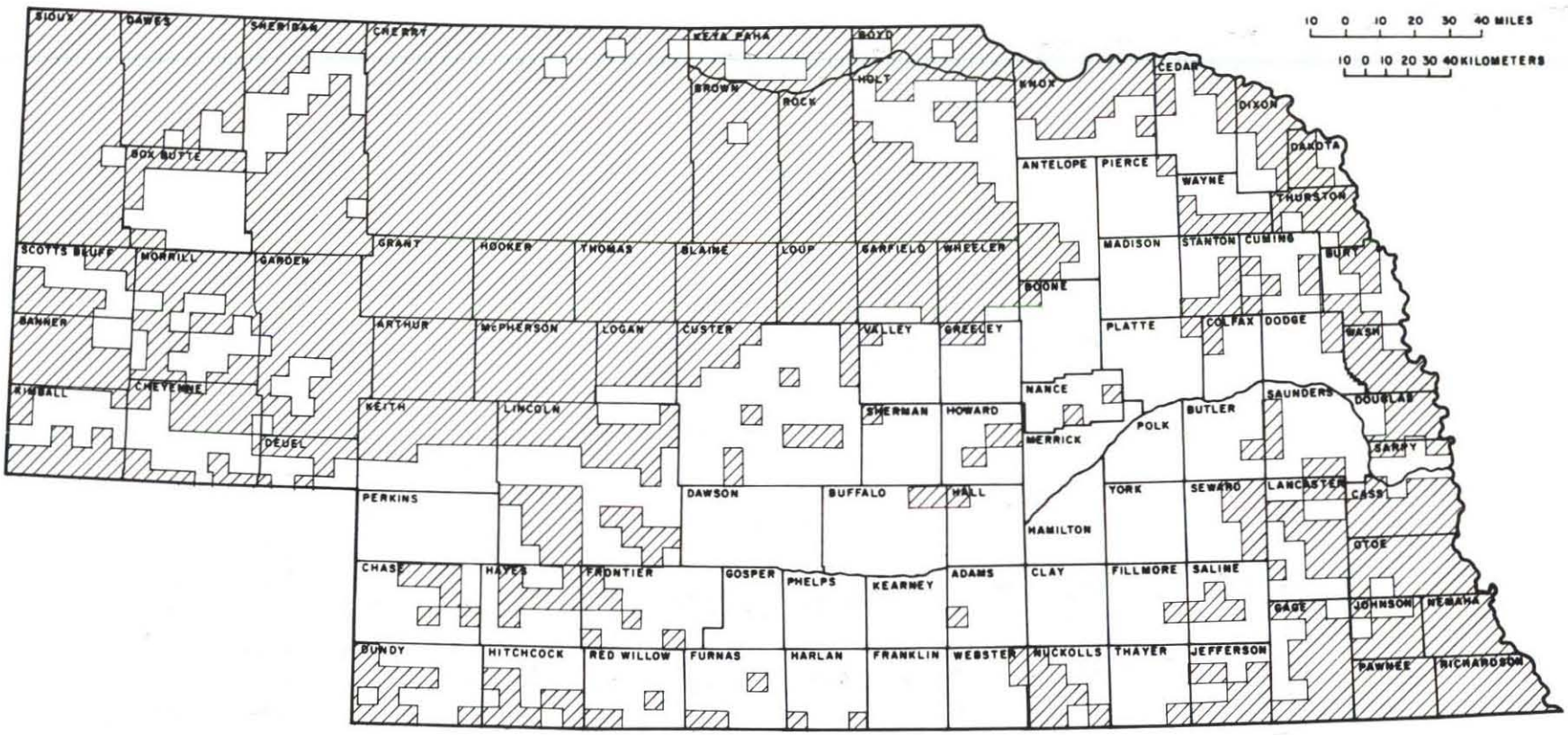


Figure 26 - Townships Where Annual Recharge From Precipitation Exceeds 1979 Level of Irrigation Development (Demand Rate Equals 120 Acre Feet/Year Per Well Equivalent)

obvious are the areas within Nebraska where sandy soils and more permeable mantlerock enhance water movement through the rootzone and downward into the principal aquifer. Groundwater withdrawal by pumping, particularly in areas of rapid recharge, could enhance the amount of recharge by allowing more rapid infiltrations through the rootzone and beyond the immediate influence of losses by evapotranspirations. Thus an additional quantity of recharge/salvage water would be added to the aquifer beyond that available under natural conditions from precipitation sources.

A series of maps was generated comparing levels of irrigation utilization and the minimum recharge that is provided by precipitation. For each township, the average annual recharge (Figure 17) was compared to the maximum well equivalents from Figure 2. It was assumed that these well equivalents were in place rather than progressively installed.

Figure 23 illustrates those townships where average annual recharge from precipation exceeds potential utilization by maximum well equivalents each having a consumptive demand of 150 acre feet/year. This level of utilization is

the maximum stress that could be expected to be placed upon the principal aquifer by irrigation development.

A similar recharge/utilization comparison was made on the basis of 120 acre feet/year per well equivalent (Figure 24). A more restrictive consumptive use of 90 acre feet/year and the same comparative process yields Figure 25. For large areas of Nebraska, even the maximum level of irrigation development projected on Figure 23 would not utilize water in excess of that provided by natural recharge from precipitation. The supply available on an annual basis can be significantly increased by including the potential salvage by a decrease in natural evapotranspiration. All comparisons made related to recharge in Figures 23, 24, and 25 assume immediate installation of maximum development.

For an additional perspective a similar comparison was made between recharge and the level of irrigation development at the end of 1979. Only the effects of the 120 acre feet/year consumptive use per well were analyzed. Figure 26 illustrates the townships in which the quantity of annual recharge exceeds the demand of the 1979 level of development. The eventual level of development will lie somewhere between Figures 23 and 26. It is apparent that on an annual basis, large volumes of water are available from precipitation even when compared to the projected maximum utilization.

As was stated earlier, groundwater in the principal aquifer is in a dynamic balance with the rest of the hydrologic system. The amount of recharge that could be utilized without obvious impact on other parts of the system will vary depending upon local conditions. Historical records do indicate that in areas conducive to rapid recharge, salvaged evapotranspiration can sustain a high rate of utilization. Withdrawals in such areas could occur without obvious effect upon regional streamflow. Priority should be placed upon more clearly identifying these areas of balanced utilization.

IMPACTS OF DEVELOPMENT

A high level of groundwater utilization is possible in some areas without significantly affecting the capability of the principal aquifer. Figures 20 through 25 illustrated the aquifer capability under extreme stress conditions. Figure 26 illustrated the impact of the 1979 level of development. It should be obvious that under more realistic projections of development even larger ares of the state have a high potential for utilization without major negative impact on the principal aquifer. In many areas this potential will be enhanced by the combined effects of recharge and salvage and the utilization of groundwater in storage. Even partial depletion of the aquifer, if anticipated, need not have significant impact on more than a local area.

An obvious concern related to intensive utilization of an aquifer is lowering of the water table in areas where depths to water are relatively shallow. Townships containing dominant areas with depth to water less than 50 feet are illustrated on Figure 27. This figure was derived

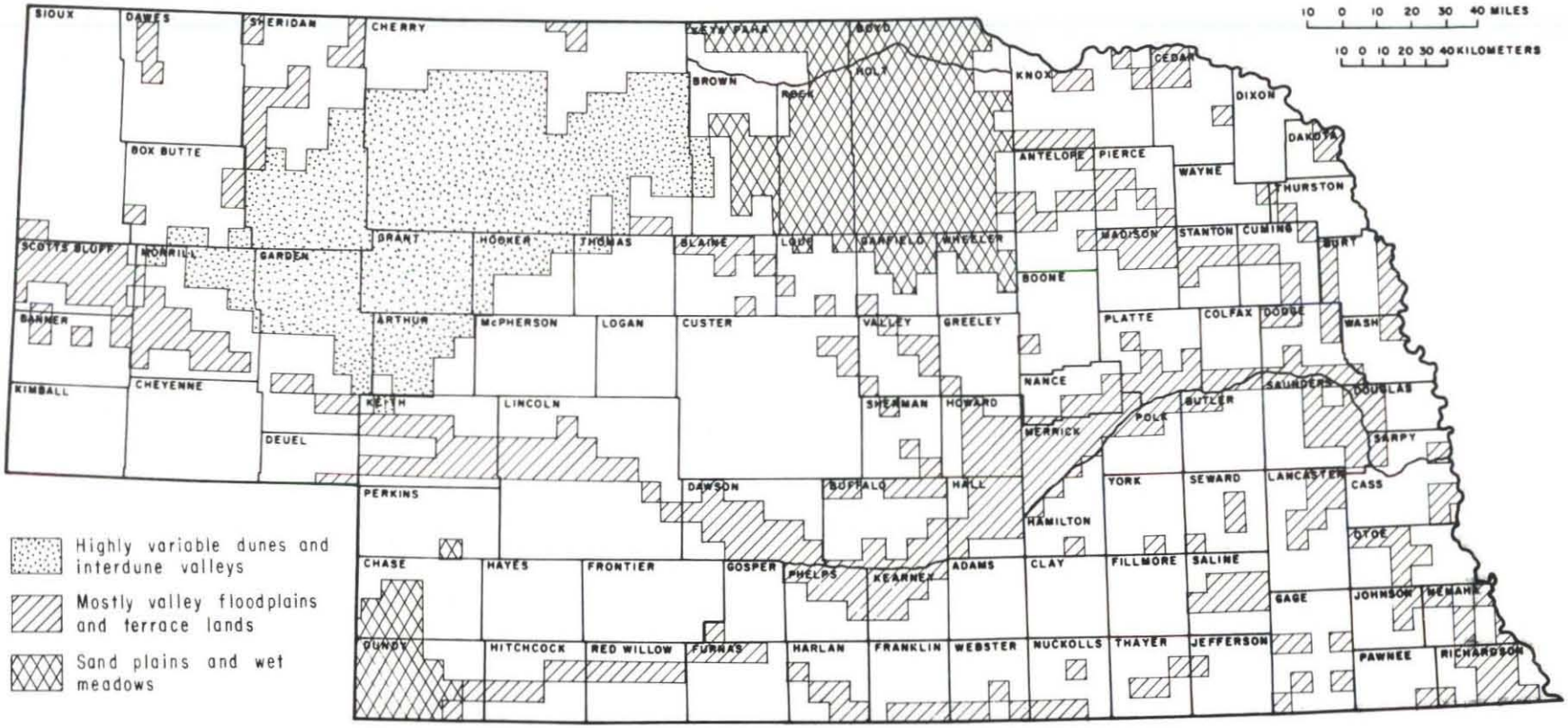


Figure 27 - Townships Containing Areas of Depth to Water Less Than 50 Feet

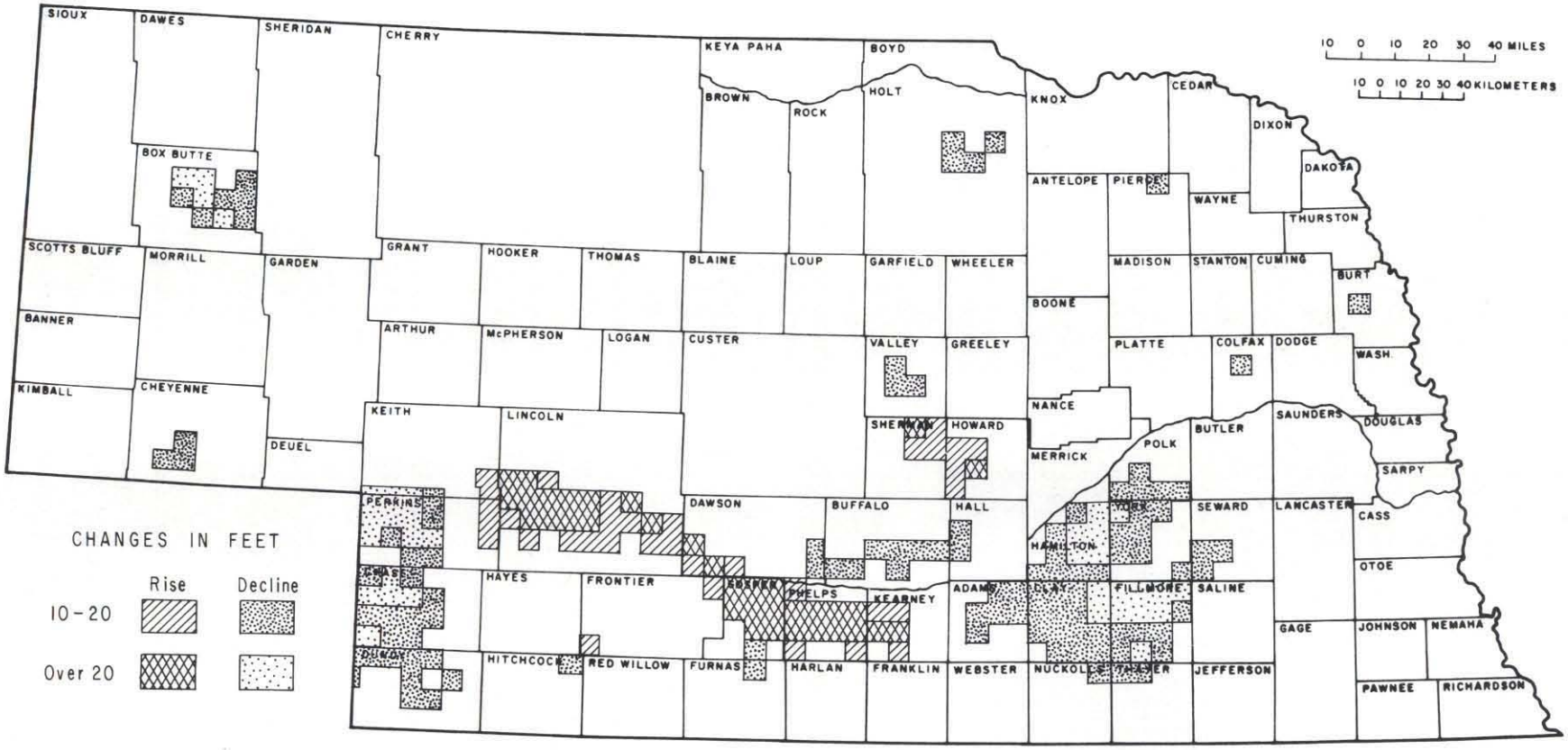


Figure 28 - Townships Containing Areas of Significant Water Level Changes Since Pre-development

from Figure 8. Obvious environmental impacts could occur within these areas if an active groundwater to surface water interface was disrupted by a lowering of the water table. Research indicated that this active zone of natural withdrawal usually does not exceed depths of 20 feet. The 50 feet zone in this study was dictated by mapping techniques as well as providing some allowance for the lack of complete data.

Three subregions of shallow water table were distinguished on the basis of land characteristics and implied relationship to the groundwater system. One subregion seems mostly to be related to the floodplains and low terrace lands of

major streams although this type may include some perched water tables in eastern Nebraska. It is suggested that even a high rate of local utilization of the groundwater in these areas will not significantly lower the water table. Natural vegetation and wetlands have expended significant amounts of water by evapotranspiration. The substitution of irrigated cropland should not alter this balance. This transition has occurred in portions of the central Platte River valley with no obvious effect on either the streamflow or the water table (Bentall and Shaffer, 1979). Development in other shallow water areas of the type would seem possible without lowering the water table.

A second subregion within the less-than-50 feet to water area is located in the western sandhills. In this subregion topography and depth to water is highly variable. Potential for irrigation development is not high due to the dune topography. Local irrigation is possible in the interdune valleys which are shallow water table areas. Even maximum utilization in these areas would not exceed the potential for salvaged evapotranspiration. There would be little negative impact on either regional stream flow or the water in storage.

A third subregion is in northcentral and southwestern Nebraska. The portion of this subregion lying in Rock and southern Holt counties would be expected to have salvage potential exceeding the demand created by development so that no significant impact is expected upon the water table. However in northern Holt, Boyd, and Keya Paha counties and much of southwestern Nebraska, recharge from precipitation is considerably lower (Figure 17). The soils and materials overlying the water table are much less permeable than in other portions of the subregion. As would be expected, areas developed for irrigation are utilizing groundwater in storage and lowering the water table (Figure 28).

In summary, this general analysis would suggest that even maximum irrigation development (Figure 18) would not create statewide impacts on the aquifer. Figure 3 illustrated those areas of the state where the potential for groundwater utilization is low and management is a local concern. Figure 20 through 22 demonstrated that in large areas of the state the groundwater resource is capable of sustaining maximum utilization for periods exceeding 200 years. Also, in many areas of shallow water tables (Figure 27), the potential for salvage of evapotranspiration would allow high rates of utilization without significant effects on groundwater in storage.

In the remaining areas of the state, there is a high potential for a decrease in groundwater in storage. In these areas, the water table is naturally below any active interface with the surface water system and a decline in water levels would not have visable local impact. Development is well underway in large parts of these remaining areas and management decisions will need to be based on detailed evaluations of the local hydrogeologic system. It should be noted that irrigation development also can have the effect of increasing the amount of groundwater in storage. Seepage of surface water from reservoirs and distribtution systems has created a rise in groundwater levels (Figure 28) in portions of the state.

The material presented in this chapter has demonstrated the differing potential for development of the principal aquifer across the state. In most cases, additional detail is needed about local aquifer capability prior to implementing the management process. Although the study emphasis has been on aquifer capability, even local management decisions need to consider all aspects of the hydrologic system.

Chapter 3

Substate Area Analysis

INTRODUCTION

Nebraska is underlain by large quantities of groundwater. However, this resource is not evenly distributed throughout the state nor is it isolated from other parts of the natural resource system. Thus, efficient utilization of the groundwater will require different techniques of management for the various subareas of the state. Within these areas, development and management of development have reached differing levels. There is also a wide variation in the availability of hydrogeologic data from area to area.

The perspective of this policy issue study was at the statewide level. There are, however, subareas within the state which contain a common level of potential development/resource stress. These substate areas (Figure 29) were defined by factors such as available physical resources, potential type and magnitude of development, permanency of impacts and obvious institutional conditions. These boundaries were then adjusted to county boundaries to provide compatibility with other data sets and other studies. In addition to the factors noted in the analysis at the statewide level, the unique resource characteristics and impacts of development will be reviewed for each substate area.

AREA 1

Area 1 consists of Sioux and Dawes counties in northwestern Nebraska. The northern one-third of this area is characterized by moderate to steep slopes and very thin soils overlying bedrock. The land is very poorly suited for development (Figure 18). In the southern portion of the area, land suitability is more favorable for irrigation. The principal aquifer is very thin or absent in the northern part of Area 1 (Figure 19). Only low-yield wells can be developed in the stream alluvium; deeper secondary aquifers contain water of poorer quality. Groundwater in storage (Figure 5) exceeds 100 feet within the southern portion of Area 1.

Depth to water is more than 100 feet in much of Area 1 that is favorable for irrigation development and exceeds 200 feet in depth under large portions (Figure 8). Except for several townships, annual recharge from precipitation is very low (Figure 17). Even low levels of irrigation development would consume groundwater from storage and cause lowering of the water table. Due to the current depth to water, this decline in water levels would have potential surface impacts only locally along streams. Even in these areas, the combination of recharge and salvage might support the desired levels of development. Any local development for irrigation, mineral resource extraction or high-yield wells for power generation would require site-specific analysis and management.

AREA 2

Area 2 contains the counties of Sheridan and Box Butte in northwestern Nebraska. Parts of northern and central Sheridan County have very rugged topography poorly suited for irrigation (Figure 18). North-central and southern Sheridan County and much of Box Butte County have favorable land suitability for development. Central Sheridan has highly variable dune topography and is less-well suited. Except for the extreme northern parts of both counties, groundwater in storage (Figure 5) is plentiful, usually exceeding 40 feet and ranging up to 160 feet.

Depth to water is highly variable in Sheridan County due primarily to the topography (Figure 8). In areas favorable for development in Box Butte, water depths exceed 100 feet. The amount of annual recharge (Figure 17) and groundwater in storage (Figure 5) in southern Sheridan County would suggest that the potential levels of irigation development would not have significant adverse impacts. However, in those portions of Area 2 most favorable for development, annual recharge is low and, as is already obvious, with-

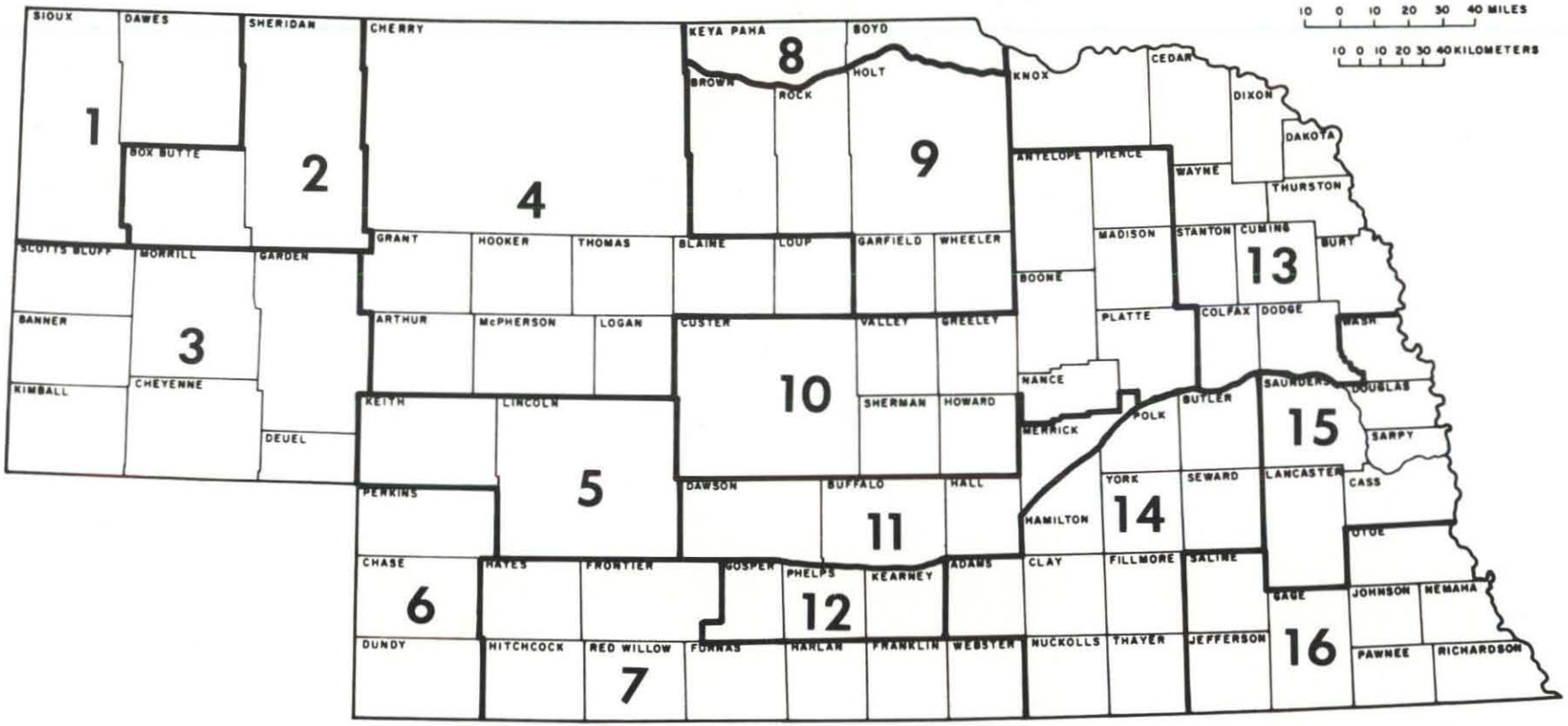
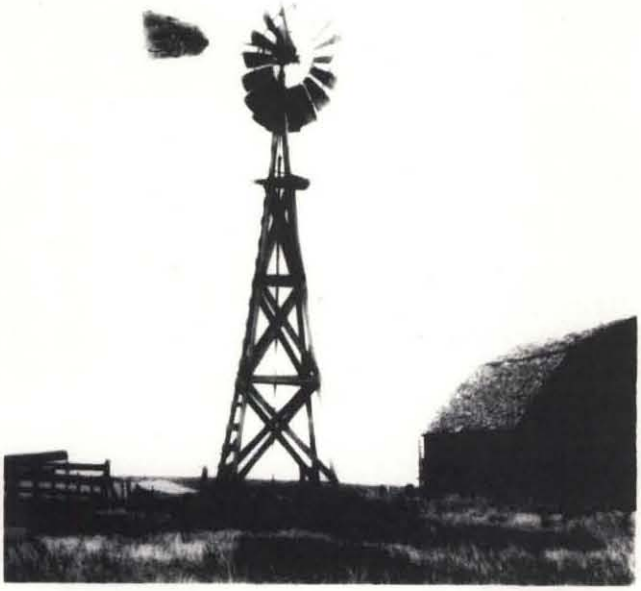


Figure 29 - Substate Areas for Analysis of Potential for Groundwater Development

drawals reduce groundwater in storage (Figure 28). Declines in water levels in Box Butte have not been significant in the shallow water table areas. Declines could have occurred in west central Sheridan County except for the utilization of surface water for irrigation. However, as groundwater development proceeds, declines should be anticipated. Of particular concern would be their impact upon the areas of shallow water tables.

AREA 3

Area 3 includes the counties of Scotts Bluff, Banner, Kimball, Morrill, Cheyenne, Garden, and Deuel. Except for a portion of eastern Garden County, land suitability is favorable for development (Figure 18). The principal aquifer is very thin or absent in much of northwestern and southern Area 3 (Figure 19). For most of the remainder of the area, groundwater in storage exceeds 40 feet and ranges up to 120 feet. Annual recharge from precipitation (Figure 17) is low except in the stream valleys and in the sandhills in northeastern Area 3.



The most advantageous combination of groundwater availability from the principal aquifer and land suitability is in northern Kimball and Cheyenne and parts of Morrill and Garden. Depth to water exceeds 200 feet in much of these areas and even low levels of irrigation development will cause declines. Similar trends are expected for aquifers in northern Banner and southern Cheyenne. Maximum irrigation development in the shallow water table area of northern Garden would not significantly affect water in storage. An additional factor in development in this area would be the impact of the current water quality in the wetlands and lakes. Another unique area which would require more local analysis prior to assessing developmental impacts is the North Platte valley.

AREA 4

Area 4 contains the counties of Cherry, Grant, Arthur, Hooker, McPherson, Thomas, Logan, Blaine, and Loup. The potential for irrigation development is low for most of the area based upon land suitability (Figure 18). Except for northern Cherry County, groundwater in storage (Figure 5) exceeds 100 feet within the area. Annual recharge is high due to the permeable materials overlying the water table (Figure 17).

Depth to water (Figure 8) is highly variable due to the dune topography. Many of the interdune wetlands reflect the water table. Large total withdrawals could be made in Area 4 without reducing storage or streamflow appreciably because pumping from wells would salvage groundwater now lost by evapotranspiration. Therefore, the management of irrigation development in this area should focus on impacts related to quality of water, loss of wetlands and sensitivity of land rather than quantity of groundwater.

AREA 5

Area 5 contains Keith and Lincoln counties. Land suitability for irrigation (Figure 18) ranges from very low in the areas of rugged topography

to high in the floodplains. Water in storage in Keith County averages 40 feet while in Lincoln County it ranges from 80 up to 140 feet. Other than in the valley of the Platte, depth to water is over 100 feet and locally exceeds 200 feet in several areas.

Annual recharge from precipitation is high in the sandhills of northern Keith and Lincoln and southwestern Lincoln and in the stream valleys. In other parts of Area 5, natural recharge is low. Water table rises in excess of fifty feet have been created in central Lincoln County by the effect of seepage from the reservoirs and canal systems. In that part of Area 5 north of the Platte valley, irrigation development is not expected to adversely impact the volume of water in storage. South of the Platte valley large-scale withdrawals could be expected to reverse rising trends of the water table and create progressive decline in water levels. Detailed studies are necessary to determine the effect of development within the valley where considerable numbers of wells already are installed.

AREA 6

Area 6 contains the counties of Perkins, Chase, and Dundy in southwestern Nebraska. The land suitability ranges from low in sandhill portions to very high on the upland plains (Figure 18). The annual recharge from precipitation is higher in the sandhill portions (Figure 17). In the valleys and throughout most of western Dundy and Chase, depths to water are less than 50 feet (Figure 1). In the upland plains areas depths to water are over 100 feet and in places exceed 200 feet.

The principal aquifer is very thin or absent in the southern margin of Area 6 although there are some local valley-fill aquifers (Figure 5). Groundwater in storage averages 40 to 50 feet under most of the remainder of Area 6. Irrigation development has reached moderate to high levels in Area 6 with several townships having over 100 wells. On the basis of land suitability, there is still much development potential remaining, particularly in Perkins County. However, the current level of development has already caused declines in the water table in excess of 20 feet (Figure 28), particularly under the upland plains. These declines in the water table will have more obvious surface impacts in those areas where the original depths to water were less than 50 feet (Figure 27).

AREA 7

Area 7 contains the counties of Hayes, Hitchcock, Frontier, Red Willow, Furnas, Harlan, Franklin, and Webster in the southern margin of Nebraska. The land suitability for irrigation in this dissected plains area is generally favorable except in those parts with more rugged topography. In the southern tier of counties, groundwater in storage in the principal aquifer (Figure 5) averages 15 feet with large areas where the aquifer is very thin to absent. In Hayes and Frontier, groundwater in storage ranges from 20 to 80 feet.

Except for the floodplains, annual recharge is very low in Area 7. Depths to water are over 100 feet in the upland plains bordering the valleys. In the more rugged portions of Hayes and Frontier, depths exceeding 200 feet are common. Considerable irrigation development has occurred throughout Area 7. Although no significant declines have been noted, they should be anticipated, particularly under the upland area.

AREA 8

Area 8 contains the counties of Keya Paha and Boyd in central northern Nebraska. Land suitability for irrigation ranges from low to moderate. The principal aquifer is very thin or absent under most of Boyd and the eastern part of Keya Paha. Western Keya Paha contains about 25 feet of groundwater in storage. Depth to water is about 50 feet under the uplands area and approaches 100 feet under the more rugged escarpments. Irrigation development within Area 8 will be variable and concentrated withdrawals may create local declines in the water table. In portions of Area 8, the Dakota sandstones (Cretaceous) are an aquifer and provide groundwater for irrigation.

AREA 9

Area 9 contains the counties of Brown, Rock, Holt, Garfield, an Wheeler in north-central Nebraska. Land suitability for irrigation is more favorable in the eastern and northern portion of the area (Figure 18). The amount of groundwater in storage in the principal aquifer is near zero along the northern margin of Area 9. It increases rapidly southward to values exceeding 140 feet.

In the portion of Area 9 north of the Elkhorn River, annual recharge from precipitation is low (Figure 17). In the sand plains south of the river recharge is very high. Depths to water (Figure 27) are less than 50 feet under much of Area 9 although in western Brown and along the northern margin of the area, depths can exceed 100 feet. The extent of irrigation development projected for the southern half of Area 9 (Figure 18) would not be expected to create more than local impact on the water levels. Thus, of greater concern would be impacts related to quality of water, loss of wetlands and sensitivity of land. The large withdrawals anticipated in northern Holt County will continue the progressive decline in water levels (Figure 28).

AREA 10

Area 10 contains the east-central Nebraska counties of Custer, Valley, Sherman, Greeley, Howard, Antelope, Boone, Nance, Pierce, and Platte. Land suitability for irrigation (Figure 18)

generally is favorable, becoming more so toward the east and southeast portions of the area. The values for groundwater in storage have the reverse trend (Figure 5). Depths to water range from in excess of 200 feet under the upland plains regions to less than 50 feet under the numerous valleys that dissect Area 10 (Figure 8). The annual recharge from precipitation is very low on the uplands to somewhat higher in the floodplains (Figure 18). Although irrigated agriculture is well developed throughout Area 10, it has nowhere approached the projected capability of the land. As development continues, declines in water levels should become obvious, particularly under the upland areas. The rise in the water table (Figure 28) should locally stabilize water levels during development. Similar trends could be expected in other areas where seepage and recharge to the aquifer result from surface water projects.

AREA 11

Area 11 in central Nebraska contains the counties of Dawson, Buffalo, Hall, and Merrick. Land suitability for irrigation (Figure 18) ranges from low in part of Dawson County to very high in much of the rest of Area 11. Groundwater in storage, which averages 40 feet in most of the area, ranges from 60 to 90 feet in Dawson County (Figure 5). Annual recharge from precipitation is very low on the uplands of Dawson and Buffalo and high to very high over the remainder of Area 11 (Figure 17).

Depths to water are less than 50 feet in the Platte valley along the southern and eastern portions of the area. In northern Buffalo and Dawson depths range up to 200 feet (Figure 8). For much of Area 11, irrigation development is close to or has reached the maximum projected for land capability. The declines that have occurred under the uplands (Figure 28) are expected to continue. In the Platte valley and the sand plains portion of Hall and Merrick, long-term water levels have not significantly declined. Recharge from precipitation, river seepage and salvage from evapotranspiration have tended to balance the withdrawals for irrigation.

AREA 12

Area 12 in south-central Nebraska contains the counties of Gosper, Phelps, and Kearney. Land suitability for irrigation is variable in Gosper and very favorable in Phelps and Kearney (Figure 18). Groundwater in storage ranges from 40 feet under much of the area to over 80 feet in northern Gosper (Figure 5). Except for the high values in the Platte valley, annual recharge from precipitation (Figure 17) is very low in Area 12.

Depths to water range from less than 50 feet in

the Platte valley to nearly 200 feet under the uplands in the southern part of the area. Long-term rises in water levels have exceeded 50 feet in the northern part of Area 12 (Figure 28). In this area, deep percolation of surface water imported for irrigation has exceeded the withdrawals by pumping. As groundwater development continues, it is expected that groundwater levels will decline under the upland portions of Area 12 in areas marginal to the groundwater mound.

AREA 13

Area 13 contains the eleven counties in northeastern Nebraska within the glacial drift region of Reed (1969). Land suitability for irrigation is high in most of this area (Figure 18). The principal aquifer exceeds 100 feet in thickness in portions of this area. However, much of the aquifer (Figure 4) is fine grained and would provide only low yields of groundwater.

The lower portion of the principal aquifer in parts of Area 13 consists of sand and gravel deposits in buried bedrock valleys. These deposits can provide moderately large supplies of water but are usually of limited areal extent. Depths to water in this area are variable and may represent perched water tables. Numerous small areas of declines can be expected. However, many of these declines are seasonal and could respond quickly to variations in amount of withdrawal. Most irrigation development in Area 13 will be best managed by analysis of local conditions.

AREA 14

Area 14 contains the counties of Adams, Hamilton, Clay, Nuckolls, Polk, York, Fillmore, Thayer, Butler, and Seward in east-central Nebraska. Land suitability for irrigation is very high in most of the area (Figure 18). Groundwater in storage ranges from 20 to 40 feet except for some areas of very thin aquifer along the southern and eastern margins of Area 14. Except for the shallow water tables in the Platte valley, depths to water range from 50 to 100 feet under most of the area.

Irrigation development for much of Area 14 is near the maximum projected considering both land suitability and groundwater availability. As would be expected from the data compiled for aquifer capability, water levels have declined over most of the area (Figure 28). Intensive research is in progress to provide management procedures and alternatives for Area 14.

AREAS 15 - 16

Areas 15 and 16 together constitute the southeastern glacial drift region of Reed (1969). They were originally defined as separate areas for analysis in this study due to the higher population concentrations in Area 15. This characteristic did not prove to be significant in the procedures and impacts related to groundwater utilization at the study level. The impacts on municipal supplies in these areas are the subject of another policy issue study. Land suitability for most of these areas is favorable for development of irrigation (Figure 2). However, groundwater availability is dependent upon low-yield wells except in the sand and gravel deposits contained within the current floodplains and the buried bedrock valleys. Several of these restricted bedrock valleys contain over 60 feet of groundwater in storage under portions of Lancaster and Gage counties (Figure 5).

Depths to water are variable and under the uplands may indicate perched water tables. Except for several concentrated areas (Figure 12) irrigation development has been low in Areas 15 and 16. The restricted occurrence of the aquifers suggest that development will be best managed by analysis of local conditions.

Chapter 4

Potential Techniques For Groundwater Management

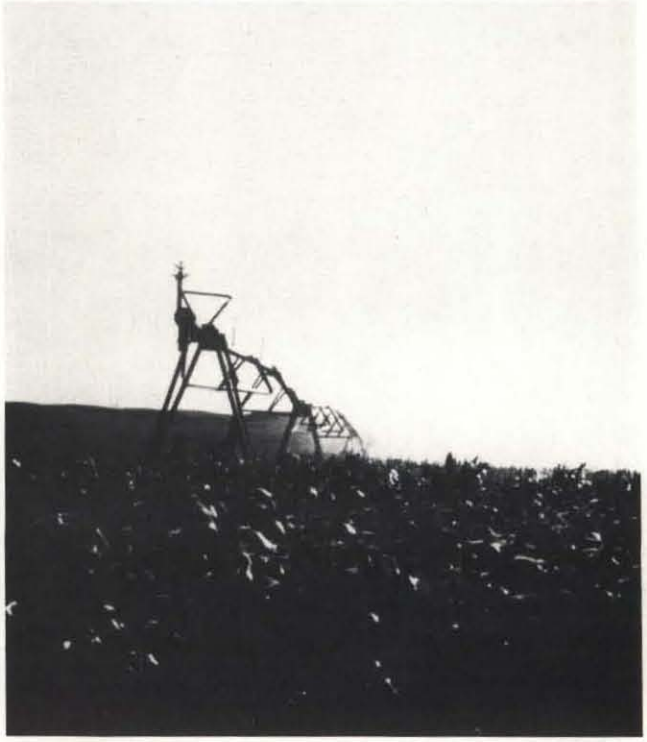
INTRODUCTION

A variety of management techniques could be utilized to achieve a particular developmental goal or goals within an area. To be effective, however, any particular management technique would have to function within the capabilities of the available resource. An additional consideration is the stress or impacts which could be created during development. These impacts could relate to the resource or to such external factors as environmental, technological, economic, social, and legal/institutional/administrative. The management alternatives selected should include an analysis of the impacts which could result.

A series of potential techniques for management of groundwater are summarized in this chapter and are discussed more fully in the separate Appendix to this report (Potential Groundwater Reservoir Management Techniques and Associated Impacts). The constraints on groundwater development (aquifer capability, utilization, and external factors) were discussed in Chapter 1. The potential for development of the principal aquifer was discussed in Chapter 2. The separate Appendix discusses more fully the external factors and the range of impacts resulting from groundwater utilization. A summary of these relationships is included in the following discussion of management techniques.

STRATEGIES FOR GROUNDWATER UTILIZATION

The purpose of this policy issue study is to provide information which helps decision-makers determine the appropriate rate of utilization of the existing groundwater supplies. Three general development strategies provide the mechanisms for groundwater utilization: 1) encourage a rate of development which exceeds the historic pattern, 2) maintain the current rate of development, and 3) stabilize or reduce the rate of development. The implementation of any particular strategy could result from external conditions or from the physical factors present within a particular area of the state.

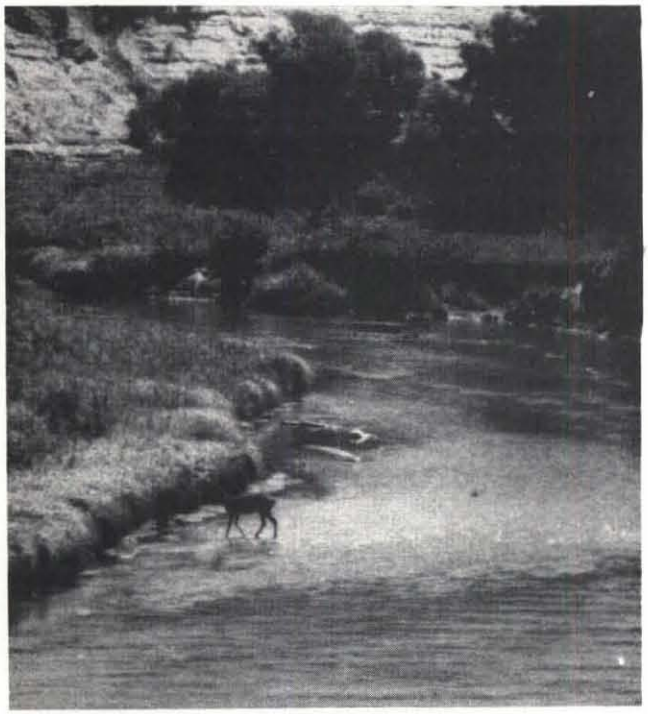


Creating incentives to accelerate groundwater development is more a function of administrative/legislative actions than of management techniques. This strategy is discussed in Chapter 5 of this study. The strategy of maintaining current rates is discussed under the sections of this chapter and in the separate Appendix on Baseline Conditions. Current issues are much more concerned with the ramifications of stabilizing or reducing the rate of development, particularly in specific substate areas. Thus considerable attention will be given here and in the Appendix to those management techniques which would implement this strategy. In all of the discussions both the potential activities and the related impacts will be examined.

BASELINE CONDITION
(See Section 2 of Appendix)

The baseline conditions is essentially a continuation of the historic pattern of development. It assumes no restrictions on water use; a continuation of present state policy. The impacts are based upon no local implementation of controls.

Environmental Impacts: Seasonal/permanent declines in sandhills wetlands and wetlands in areas of high water table; evapotranspiration salvage potential; leaching of nitrates and other agricultural chemicals; reduced streamflows in areas of high water tables; surface water quality problems; erosion increase; reductions in aquatic and terrestrial habitat; fish and wildlife population declines; and negative impact on recreation resources



Technological Impacts: Increased use of shorter growing season crops; no-till or minimum tillage practices; improved crop hybrids which produce greater yields per unit of water applied; and irrigation scheduling

Economic Impacts: Increasing a pumping lift from 46-104 feet across the state and reversion of nearly two million irrigated acres to dryland by 2020

Social Impacts: Increased land values for irrigable lands; unequal distribution of wealth; larger farm sizes; increased or maintained population; and opportunity for improved funding to education, health facilities, and public safety until ground water is economically depleted.

Legal/Institutional/Administrative Impacts: Increasing costs for administration of control area responsibilites by natural resource districts and Nebraska Department of Water Resources

STABILIZE OR REDUCE GROUNDWATER UTILIZATION *(See Section 3 of Appendix)*

A current major policy issue is the potential restriction of groundwater development to extend aquifer life. This policy could contain a number of more specific objectives requiring various management actions and implementation methods. Three major objectives were identified: 1) to reduce irrigation water need, 2) to reduce future groundwater development, and 3) to reduce the amount of groundwater withdrawn.

A series of six management actions were defined which in differing combinations could accomplish the three major objectives. The implementation of the management actions could be accomplished by any or all of three methods: 1) research and educational efforts, 2) financial incentives/disincentives, and 3) regulations. Both the action and the implementation process can create impacts which should be evaluated as a part of any policy decision. The following is a summary from the Appendix of the management alternatives and their impacts which would accomplish the objectives defined as a part of this strategy of stabilizing or reducing groundwater utilization. Citations are provided to the more complete discussions in the Appendix.

Management Action 1: Reduce irrigation water need by improving irrigation efficiency *(See Section 3 of Appendix)*

This action could be implemented with mechanisms such as irrigation scheduling or reuse pits. It could be accomplished through research, education, financial incentives and/or regulations.

Environmental Impacts: Modest impact on wetlands and other areas of high water table; reduced leaching, run-off, and erosion; and mineral effects on wildlife habitat

Technological Impacts: Increased research and education to encourage adoption

Economic Impacts: Relatively little impact on pumping life; small impact in reducing the number of acres reverting to dryland; improved net returns; no appreciable change in overall agricultural productions; and slight increase in output of off-farm economic sectors

Social Impacts: Continuation of increasing farm size; equity for both large and small scale irrigation operations; maintenance of quality of

life; and lack of acceptance of voluntary controls if they were unprofitable

Legal/Institutional/Administrative Impacts: Requiring the continuation of research and education programs to improve irrigation efficiency; implementing cost sharing assistance; legislating state income tax credits; establish irrigation efficiency requirements to address water depletion or quality concerns in control areas; and legislating other possible actions to improve irrigation efficiency.

Implementation Method 1a: Encourage irrigators to adopt improved irrigation practices through research, demonstration projects and persuasion

The effectiveness of this method will depend upon persuading irrigators that it will be profitable. The social impact of this method would only be felt by the new "believers" in irrigation efficiency which it might "convert." Impact analyses for this method have been more fully illustrated through the use of an example, denoted as "For Instance" Case la(i) and discussed in the Appendix C of the separate Appendix to this report.

Implementation Method 1b: Encourage irrigators to adopt improved irrigation practices through cost sharing assistance or state income tax credits for the cost of such practices

The financial incentives resulting from this method would need to be equitable to both large and small irrigation operations so that irrigators now operating near peak efficiency would not be penalized. Administration of this method would pose no particular difficulties.

Implementation Method 1c: Require irrigators to adopt improved irrigation practices through legislative requirement or administration regulation

Problems of inequity and uniqueness of location resulting from this method could create social impacts especially on those irrigators currently with an efficient operation. Administration of this method would be difficult, requiring field level surveillance.

Management Action 2: Reduce irrigation water need by improving crop water use efficiency *(See Section 3 of Appendix)*

This action could be accomplished by developing crop varieties using less water and by switching to crops requiring less water, such as grain sorghum or soybeans. This action could be implemented by encouraging or requiring irrigators to improve crop water use efficiency.

Environmental Impacts: Maintenance or reduction of decline in areas of high water table; reduced leaching; maintenance of streamflow; reduced runoff; and minimal impact on wildlife habitat

Technological Impacts: Stimulation of the development of improved crop varieties which use less water

Economic Impacts: Relatively little impact on lift; small impact in reducing the number of

acres reverting to dryland; improved net returns; no appreciable change in overall agricultural production; and slight increase in output of off-farm economic sectors

Legal/Institutional/Administrative Impacts: Continuation of research and education programs to improve irrigation efficiency; implementation of cost sharing assistance; legislating state income tax credits; establishing crop water use efficiency requirements to address water depletion concerns in control areas; and other new legislation for actions to improve crop water use efficiency

Implementation Method 2a: Encourage irrigators to adopt practices improving crop water use efficiency through research, demonstration projects, and persuasion

The impacts analyses for this method have been more fully illustrated through the use of examples, denoted as "For Instance" Case 2a(i) and "For Instance" Case 2a/1a. These examples are discussed in Appendix C of the seperate Appendix to this Report.

Implementation Method 2b: Encourage irrigators to adopt practices improving crop water use efficiency through cost sharing assistance or state income tax credits for the cost of such practices

Financial incentives might increase the rate at which irrigators adopted irrigation scheduling techniques if the irrigators believed they would financially benefit from doing so. Cost sharing assistance programs could be administered by the Nebraska Natural Resources Commission and natural resources districts. Tax programs could be administered by the Nebraska Department of Revenue.

Implementation Method 2c: Require use of practices improving crop water use efficiency through legislative requirement or administrative regulation

Irrigators could be required to adopt practices which improve crop water use efficiency, although monitoring such a program would be difficult. It is possible that a program of this nature might be implemented by natural resources districts in control areas.

Management Action 3: Reduce irrigation water need through improved water conservation practices *(See Section 3 of Appendix)*

Groundwater use for irrigation could be reduced by improving the utilization of natural precipitation and irrigation water. Storage of water in the soil profile could be increased by a number of on-farm conservtion practices. Residue management, minimum or conservation tillage, and basin tillage are all methods that have shown to be effective in conserving soil moisture, thereby making it available to crops. In addition, some of these practices may also increase recharge to the aquifer.

Environmental Impacts: Maintain areas of high water table; reduce erosion; possible positive or negative impacts on water quality; and increase cover and food for wildlife.

Technological Impacts: Continuing research and education in the development and use of tillage and in the reduction in quantities of required irrigation water.

Economic Impacts: Relatively little impact on lift; small impact in reducing the number of acres reverting to dryland; improved net returns; no appreciable change in overall agricultural production; and slight increase in the output of off-farm economic sectors

Social Impacts: Increased farm sizes; maintain quality of life; and equity for most irrigators

Legal/Institutional/Administrative Impacts: New legislation for state income tax credits

Implementation Method 3a: Encourage irrigators to adopt water conservation practices through research, demonstration projects, and persuasion

Irrigators could be encouraged to improve on-farm water conservation practices through continued or accelerated programs of research, demonstration projects, and persuasion. These programs may require additional funding. Irrigators are unlikely to adopt such practices, however, unless they are persuaded that such actions would be profitable.

Implementation Method 3b: Encourage irrigators to adopt water conservation practices through cost sharing assistance or state income tax credits for the cost of such practices

Irrigators could be encouraged to adopt on-farm water conservation practices by providing cost sharing, by providing state income tax credits for such practices, or by expansion of the Resources Development Fund. This might provide the additional incentives needed to increase the adoption of on-farm water conservation practices.

Implementation Method 3c: Require irrigators to use water conservation practices through legislative requirement or administrative regulation

Irrigators could be required to adopt water conservation practices, although monitoring and regulating such a program would be difficult and possibly not equitable to all impacted irrigators. The Nebraska Department of Environmental Control could establish water conservation requirements to protect water quality.

Management Action 4: Reduce groundwater development based on water supply criteria *(See Section 3 of Appendix)*

Groundwater depletion rates are the best example of a groundwater supply constraint. The depletion rate could range from no depletion to, e.g., 10 percent annual depletion. Depletion rates may be expressed in terms of the life of the groundwater supply -- a 100 year life would suggest a depletion rate of up to one percent per year, etc. Depletion rates could be local (e.g., within three miles of a proposed well site), regional (e.g., within all or part of a natural resources district) or statewide.

Environmental Impacts: Maintain groundwater and surface water quantities and maintain habitat if development is limited

Economic Impacts: Extended aquifer life; less reversion of irrigated land to dryland; increase in sorghum and wheat production; decrease in soybeans and alfalfa; reduced returns to land and management; and decline in off-farm economic sectors

Social Impacts: Increased land values for irrigated lands; decreased value of land restricted from irrigation; no penalty for landowners who created overdraft problem; and limiting of population growth

Legal/Institutional/Administrative Impacts: Implementation of research and education programs in groundwater control areas; implementation of development restrictions; and possible discouraging development through taxing authorities

Implementation Method 4a: Encourage irrigators through research, demonstration projects, and persuasion not to develop irrigation wells which would violate groundwater supply criteria

Landowners might be persuaded by educational programs not to develop wells that would violate: (1) groundwater supply constraints; or (2) geographical/environmental constraints. Educational programs will likely fail, however, if landowners believe that groundwater development would result in economic gain.

Implementation Method 4b: Encourage irrigators through financial incentives or disincentives not to develop irrigation wells which would violate groundwater supply criteria

Irrigators can be encouraged not to develop wells which would violate groundwater supply criteria through financial incentives or disincentives, such as Implementation Options 4b(i) and 4b(ii), below. Financial incentives might increase the rate at which irrigators adopted these options if the irrigators believed they would financially benefit from doing so.

Implementation Option 4b(i): Purchase groundwater development rights which, if exercised, would violate groundwater supply criteria

Implementation Option 4b(ii): Discourage groundwater development which would violate groundwater supply constraints by increasing the cost of development through taxing authorities

Implementation Method 4c: Require irrigators to reduce groundwater development based on water supply criteria through legislative requirements or administrative regulation

Irrigators could be restricted from developing through regulatory methods and controls implemented at the natural resources district level such as in Implementation Options 4c(i) and 4c(ii), below. Of these two options 4c(ii) would have the social impact of being a fairer method of restricting well drilling. An illustrative example which analyses option 4c(i), denoted as "For Instance" Case 4c(i)(a), is explained in Appendix C of the separate Appendix to this report.

Implementation Option 4c(i): Prohibit or limit groundwater development that would violate groundwater supply criteria

Implementation Option 4c(ii): Prohibit or limit groundwater development that violated groundwater supply criteria but compensate landowners for the loss of their groundwater development rights

Management Action 5: Reduce groundwater development based on geographic/environmental criteria *(See Appendix C of Appendix)*

This action is proposed as a means to reduce or prevent adverse environmental impacts, such as streamflow reduction, wetland loss, soil erosion, or groundwater pollution.

Environmental Impacts: Reduced leaching; reduced water and wind erosion; and maintain habitat

Economic Impacts: Limited extension of aquifer life; reduction of total agricultural production; smaller returns to land and management; and reduced off-farm economic returns

Social Impacts: Increased land values for irrigated lands; decreased value for land restricted from irrigation; no penalty for landowners who created overdraft problem; and limited population growth

Legal/Institutional Impacts: Expanded research and education programs; implementation of purchasing development rights; implementation of compensated and uncompensated groundwater development restrictions; and possible discouraging irrigation development through taxing authorities

Implementation Method 5a: Encourage irrigators through research, demonstration projects, and persuasion not to develop irrigation wells that would violate geographic/environmental criteria

Irrigators can be encouraged not to develop irrigation wells that would violate geographic/environmental criteria. This could be accomp-

lished through the expansion of existing programs administered by the UNL Agricultural Experiment Station, Cooperative Extension Service, the USDA Agricultural Research Service, or natural resources districts.

Implementation Method 5b: Encourage irrigators through financial incentives or disincentives not to develop irrigation wells that would violate geographic/environmental criteria

Groundwater development violating geographic/environmental criteria could be discouraged through outright purchase of well-drilling rights and through taxation mechanisms, as described in Implementation Option 5b(i) and 5b(ii), below.

Implementation Option 5b(i): Purchase groundwater development rights which, if exercised, would violate geographic/environmental criteria

Implementation Option 5b(ii): Discharge groundwater development which violates geographic/environmental criteria by increasing the cost of development through taxing authorities

Implementation Method 5c: Require irrigators through legislative regulation not to develop irrigation wells that would violate geographic/environmental criteria

Development of irrigation wells could be restricted through prohibiting or limiting development with or without compensation, or by requiring irrigators to meet certain performance standards prior to development. These are described further in Implementation Options 5c(i), 5c(ii), and 5c(iii) below. The social impact of option 5c(iii) is more fair than from the other two options. An illustrative example which analyses option 5c(i) was developed and is denoted as "For Instance" Case 5c(i)(a). It is explained in Appendix C of the separate Appendix of this Report.

Implementation Option 5c(i): Prohibit or limit groundwater development that would violate geographic/environmental criteria

Implementation Option 5c(ii): Prohibit or limit groundwater development that would violate geographic/environmental criteria, but compensate landowners for the loss of development rights

Implementation Option 5c(iii): Condition groundwater development on meeting performance standards regarding geographic/environmental criteria

Management Action 6: Reduce groundwater withdrawals to prolong groundwater supplies and reduce environmental impacts *(See Section 3 of Appendix)*

Irrigators can be encouraged or required to reduce their withdrawals through educational programs, financial incentives or disincentives, and regulatory methods

Environmental Impacts: Maintain groundwater and surface water quantities; reduce leaching and erosion; and reduce wind erosion by planting dryland crops

Technological Impacts: Explotiation of existing technologies; new research into crop yield improvement and crop stressing; and improvement of dryland farming methods

Economic Impacts: Extended aquifer life; less reversion of irrigated land to dryland; reduction of agricultural production; reduced net returns; and reduced off-farm economic returns

Social Impacts: Increased farm size; continued level of quality of life; and continued trends in income distribution

Legal/Institutional/Administrative Impacts: Expansion or acceleration of research and education programs and implementation of purchasing development rights.

Implementation Method 6a: Encourage irrigators through research, demonstration projects, and persuasion to reduce groundwater withdrawals to prolong groundwater supplies and to reduce adverse environmental impacts

Irrigators could be encouraged to reduce withdrawals by improving irrigation efficiency or by improving crop water use efficiency through research, demonstration projects and persuasion. Educational efforts are likely to fail, however, unless irrigators are persuaded that reducing withdrawals is more profitable than not doing so.

Implementation Method 6b: Encourage irrigators through a financial incentive, i.e., the purchase of rights to withdraw groundwater, to reduce groundwater withdrawals to prolong groundwater supplies and reduce environmental impacts

Rights to withdraw groundwater could be retired by purchase from landowners. If this occurred, the land for which withdrawal rights had been purchased could not be irrigated with ground water. Implementation of this option could be expensive if many irrigated acres were retired.

Implementation Method 6c: Restrict groundwater withdrawals based on legislative or administrative action

Groundwater withdrawals can be restricted by metering wells and establishing groundwater allocations, or by requiring irrigators to either reduce irrigated acreages or grow crops using less water. These are described below in Implementation Options 6c(i) and 6c(ii). The degree of regulation would determine the severity of social impact. The impacts of option 6c(i) are analyzed in four illustrative examples, denoted "For Instance" Cases 6c(i)(a), 6c(i)(b), 6c(i)(c) and 6c(i)(d), and are explained in Appendix C of the separate Appendix of this Report.

Implementation Option 6c(i): Restrict groundwater withdrawals through an allocation program

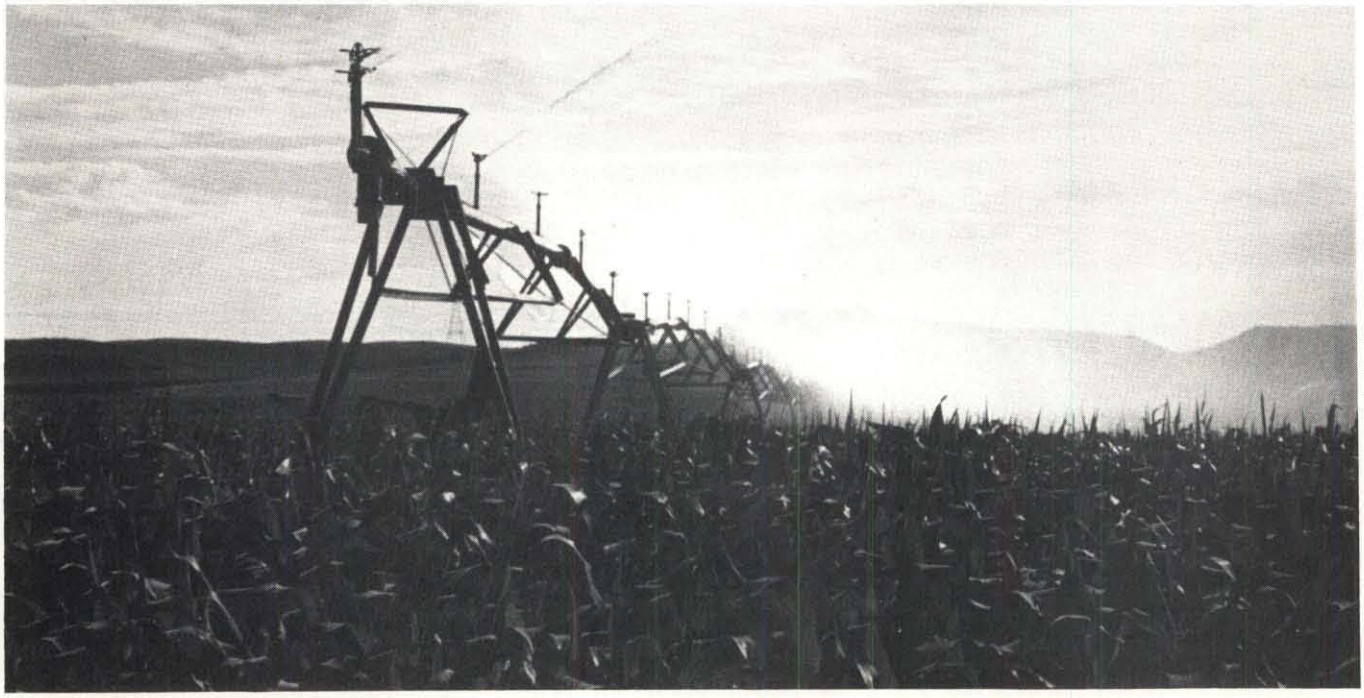
Implementation Option 6c(ii): Require irrigators to either reduce irrigated acreage or grow crops using less water, by legislative or administrative regulation

GENERAL COMPONENTS OF GROUNDWATER MANAGEMENT

In addition to the major objectives, the specific actions and the implementation methods; there are other components to be considered within the overall strategy. Some type of criteria must be selected upon which to base the management. These criteria are required to both provide guidelines for implementation as well as to provide standards to assess results. Examples of these criteria are included in Section 3 of the Appendix.

Another component of management to be considered is the geographic scope; statewide, regional or problem areas. The institutional arrangements will be a part of the implementation. A final component discussed in Section 3 of the Appendix is the funding alternatives including federal, state, local tax or water use charges.

These components, in addition to those previously discussed in this chapter, provide some insight into the complexities of groundwater management. There are a multitude of possible strategies each of which can create a series of impacts all of which must be evaluated prior to formulating administrative/legislative decisions.



Chapter 5

Potential Administrative-Legislative Actions

INTRODUCTION

Eleven legislative alternatives were identified that would provide the mechanisms for groundwater reservoir management. They may be combined to provide desired results. Such legislation would either allow or require the implementation of those management techniques identified in Chapter 4 and the Appendix. These legislative alternatives are closely tied to appropriate administrative actions.

Three major strategies are possible for the utilization of groundwater: (1) accelerate the rate of development, (2) maintain the current rate, or (3) reduce the rate of development. The eleven legislative alternatives encompass, in differing combinations, each of the strategies. This chapter discusses, in detail, each legislative alternative; the anticipated user response and the impacts related to such factors as environmental, technological, social, economic and legal/institutional/administrative. As a result of emerging public awareness of declining water tables, an important focus of the alternatives was on the regulatory aspects of groundwater management.

Following is a short introduction of the issue. The chapter then presents the alternatives in full, and also discusses the anticipated "water user response" to these policy options, together with the expected subsequent impacts.

It should be noted that many of the alternative management techniques and policy options considered are oriented toward areas of the state where ground water depletion problems are occurring or are likely to occur. Impacts associated with various alternatives may not be appropriate indicators of events likely to occur in areas of Nebraska where recharge may be adequate to replace present or projected rates of withdrawal, or where the quantity of ground water in storage exceeds any foreseeable maximum withdrawals that may be imposed.

THE ISSUE

Irrigation is the largest use of groundwater in Nebraska, accounting for 87 percent of the groundwater withdrawals in 1975. In parts of Nebraska irrigation development has led to groundwater mining (i.e., it being withdrawn faster than it is being naturally recharged). In other parts of the state irrigation development will lead to additional groundwater mining. Groundwater mining can be prevented or controlled by regulating groundwater development and use. The Groundwater Management and Protection Act (GMPA) authorizes natural resources districts (NRDs) to regulate groundwater development and use to prevent or control groundwater mining. NRDs are given broad regulatory authorities to control groundwater mining, principally by regulating groundwater development through well spacing and well moratorium controls, and by regulating groundwater withdrawals. Groundwater controls are being implemented in the Upper Republican NRD and are being developed in the Upper Big Blue and Little Blue NRDs. In several other areas where groundwater supplies are being depleted, however, the local NRDs have not acted to control irrigation development and water use.

Under the GMPA the decision whether groundwater regulations should be established remains with the NRD, although the Nebraska Department of Water Resources must approve establishing groundwater control areas and NRD regulations within those control areas. The major policy decision facing the Legislature is what state policy should be regarding groundwater depletion. Should it be encouraged or discouraged? Should groundwater supplies be regulated to last as long as possible? A related issue is whether the NRDs are taking appropriate action to deal with groundwater depletion. If the Legislature determines that they are, then no

legislative action is needed. If NRDs are not taking the appropriate action to deal with present or future groundwater depletion, however, then the Legislature could amend the GMPA: (1) to require NRDs to establish groundwater controls, or (2) to authorize state groundwater controls in the absence of NRD controls.

An important focus of this chapter is on regulatory aspects of groundwater management. This report does not evaluate water supply augmentation, which is an important management alternative or supplement to groundwater regulation in dealing with groundwater depletion. Water supply augmentation is the subject of a subsequent State Water Planning and Review Process report on *Supplemental Water Supplies*.

ADMINISTRATIVE-LEGISLATIVE ACTION ALTERNATIVES AND ASSOCIATED IMPACTS

The alternatives which follow represent potential legislative and/or administrative policy options which may be adopted and implemented

by the legislature, governor, state natural resources agencies, or local entities, such as natural resources districts. These alternatives, either individually or severally, are intended to provide mechanisms for affecting the rate of groundwater withdrawal and/or development, and represent a spectrum of philosophy regarding groundwater management policy. Some are designed to promote (or at least not discourage) groundwater utilization; the intent of others is to slow down groundwater development, or, in some geographic areas, preclude it altogether.

The mission of the task force was not to direct its emphasis toward any one particular philosophy regarding groundwater utilization, but rather to present alternatives representing different, often conflicting views. The arena for policy making comprises the legislature, governor, appropriate state agencies, and others charged with formulating and articulating state water policy. The purpose of these alternatives, then, is to provide those decision makers with a range of groundwater management policy choices, the selection from which may help to articulate Nebraska's groundwater management policy.

ALTERNATIVE 1: Enact No New Groundwater Management Legislation and Do Not Modify Existing Groundwater Legislation *(Maintain Status Quo)*

DESCRIPTION

The major elements of the status quo having a significant impact on the rate of groundwater development and use are: (1) well spacing requirements; (2) irrigation runoff controls; and (3) groundwater regulations in groundwater control areas.

This alternative assumes that no legislative or administrative groundwater policy decisions are changed from the existing policies. This means that no new legislation is enacted, existing legislation is not modified, no new groundwater control areas are designated, existing control area regulations are not modified, and enforcement of groundwater runoff regulations is not increased. Existing law is discussed in the separate Appendix pp. 32-45.

WATER USER RESPONSE

The water user response to maintaining the status quo depends primarily on what happens to the exogenous factors which influence the future of irrigated agriculture. The most important influencing factors are energy prices, crop prices, dryland and irrigated yields, irrigation technology and water levels. These factors were analyzed in the Appendix, Section 2, and it was found that the status quo or baseline situation would probably result in the following key responses:

1. A doubling of groundwater irrigated acres over the next 40 years;
2. Reduction in the average amount of water pumped per acre of about 30 percent in the

case of gravity irigation systems by the year 2000, and about 10 percent for sprinkler systems by the year 1990.

3. An increase in the proportion of irrigated acres devoted to soybeans from about 7.3 percent in 1980 to 22.5 percent in 2020, with a corresponding reduction in irrigated alfalfa and wheat.
4. Long-term growth in the profitability of irrigated agriculture. Average returns to land and management in irrigated agriculture were projected to increase four-fold over the next 40 years when measured in constant 1977 dollars. If this phenonmenon occurs, it will be reflected in steadily rising land values.

IMPACT ASSESSMENT

Environmental Impacts

This alternative would have the same general impacts as those described under the "Baseline Condition" in the Appendix, pp. 47-48. Present trends may extend into the future, and the overall situation should be considered dynamic rather than static in terms of potential new areas shifting to irrigated agriculture with consequent impacts on terrestrial vegetation and habitat, possible draining of wetlands and surface and groundwater impacts on quality and quantity. Over the long-term, shifts from irrigated cropland to dryland farming due to aquifer depletion are likely as noted in the economic discussion in the seperate Appendix. The environmental effects of this trend are uncertain due to management decisions as to what the land would revert to. Some dryland farming practices could produce impacts similar to those discussed in The Separate Appendix, depending on technology and conservation practices such as residue management and other decisions. Reversion to permanent cover such as grassland probably would have fewer negative impacts on habitat and reduced soil loss.

Groundwater Quantity

Declines in water levels may continue in many areas as usage and development are not regulated (with exceptions in management areas). Impacts in areas of high water table including seasonal and possibly permanent declines in Sandhills wetlands, wet meadows and shallow wells, change in ET salvage potential.

Groundwater Quality

Increased leaching of nitrates and other chemicals is possible in vulnerable (depending on water level, soil type and depth) and unmanage areas. Current impacts are evident in the concentrations of nitrate in the central Platte valley and Holt County and the trend is toward increasing concentrations across the state.

Surface Water Quantity

Impacts on streamflows related to declines in areas of high water table are most significant. Impoundments and those Sandhills lakes which are associated with groundwater levels could be affected.

Surface Water Quality

Reduced amounts of surface water may, in some cases, lead to increases in chemical concentrations, but decreases in water quality parameters related to runoff (sedimentation). Where runoff increases, additional impacts will occur.

Soils

Increased development of less well-drained soils will increased erosion from runoff as will the absence of soil and water conservation practices. Development of well-drained soils will not lead to commensurate increase in erosion from runoff. But, sandy soils will be susceptible to wind erosion barring appropriate cultural practices.

Vegetation and Wildlife Habitat

Reduced streamflow will reduce aquatic and riparian habitat thus affecting fish, mammal and bird populations including sandhill cranes. Change in area and depth of Sandhills wetlands will lead to succession by dryland vegetation and reduced habitat for migratory birds, mammals and other populations, as well as reduced hay production. Continued expansion of irrigated cropland into grassland, or less intensive, mixed farming areas may lead to reduced habitat for upland game birds, deer and other species depent on a mix of food and cover areas. Irrigation provides some opportunities for habitat management on "corners" and other areas.

The effect on recreation and aesthetic factors will be closely associated with changes in surface water quantity and quality and habitat maintenance.

Technological Impacts

The anticipated technological impacts of this alternative are identical to those discussed under the "Baseline Condition" in the Appendix, pages 48-51. These impacts reflect no increase in current funding for education, research, or extension programs. To follow is a discussion of potential technological changes which may occur in the future under these given conditions:

Evapotranspiration

Antitranspirants. Artificially-induced reductions in the amount of water lost from plant surfaces from evaporation or transpiration (evapotranspiration, or ET) by applying chemicals to plant surfaces do not hold much promise to significantly reduce crop ET requirements in the near future. Modifications of plant size, i.e., dwarf varieties which would significantly reduce ET demand, also are not expected to occur in the foreseeable future. The development of shorter growing season crops appears to offer the greatest potential to reduce ET losses.

Genetic Improvements. Improvements in the adaptability of crops to limited water at selected stages in the life cycle with only minor reductions in yield show promise for water savings in the future. Although no new crop hybrids which produce current average yields per acre with reduced amounts of water are expected to be developed soon, hybrid improvements are expected which would increase yield per acre with current levels of water application.

Cultural Practices

Reduced tillage practices can save up to one to two inches of irrigation water per season. Although almost one-half of Nebraska's planted cropland was farmed with some type of conservation tillage practice in 1980, the potential exists, through continued extension programs, to expand the use of such water-saving techniques throughout the state.

Conveyance System Efficiency

Surface irrigation system operators have the potential to improve conveyance system efficiency by reducing water losses or wastes arising from spills, seepage, evaporation, and other factors. these losses can be eliminated substantially through present available technology, facilities and equipment.

Application Efficiency

Irrigation water application efficiency can be improved through the use of techniques such as irrigation scheduling, reuse pits, and tillage practices. It has been estimated that scheduling alone can reduce the amount of irrigation water applied during a growing season by 30 to 35 percent. It also has been estimated that application efficiency will improve for surface irrigation systems across the state from a current average efficiency of 65 - 70 percent to up to 80 percent in 2020. Current sprinkler system efficiency is considered to be at 75 percent statewide and is estimated to improve to 85 percent by 2020. It must be noted, however, that application efficiency will vary significantly, depending on soil type.

Economic Impacts

Aggregate economic impacts from the status quo (or "Baseline") should be quite favorable over the next 40 years. The value of total crop production is projected to increase by 278 percent while estimated total returns to land and management are projected to increase by 446 percent, with corresponding positive effects on the total Nebraska economy. The output multiplier for crop agriculture is about 2.12, which means that every dollar of sales from agriculture increases total sales in the Nebraska economy by $2.12.

The aggregate economic situation is projected to improve throughout the study period (1977-2020), with continued ups and downs around the long-term trend. However, after about the year 2000 the rate of increase is expected to slow

down, reflecting the expectation that land will revert to dryland production at an increasing rate. In fact, one can infer from the analysis that under status quo conditions, net economic declines will begin to occur sometime after the year 2020, but further analysis is needed to determine exactly when that would happen.

The aggregate picture does not tell the whole story, however. While the statewide economic outlook is very positive, localized regions may face economic difficulties if the status quo remains. Under the status quo condition, approximately 1,850,000 acres are projected to revert to dryland production from aquifer exhaustion. These acres are concentrated in the east-central, east-south central and southwest parts of the state. Landowners who can no longer irrigate will be harmed economically, with net returns falling by more than $100 per acre. The communities in the areas of greatest decline also will suffer declines in business volume, taxes, personal income and population, relative to what would occur if irrigation could be continued. The painfulness of these changes will depend largely on how rapidly they occur and how well they are anticipated. If the adjustments are anticipated and occur over several years, most of the communities involved would likely adjust without an alarming degree of economic stress.

Social Impacts

The social impacts are divided into two types: (1) **short-term impacts**, or those events expected to occur in the near future under current levels of groundwater management and with current irrigation development trends; and (2) **long-term impacts**, or those events expected to occur when aquifer depletion takes place. While relationships may exist as described, it is also recognized that other factors such as energy prices or market conditions could intervene.

Short-Term Social Impacts

Many areas of the state may continue to experience economic growth related to agriculture. Irrigated land values probably will increase, thereby increasing the tax base and providing potentially greater tax revenues. Higher levels of community services such as fire and police protection, road repair, and aid to education may be available. Farm size probably will continue to increase as holdings consolidate. Local business expansion and the introduction of new operations related to agriculture, e.g., feed yards, grain elevators, etc., should provide new job opportunities and, therefore, a net population increase or retention of persons who otherwise may have out-migrated from these areas. Rural industrialization induced by stable local economies also may contribute to local population growth.

Extended irrigation development may lead to degradation or depletion of domestic and municipal water supplies. (See Section 2 of the Appendix.)

Long-Term Social Impacts

Provided no replacement activities are found, agricultural/commercial activities probably will decline and reduced household expenditures will negatively affect the producers of consumer services. Specific effects on communities will vary according to size, economic diversification, proximity to other communities, and potentials for other economic activity as a substitute. Institutions which depend on property taxes for financial support may be negatively affected; banks and other lending institutions may become less willing to make farm real estate loans.

Increased dryland farming would encourage add-ons from smaller farm units that could not succeed. Net population decrease probably would occur from rural communities as farm incomes decline and dislocation of commercial establishments takes place. However, the level of out-migration will depend upon the amount and rate at which irrigated land goes out of production and the number of businesses in a community which rely on local irrigated agriculture for their economic livelihood. Locally supported public services which depend on property taxation, community prosperity, or population density may face reductions.

Legal/Institutional/Administrative Impacts

As described above, this alternative assumes that no legislative or administrative groundwater policy decisions are changed from the existing policies. Implementing this alternative would not affect existing legal and administrative policies.

ALTERNATIVE 2: Enact Legislation Modifying the Groundwater Management and Protection Act (GMPA)

DESCRIPTION

Eight ways to modify the GMPA were identified by the work group and are discussed, in turn, below:

(a) **Enact legislation repealing the well spacing authority in the GMPA.**

Under the GMPA, NRDs can establish (subject to approval of the Nebraska Department of Water Resources [DWR]) "reasonable" well spacing requirements more restrictive than statutory well spacing requirements in groundwater control areas. For example, NRDs could require in a control area that new irrigation wells be located at least one-half mile away from existing irrigation wells, one mile away, etc. An NRD could also establish well spacing requirements to protect domestic wells. If it determined that well spacing is not an appropriate groundwater management technique, or determined that NRDs were likely to abuse the exercise of that authority, the Legislature could repeal the well spacing authority in the GMPA.

This option would take from NRDs the well spacing authority in control areas. This means that the statutory 600 foot well spacing requirements between irrigation wells would be the major groundwater development restriction.

The major development impact of implementing this alternative is that NRDs would not be able to restrict groundwater development (well drilling) in control areas except through well drilling moratoria. A more subtle impact is that NRDs might interpret this action as implying less confidence in the judgment of NRDs to make groundwater management decisions, as well as a reduced legislative commitment to groundwater management in general.

(b) **Enact legislation limiting the well spacing authority in the GMPA**

NRD control area well spacing authorities are limited only in that they must be "reasonable" (which is not legislatively defined), and that they must be approved by the DWR. If it determined that NRDs were likely to abuse the exercise of that authority, the Legislature could limit the well spacing authority in the GMPA by authorizing well spacing limitations, e.g., of up to one-half mile from existing irrigation wells, or authorizing well spacing authorities to be exercised only when the aquifer depletion rate exceeds, e.g., one percent per year.

The significance of this alternative depends almost entirely on the conditions that are placed on the exercise of well spacing authorities. For example, restricting the well spacing authority to no more than, e.g., one-half mile would prevent more severe development restrictions from being imposed in control areas. Restricting well spacing authority until the rate of groundwater depletion reached, e.g., one per cent per year probably means that NRDs would not request control area designation, if all all, until the groundwater depletion rate was at least one per cent per year.

A more subtle impact is that NRDs might interpret this action as implying less confidence in the judgement of NRDs to make groundwater management decisions, as well as a reduced legislative commitment to groundwater management in general.

(c) **Enact legislation repealing the well drilling moratorium authority in the GMPA.**

In control areas NRDs may prohibit well drilling for one year, subject to DWR approval. Well drilling moratoria may be renewed for additional one year periods with DWR approval. If it determined that well drilling moratoria are not an appropriate groundwater management technique, or determined that NRDs were likely to abuse the exercise of that authority, the Legislature could repeal the moratoria authority in the GMPA.

The major development impact of implementing this alternative is that NRDs would not be able to restrict groundwater development (well-drilling) in control areas except through well spacing regulations. A more subtle impact is that NRDs might interpret this action as implying less confidence in the judgment of NRDs to make groundwater management decisions, as well as a reduced legislative commitment to groundwater management in general.

(d) **Enact legislation limiting the well drilling moratorium authority in the GMPA**

NRD control area well drilling moratoria authorities are limited only in that they must be "reasonable" (which is not legislatively defined), and that they must be approved by the DWR. If it determined that NRDs were likely to abuse the exercise of that authority, the Legislature could limit the moratorium authority in the GMPA by limiting it, e.g., to one year periods without the option of renewal, or authorizing moratoria authorities to be exercised only when the aquifer depletion rate exceeds, e.g., one percent per year.

The major development impact of implementing this alternative is that the NRDs would not be able to restrict groundwater development (well drilling) in control areas except through well spacing regulations. The significance of this alternative depends almost entirely on the conditions that are placed on the exercise of the moratorium authority. For example, restricting the well moratorium authority until the rate of groundwater depletion reached one percent per year probably means that NRDs would not request control area designation, if at all, until the groundwater depletion rate is at least one percent per year.

A more subtle impact is that NRDs might interpret this action as implying less confidence in the judgment of NRDs to make groundwater management decisions, as well as a reduced legislative commitment to groundwater management in general.

(e) **Enact legislation repealing the authority to limit groundwater withdrawals in the GMPA.**

Under the GMPA, NRDs can establish "reasonable" limitations on groundwater withdrawals in groundwater control areas, subject to DWR approval. For example, in a control area NRDs could require that meters be installed on all high capacity wells and that groundwater withdrawals be limited to some specified amount. The quantity could be low enough to eliminate irrigation runoff, to require irrigation scheduling, or to require either a reduction in irrigated acres or else production of crops requiring less water. If it determined that withdrawal limitations were not an appropriate groundwater management technique, or determined that NRDs were likely to abuse the exercise of that authority, the Legislature could repeal the withdrawal limitation authority in the GMPA.

The major impact of implementing this alternative is that NRDs would not be able to restrict groundwater use in control areas except through irrigation runoff control regulations. If this alternative were implemented, the entire GMPA might as well be repealed. A more subtle impact is that NRDs might interpret this action as implying less confidence in the judgment of NRDs to make groundwater management decisions, as well as a reduced legislative commitment to groundwater management in general.

(f) **Enact legislation limiting the groundwater withdrawal limitation authority in the GMPA.**

NRD control area groundwater withdrawal limitation authorities are limited only in that they must be "reasonable" (which is not legislatively defined), and that they must be approved by the DWR. If it determined that NRDs were likely to abuse the exercise of that authority, the Legislature could limit the withdrawal limitation authority in the GMPA by authorizing groundwater withdrawals, e.g., only to the extent that irrigation runoff would be eliminated, or by authorizing withdrawal limitations only when the aquifer depletion rate exceeds, e.g., one percent per year.

The significance of this alternative depends almost entirely on the conditions that are placed on the exercise of withdrawal limitation authorities. For example, restricting the withdrawal limitation authority until the rate of groundwater depletion reached one percent per year probably means that NRDs would not request control area designation, if at all, until the groundwater depletion rate was at least one percent per year.

A more subtle impact is that NRDs might interpret this action as implying less confidence in the judgment of NRDs to make groundwater management decisions, as well as a reduced legislative commitment to groundwater management in general.

(g) **Enact legislation requiring a statement of groundwater management goals, objectives, and implementation methods as part of an NRD's request for a control area designation hearing.**

Control areas may be designated by the DWR director after a public hearing held at the request of an NRD to determine whether a control area should be designated. The GMPA requires an NRD to describe the area proposed to be included in a control area in its request to the DWR that a control area designation hearing be held. The NRD also must testify at the control area designation hearing. If it determined that an NRD should evaluate its groundwater availability, problems and alternatives for dealing with those problems prior to requesting a control area designation hearing, the Legislature could require the NRD to submit a statement of its groundwater management goals, objectives, and implementation methods in its request to the DWR for that hearing.

This alternative would require the NRD to consider the problems justifying the control area designation request and how the NRD would use control area regulations to address those problems. If implemented, this alternative might prevent control area designation requests by NRDs which do not understand the control area process or which are unwilling to implement control area authorities.

(h) **Enact legislation repealing the GMPA.**

If it determined that groundwater management decisions should be the prerogative of landowners only, the Legislature could repeal the GMPA.

The repeal of the GMPA would be interpreted as the legislative abandonment of public groundwater management in Nebraska. Groundwater management opportunities then would be dictated by economics only as influenced by educational activities.

WATER USER RESPONSE

The impacts from legislative action depend on how the rules change as a result of the action and on how water users, mainly irrigators, respond to those rule changes. In the case of actions to modify the GMPA, the central and most difficult issue to consider is what effect it will have on the rules under which irrigators must operate. For example, if the legislature repeals an authority which NRDs were not using or would not likely use in the future, the impact is zero. On the other hand, if the legislative action changes what NRDs are likely to do, the rules under which irrigators operate have been changed and thus there is a potential for impacts on the welfare of Nebraskans.

Given the perspective outlined above, it is unlikely that there will be any user response from repealing or limiting drilling moratorium authority, because such authority has not been used to date by any NRD, nor does there appear to be any likelihood that NRDs will invoke such authority in the future. For those who believe that NRDs may someday use their authority to restrict drilling, the user responses and impacts associated with Alternative 8a would apply.

With respect to well spacing authorities, the situation is somewhat different. In this situation the suggested legislative alternatives might indeed affect what NRDs have implemented and/or will implement concerning well spacing. Extremely restrictive well spacing regulations could influence the amount of irrigation development which occurs, but unless the rules are restrictive enough to prevent more than nine wells per section, the effect is likely to be negligible. To slow development one would need to restrict wells to being no less than about 1,420 feet apart within or between ownership units. Those who believe that NRDs might elect to limit development through well spacing in one or more areas should turn to the discussion of Alternative 8a for an assessment of the possible implications.

Alternative 2c, repeal withdrawal limitation authority in the GMPA, would clearly be a substantive action. The NRDs are already limiting or proposing to limit withdrawals and this legislative action would preclude implementation of such programs. The implications of this occurring are discussed under Alternative 9a.

Repeal of the GMPA essentially would result in responses and impacts similar to those described under the status quo alternative (Alternative 1). At the present time no NRD has implemented programs which effectively restrict what irrigators would do in the absence of such rules. This means that the status quo is equivalent to repeal of the GMPA, unless one assumes that NRDs eventually will use this authority to control groundwater use if the GMPA remains in force. In view of the management plans developed by the three NRDs with established control areas, it is in fact likely that repeal of the GMPA would influence water use over time with all the associated impacts. However, the implication of using the major powers available under the Act are discussed elsewhere in this report (Alternatives 8a, 9a and 10). The implications of repeal are merely the inverse of the implications from use, with the magnitudes dependent upon one's assumptions regarding NRD actions.

IMPACT ASSESSMENT

For reasons discussed within the water user response, above, no separate impact assessment for this alternative is necessary.

ALTERNATIVE 3: Enact Legislation Establishing State Income Tax Credits For Irrigation Equipment and Development Costs

DESCRIPTION

If it determined that additional economic incentives to develop additional irrigation or to purchase more efficient irrigation equipment were needed, the Legislature could establish a program to directly subsidize irrigation development. The program could be administered by making direct payments to those who develop irrigation for some proportion of their investment costs. Alternatively, the developer could be given a special deduction or tax credit which may or may not be limited to the developer's state income tax liability. The irrigation investment credit could range from one to 100 percent. The latter could represent a complete state subsidy of irrigation development.

Implementing this alternative would encourage irrigation development even where it was not otherwise economically feasible, i.e., where the investor could not otherwise make enough money from the investment to cover his expenses. Implementing this alternative also could lead to a premature exhaustion of groundwater supplies.

WATER USER RESPONSE

The response to this alternative would be accelerated irrigation development and accelerated replacement of irrigation equipment, with

the magnitude dependent upon the size of the subsidy and on how the program is administered.

If the program is administered as a tax credit, meaning that only those who otherwise would be paying state income taxes could benefit from it, the response is likely to be small. Many irrigators have ample opportunity under existing tax law to manage their affairs to the point where they pay very little in state income taxes. In this case, development incentives will be only marginally affected irrespective of the size of the potential credit, except perhaps for outside investors looking for a tax shelter. On the other hand, if the program is administered as a direct rebate (the state sends the developer a check for some percentage of his investment costs) or negative income tax (the developer receives a check from the state for some percentage of the investment costs irrespective of his tax liability), the response is likely to be much greater if the size of the subsidy is large enough. It seems reasonable to expect that the subsidy would have to be at least 10 percent of investment costs (about $5,000 per system) before development rates would be appreciably affected.

IMPACT ASSESSMENT

Environmental Impacts

This alternative could accelerate many of the trends described under Alternative 1. In particular it could increase the rate of new land being developed in areas with significant water supplies and the intensification of irrigated use of existing cropland. Impacts could include accelerated groundwater declines with related impacts in areas of high water table, including loss of wetlands, reduced streamflow and related effects on aquatic and riparian vegetation and habitat. Groundwater quality could be affected if vulnerable areas are developed. Erosion from wind and runoff could increase if development proceeds without suitable management practices.

Technological Impacts

The use of best available or best practical technology may not increase as rapidly if incentives are given to increase irrigation development while incentives to use water more efficiently remain constant or decrease.

Non-irrigators may become involved in irrigated agriculture, possibly leading to a need for increased education programs to assist novice irrigators to learn and use water-saving or more economical irrigation techniques, e.g., scheduling.

Economic Impacts

Use of tax credits to accelerate development would mean higher farm and non-farm incomes in the early years when water is available, and lower incomes in later years due to more rapid aquifer exhaustion. It also would mean the transfer of wealth from the non-farm to the farm sector, due to shifts in the tax burden.

This wealth transfer would be extremely large if the subsidy were large enough to induce much of a change in the irrigation development rate. Assuming a 10 percent subsidy, the historic rate of new development (about 2,500 new systems per year) and a total investment per system of $55,000, the cost to the state would total approximately $11,000,000 per year. This would mean a wealth transfer of $11,000,000 per year from non-irrigators (excepting the irrigation supply industry which also would gain) to irrigators. Non-irrigators would pay increased taxes and/or enjoy fewer public services.

Accelerated development would have a particularly adverse impact on those communities where aquifer exhaustion will first occur. More development means aquifer exhaustion will occur at a faster rate, thus making it more likely that there will be difficulties in adjusting to the economic declines associated with a transition from irrigated to dryland agriculture.

Social Impacts

Acceleration of irrigation development would increase local business activity, raise property values as non-irrigated lands become irrigated, and would encourage overall short-term economic growth. However, tax credits may promote the irrigation of marginal lands which may contribute to erosion and other problems. This could lead to intense social/political pressures to discontinue the policy which encourages the development of marginal lands. The long-term social impacts identified in the Baseline also would be accelerated under this alternative.

Legal/Institutional/Administrative Impacts

Implementing this alternative would require new legislation. Administrative implementation could be handled in several ways. If the irrigation development subsidy payment were made directly to the developer, the program could be administered by a number of state agencies: the Department of Agriculture, the Department of Revenue, the Natural Resources Commission,

etc. If the irrigation development subsidy were implemented as a state income tax deduction or credit, the program would be administered through the Nebraska Department of Revenue.

ALTERNATIVE 4: Enact Legislation Establishing A Groundwater Depletion Payment.

DESCRIPTION

If it determined that landowners should receive some economic assistance if groundwater supplies are being depleted, the Legislature could establish a groundwater depletion payment. The program could be administered by making direct payments to those who develop irrigation for some proportion of their investment costs. Alternatively, the developer could be given a special deduction or tax credit which may or may not be limited to the developer's state income tax liability.

If an individual acquired land costing $500 per acre with a dryland value at the time of purchase of $200 per acre, with 100 feet of aquifer beneath it, the individual's investment would depreciate $3 per foot of water level decline (the value of one foot of water equals the total price less the dryland price divided by aquifer thickness). If the individual owned 100 acres, the depletion payment was ten percent and the water level decline was two feet, the depletion payment would be $60. The cost of water would be greater for land purchased recently because of inflating land prices.

Water level declines could be documented by well monitoring programs. If the water level rose, no additional depletion credits could be obtained until the water level fell below the previous low point. For example, if the water level were 500 feet in 1980, rose to 498 feet in 1981, and fell to 502 feet in 1982, the depletion in 1982 would be two feet, not four feet.

The amount of the depletion credit could be varied from one to 100 percent.

WATER USER RESPONSE

Depletion payments, either direct or in the form of a tax credit, would probably have an impact on the amount of water pumped by irrigators. It is unlikely that irrigators would manage differently, because no single irrigator could significantly influence the rate of decline, thus influencing the size of his tax credit. In other words, the individual irrigator would receive the same size payment irrespective of the amount he pumped; thus he would have no economic incentive to conserve or to increase pumpage as a result of the program.

About the only significant potential user response from a depletion payment would be accelerated irrigation development. Existing landowners would find irrigation development more attractive as a result of depletion payments, but unless the payments are or exceed about $20 per acre, the development response is likely to be nominal. It almost surely would be nominal in the case of tax credits, as opposed to a direct depletion payment, because many irrigators would not have enough of a tax liability to take advantage of the full credit. Moreover, it is important to note that the value of tax credits will immediately be reflected in land values. Thus, the incentives for people to buy land and develop it for irrigation would not be appreciably affected.

IMPACT ASSESSMENT

Environmental Impacts

This alternative possibly could increase the rate of water use and thus lead to impacts on groundwater quantity -- declines generally and in vulnerable areas of high water table resulting in reduction in size and depth of wetlands, change in ET salvage potential and reduced streamflows. Increased leaching of nitrates and other chemicals into groundwater supplies in vulnerable areas could result from increased water usage. Surface impacts on erosion rates and vegetation and wildlife habitat would depend on management decisions.

Technological Impacts

Impacts would be similar to those described under the Baseline, as irrigators would continue to adopt water-saving practices to reduce energy costs. (See pages 48-51, the Appendix.)

Economic Impacts

In the case of a direct depletion payment, the principal economic impact would be increased net farm income equal to the size of the tax payment. On the other hand, if the program were administered as a depletion tax credit, the size of the net income improvement would be conditioned by the extent to which irrigators have enough of a tax liability to take advantage of the credit. This income improvement would accrue only to existing landowners, because it would be im-

mediately reflected in the value of the land. The effect of tax credits on land values can be approximated by dividing the size of the credit on a per acre basis by the prevailing interest rate. For example, if the tax credit amounted to $5.00 per acre per year, the expected impact on land values would be $50.00 per acre at 10 percent interest and $33.00 at 15 percent interest.

As a result of the net income improvement, there would be an increased incentive for existing landowners to install irrigation systems, although the credit would have to be quite large (perhaps in excess of $25 per acre per year) before the effect is likely to become significant.

Most non-irrigators in Nebraska would be negatively affected by depletion payments either in the form of increased taxes or reduced public services. Essentially, depletion payments would amount to a transfer of income and wealth from other people in Nebraska to irrigators.

The size of the wealth transfer effect would of course depend on the size of the depletion payment, but it might be useful to consider the general magnitude of the cost to the state of a depletion program tht was large enough to make much of a difference to an individual irrigator. Assuming that depletion payments would have to average $25 per acre (the equivalent of about eight bushels of corn) to make much of a difference, the cost to the state for the current number of groundwater-irrigated acres would be about $150,000,000 per year, an obvious impossibility. Even if a payment program were made applicable only to the most severe situation, the cost would be in the range of several million dollars. If the state were inclined to transfer this much income to irrigators, a better option might be to subsidize water development projects which augment available supplies.

Social Impacts

Establishing income tax credits for groundwater depletion may increase the rate of groundwater use and may accelerate local business activity, raise property values as more non-irrigated lands become irrigated, and might encourage short-term economic growth. However, tax credits may promote the irrigation of marginal lands which, in turn, may contribute to erosion and other problems. This could lead to intense social/political pressures to discontinue policy which encourages development of marginal lands. Long-term social impacts identified in the Baseline would be accelerated under this alternative.

Legal/Institutional/Administrative Impacts

This would require new legislation. If this alternative were implemented, NRDs (as a practical matter) would be required, in cooperation with the UNL Conservation and Survey Division, to expand and accelerate the water level monitoring program to supply the information needed by irrigators to calculate their depletion allowances. Financial administrative implementation could be handled in several ways. If the groundwater depletion payment were made directly to the irrigator, the program could be administered by a number of state agencies: the Department of Agriculture, the Department of Revenue, the Natural Resources Commission, etc. If the groundwater depletion payment were implemented as a state income tax deduction or credit, the program would be administered by the Nebraska Department of Revenue.

ALTERNATIVE 5: Enact Legislation Increasing State Funding For Research And Educational Activities To Improve Irrigation Practices.

DESCRIPTION

If it determined that educational and research activities to improve irrigation practices should be expanded, the Legislature could appropriate greater funds for those purposes. Funding for those purposes. Funding for UNL research and educational activities related to improved irrigation practices could be increased. The NRD mill levy authority could be increased for the purpose of providing educational programs related to improved irrigation practices.

WATER USER RESPONSE

Potential responses to increased funding for research and education are extremely difficult to assess. First, there is inevitably considerable uncertainty associated with what can be accomplished with research. Likewise, it is difficult to say what impact education could have on irrigation (water use) practices. It is clear that the amount of water pumped could be reduced through expanded education programs, because of evidence that many irrigators apply more water than needed, but the magnitude of the impact is impossible to specify. Moreover, reduced pumpage does not mean significantly less consumptive use and for this reason it is unlikely that education could significantly affect the rate of groundwater mining.

Research funding, in contrast to education, offers more potential. For example, scientists claim that it is possible to increase grain production per unit of water consumed by as much as 50 percent. Other possibilities include increasing the profitability of lower water-using crops such as soybeans and grain sorghum. It is important to keep in mind, however, that such research programs may not lead to less water use per acre, assuming no regulations, but merely increase profits per unit of water used.

IMPACT ASSESSMENT

Environmental Impacts

Environmental impacts of this alternative, in terms of reduction in the rate of groundwater decline, will depend on hydrologic conditions as well as the extent of actual net reductions in withdrawals. Related reduction in the rate of wetland decline, streamflow decline and related changes in aquatic and riparian habitats may occur in some areas. Streamflow could be reduced in some cases by reductions in runoff resulting from management practices. Concentrations of nitrates could be reduced at least in terms of the rate of concentration by reduced water usage and water management practices. Certain tillage practices may reduce erosion, improve soil moisture and provide crop residue for wildlife cover and food, but they also may increase herbicide and possibly insecticide requirements. Reversion to dryland farming would continue at possibly slightly reduced rates with uncertain impacts on terrestrial habitat. (See the Appendix, pp. 67, 71, 73.) The effectiveness of these programs will lead to the degree of difference in impacts as compared to those related to Alternative 6.

Technological Impacts

Increased research could accelerate the development of shorter growing season crops, which could reduce the amount of water applied. Accelerated research could lead to increased improvements in crop varieties that are more adaptable to limited water at selected stages in the life cycle. Crop yields per unit of water applied would improve significantly under this alternative. Increased crop yields would be expected if additional funds were provided for research in improved crop varieties. Increased educational activities would increase adoption of water-saving practices, such as scheduling, minimum tillage, etc., if irrigators could be convinced that to do so would be profitable. (See page 73, of the Appendix.)

Economic Impacts

The economic impacts from research and education programs depend, of course, on the success of such programs. Highly successful programs would reduce irrigation costs, increase agricultural production and lead to substantial improvements in both farm and non-farm income. Readers interested in specific impacts from a research and education program where particular successes are assumed should refer to pages 103-111, of the Appendix.

It is unlikely that research and education will have much of an impact on the consumptive use of water per acre. For this reason, research and education offer a means of mitigating the economic consequences of water level declines, as opposed to a method of slowing that rate of decline.

It is important at this point to consider the possibilities for a research and education program combined with groundwater withdrawal limitations. Much as education and research can mitigate the effects of running out of water, such programs could make withdrawal restrictions more attractive economically. The implications of this are addressed as part of Alternative 9a.

Social Impacts

Demonstration projects and other educational efforts may foster changes in attitudes toward groundwater; that is, that supplies are limited and water conservation may be in the best interests of everyone. Also, individuals unaware of more efficient irrigation techniques may benefit from increased educational efforts. Some irrigators, however, may not be receptive to any new ideas for improvements in efficiency. Increased persuasion to adopt water-saving practices could result in additional peer pressure on irrigators and might improve irrigation efficiency. (See pages 68-69, of the Appendix.)

Actual short-term social impacts also would depend upon the amount of economic gain provided by this alternative. Long-term impacts may result in a deceleration of impacts identified in the Baseline if decreased groundwater use occurs.

Legal/Institutional/Administrative Impacts

No new legislation would be required if this alternative were accomplished by increasing UNL appropriations. New legislation would be required to increase the NRD mill levy authority, however.

ALTERNATIVE 6: Enact Legislation Providing Financial Incentives For Improved Irrigation Practices

DESCRIPTION

If it determined that irrigators should adopt improved irrigation practices, the Legislature could establish financial incentives to help meet this objective. For example, state income tax credits or state cost sharing could be provided for any investments related to improving irrigation efficiency, such as reuse pit installation, flow meters, or more efficient water distribution equipment. A second approach would be increased cost sharing for investments or practices that increase irrigation efficiency, such as reuse pits or irrigation scheduling.

WATER USER RESPONSE

The response of irrigators to financial incentives for improved irrigation practices would, of course, depend on the magnitude of the incentives involved. The higher the incentives, the more likely irrigators would be to adopt them. Moreover, there are several useful practices that one could elect to encourage through financial incentives, including irrigation scheduling and reuse pits. If one successfully encouraged improved scheduling and the installation of more reuse pits, the amount of water pumped would clearly be reduced, but it is unlikely that this would have much impact on consumptive water use. For this reason, incentive programs to improve irrigation practices do not have much potential as a means of extending aquifer life or slowing the rate of water level declines.

A note of caution is perhaps in order for those who view incentives to improve irrigation practices as a water saving approach that extends aquifer life. Although such programs may slightly slow the rate of aquifer decline (not all excess pumpage gets back to the aquifer), this effect may be more than compensated for by the effect such programs would have on the rate of irrigation development. Incentive programs necessarily increase the profitability of irrigation, thus increasing the incentive to develop. It is therefore possible, if not likely, that the net effect of incentive programs directed at irrigation practices would be an increase in the rate of water level declines.

IMPACT ASSESSMENT

Environmental Impacts

It is possible, but not at all certain, that reductions in the rate of groundwater depletion (and related effects) could take place. This outcome will depend on hydrologic conditions and actual net reductions in withdrawals. Additional effects could be similar to those described in relation to Alternative 5. Otherwise, impacts would be similar to those discussed in relation to Alternative 1.

Technological Impacts

Substantial financial incentives probably would result in the accelerated adoption of improved irrigation practices. Irrigation scheduling, lower-pressure irrigation, and conservation tillage practices probably would be used more extensively. Other improved practices, such as installation of reuse pits, may be adopted more readily if to do so would be profitable. The amount of financial incentives would determine the degree to which improved practices are adopted.

Economic Impacts

Incentive programs directed at improved irrigation management would reduce irrigation costs, thus increasing the net incomes of irrigators. While the irrigation industry is gaining, however, most of the rest of the economy is necessarily losing because it must pay the cost of the incentive programs. Thus, such a program essentially would amount to a transfer of income and wealth from the general economy to irrigators and perhaps to some irrigation equipment suppliers.

To the extent that such incentive programs result in an accelerated rate of irrigation development, the resulting increase in agricultural production might cause a total net increase in the size of the economic "pie". This net gain would be only temporary, however, because accelerated development means more consumptive use of water and thus a shorter aquifer life.

Social Impacts

Improved irrigation practices should benefit irrigators if the practices reduce energy costs. Practices such as irrigation scheduling and minimum tillage may be adopted more readily if tax credits or other financial incentives are avail-

able. However, adoption of such techniques would probably not affect population, health/safety/education, or the tax base over the short- or long-term unless economic benefits were significant. (See pages 68-70, in the Appendix.)

Legal/Institutional/Administrative Impacts

This could be implemented by increasing the Water Conservation Fund appropriation. As a practical matter, however, legislative direction to the NRD probably would be needed to ensure that the Fund would be administered to help improve irrigation practices. Financial administrative implementation could be handled in several ways. If the irrigation efficiency payment were made directly to the irrigator, the program could be administered by a number of state agencies: the Department of Agriculture, the Department of Revenue, the Natural Resources Commission, etc. If the irrigation efficiency payment were implemented as a state income tax deduction or credit, the program would be administered through the Nebraska Department of Revenue.

ALTERNATIVE 7: Enact Legislation Requiring Irrigators To Adopt Improved Irrigation Practices.

DESCRIPTION

If it determined that irrigators should adopt improved irrigation practices, the Legislature could require irrigators to adopt specified types of practices. For example, irrigators could be required to install irrigation water reuse pits, or to implement irrigation scheduling. Currently, groundwater irrigators are prohibited from generating "improper runoff", are subject to NRD runoff regulations, and must equip sprinkler systems with shutoff valves to avoid damaging a public road.

This alternative could be implemented statewide or in problem areas (e.g., where depletion rates are greater than one percent per year). The NRDs are the logical agencies to implement this option if it were established by the Legislature.

WATER USER RESPONSE

The response to laws requiring improved irrigation practices would be to install them, assuming the enforcement penalties are great enough to ensure compliance. The response issue which is important for purposes of impact assessment concerns specification of exactly what the requirements could mean at the farm level.

What these regulations mean is that total pumpage would decrease, due to both scheduling and reuse pits; total irrigation costs would decrease significantly; and these would have some effect on net withdrawals, although in some cases a change in pumpage does not significantly change net withdrawals.

IMPACT ASSESSMENT

Environmental Impacts

Environmental impacts of this alternative could reflect a reduction in the rate of groundwater decline, but that will depend on hydrology and reductions in net withdrawals. Related effects on wetlands and streamflow (possibly offset by reduced runoff) could be possible. Reductions in nitrate leaching and soil erosion could possibly result. Possible maintenance of supplies could slow the rate of conversion to dryland farming in aras of major aquifer decline.

Technological Impacts

Irrigators could be required to adopt improved irrigation practices. As stated earlier, conservation tillage practices are applied to less than one-half of the state's cropland. This amount could be increased significantly through regulation; however, minimum tillage practices which work well in eastern Nebraska do not necessarily provide similar benefits in the western part of the state. More irrigators could be required to adopt scheduling. This should result in significant water and energy savings.

Regulations could require that all canals be lined, but this would reduce percolation from leaky canals. Irrigators could be required to grow shorter-season crops. This probably would reduce the amount of water consumed by the crop during the growing season, but the farmer's profits subsequently may be reduced. All surface irrigators could be required to install reuse pits, but not all pits are economically feasible or necessary.

Economic Impacts

The economic impacts from the specified regulations would be generally positive since improved scheduling and the installation of reuse pits will lower irrigation costs in most instances.

Those irrigators who alrady are doing a good job of scheduling will incur an unnecessary reuse system costs unless exceptions are made. All other irrigators should gain from such regulations.

The non-irrigation economy would probably not be significantly affected, unless enforcing the regulations becomes especially expensive. High enforcement costs would mean that some people would find themselves paying taxes for programs from which they receive little or no benefit.

Social Impacts

Adoption of such practices as irrigation scheduling and minimum tillage should benefit irrigators if energy costs are reduced. However, requiring the use of improved irrigation practices without financial assistance might be unfair to irrigators since many may be unable to afford to implement or install them. This especially would be true if prior financial decisions had been based upon not needing to adopt such practices. Across-the-board requirements would not account for climatic, topographic, soil type, or other environmental variations in the state.

Legal/Institutional/Administrative Impacts

This alternative can be implemented by NRDs in control areas, and probably could be implemented by DEC to protect water quality. Implementation beyond this would require new legislation. Administrative requirements would vary among NRDs depending on the amount of irrigation in the district and the emphasis on groundwater management within a district. If NRD administration of runoff regulations is any indication, enforcement efforts will vary considerably based on these two factors.

ALTERNATIVE 8: Enact Legislation Requiring Groundwater Withdrawals To Be Restricted In Problem Areas.

DESCRIPTION

The work group identified three variations of this alternative, each of which is described in turn.

(a) **Enact legislation requiring NRDs to restrict groundwater withdrawals in problem areas, and requiring the DWR to restrict groundwater withdrawals in problem areas in the absence of NRD groundwater controls.**

Under current law, groundwater withdrawals can be administratively restricted only in control areas or to meet runoff control requirements. This alternative could be implemented by restricting groundwater withdrawals to, e.g., 60, 80, or 100 percent of crop irrigation requirements. This could be implemented statewide or in problem areas, e.g., (1) where withdrawals approach recharge; (2) where the aquifer depletion rate exceeds one percent per year; or (3) where groundwater withdrawals deplete streamflow by 25 percent.

Without a doubt, controlling groundwater withdrawals is the groundwater management technique that must be used if the life of groundwater supplies is to be significantly extended (in the absence of developing supplemental irrigation water supplies). In addition, groundwater withdrawals probably need to be reduced to the extent that irrigators are required to change cropping patterns (such as through crop rotation) or to reduce irrigated acreage before withdrawal limitations will have a significant effect on aquifer life.

A major feature of the GMPA is its local control approach. Groundwater control area proceedings can be initiated by NRDs only. If groundwater depletion is occurring in an area, but the NRD does not wish to pursue groundwater regulations to extend aquifer life, no action can be taken. A major policy question suggested by this alternative is whether NRDs should have the exclusive authority to make these groundwater management decisions. An alternative would be to give NRDs the option to request control area hearings, but also authorize DWR: (1) to force NRD action if a specified rate of groundwater depletion occurs, and (2) to regulate groundwater development and use if the NRD fails to take the necessary action.

For example, the Legislature could specify that if groundwater depletion rates approach one percent annually, the NRD must prepare a groundwater management plan within one year, specifying how the NRD will deal with the depletion. The DWR would be authorized to notify the NRD that the groundwater depletion rate limit was being approached and that preparation of a management plan was necessary. The DWR (or the NRC or perhaps a combination of state agencies) would review the plan to evaluate whether the proposed regulations would slow or stabilize the depletion rate. The DWR also would have authority to promulgate rules and regulations in the absence of NRD enforcement.

The proposal described above does not contemplate statewide regulation of groundwater withdrawals. As the water supply and development evaluations will demonstrate, many areas

of the state have had an ample supply of groundwater for irrigation purposes for centuries (presuming that the assumptions regarding how much irrigation development if feasible hold true). It is unlikely that groundwater controls would be implemented in these areas to prevent aquifer depletion.

A more subtle impact of implementing this alternative is that NRDs might interpret this action as implying less confidence in the judgment of NRDs to make groundwater management decisions. Implementing this alternative could be interpreted as a greater legislative commitment to groundwater management in general, however.

Surface-groundwater conflicts. Special difficulties would occur in addressing the surface water depletion effects of groundwater withdrawals. While state, federal, and local agencies have been effective in developing information related to groundwater level changes (which is an indication of groundwater depletion), little information has been developed regarding the surface water depletion effects of groundwater withdrawals. Perhaps the most effective legislative response to this situation would be: (1) to financially support the Missouri River Basin States Association hydrology study, which will describe the surface-groundwater interrelationship in the Platte River basin, and (2) to fund additional hydrologic studies of surface-groundwater interrelationships in other river basins. Once the information from these studies is available, policy analysis can more easily evaluate options for dealing with possible surface-groundwater conflicts.

(b) **Enact legislation requiring that groundwater withdrawals be reduced in problem areas (including control areas) by allocating groundwater on a per irrigated acre basis.**

Under this alternative groundwater allocations (i.e., the right to withdraw groundwater allocations (i.e., the right to withdraw groundwater) for irrigation purposes would be based on the number of acres irrigated. The quantity of the allocation would depend on what depletion rate (if any) is established for the problem area. An important part of this alternative is the legislative definition of what constitutes a problem area: when groundwater depletion exceeds, e.g., one percent per year; when groundwater withdrawals deplete streamflow; etc. A second issue is if and how a groundwater depletion rate is established.

(c) **Enact legislation requiring that groundwater withdrawals be reduced in problem areas (including control areas) by allocating groundwater on a per irrigable acre basis and permitting the local sale of groundwater pumping rights.**

This alternative could go the farthest in recognizing the "correlative" or coequal rights of landowners to use a common groundwater supply if the groundwater allocation were low enough (e.g., 3-5 acre-inches of water per irrigated acre per year) to require irrigators to purchase groundwater allocations (i.e., groundwater pumping rights, **not** the groundwater itself) from owners of local irrigable land that is not irrigated. In other words, irrigators would be required to pay non-irrigators for the irrigators' disproportionate use of the common groundwater supplies. This alternative would not have this effect, however, if the groundwater allocation were high enough to permit irrigators to irrigate without purchasing the groundwater development rights of others.

This alterntive could be difficult to administer. The major problem is that the sale of allocations essentially permits a greater rate of groundwater depletion in the area where the purchased allocation is used. The major administrative issue would be defining the geographical area within which transfers may occur. For example, sale of pumping rights could be authorized between contiguous, e.g., irrigators only, which would limit the depletion rate. In addition, the total quantity that could be limited. This would prevent, e.g., an irrigator from purchasing five times his allocation to be withdrawn from a single well for use on a single tract. If this were permitted, neighboring well-owners would be penalized in that groundwater depletion would be occurring faster than if all users were restricted to the same rate.

WATER USER RESPONSE

The response of irrigtors to withdrawal limitations depends on the specifications of the program and on the technical alternatives available to irrigators. Two types of specifications were considered: allocation on a per irrigated acre basis, with no provision for buying and selling of allocated rights; and allocation on a per irrigable acre basis, with provisions for allowing local buying and selling of allocated rights.

Allocation on a per irrigated acre basis would result in cropping pattern shifts, including shifts from corn to grain sorghum and soybeans with

some shift to less than full irrigation. At very extreme limits, it becomes profitable for irrigators to concentrate their allocations on their best irrigated land and growing dryland crops on the remainder.

Allocation on a per irrigable acre basis would mean a slowdown in the development rate as well as some of the same types of cropping pattern shifts. The development rate would be reduced, because in many cases the rights to undeveloped irrigable land would be worth more to an established irrigation operation. In other words, the owner of undeveloped irrigable land would be better off selling off the rights of someone else or using them on some of his own land that was already developed, instead of developing the additional acreage.

IMPACT ASSESSMENT

Environmental Impacts

Restriction of groundwater withdrawals could have significant impact depending on the degree of restriction and the form of regulation. These could include reduced rates of groundwater decline and related maintenance of streamflow, and ares of high water table and also including reduced ET salvage potential if water levels remain in the root zone of phreatophytes or aquatic vegetation. Reduced leaching of nitrates and other chemicals could result, although it might be affected by whether concentration of water use was permitted and whether this was a susceptible area. In addition to possible reductions in the rate of streamflow decline, water levels in both impoundments and Sandhills lakes could be maintained. Reduced runoff could reduce streamflows in areas outside the Sandhills which have less well-drained soils. Improvements in streamflow could lead to improvements in surface water quality. Erosion reductions could result from reductions in withdrawal, although this could be affected by concentration of use. Water and wind erosion could increase if there are shifts to crops which use less water -- without appropriate management practices. Aquatic vegetation and habitat will depend on managemnt decisions. (See the Appendix, pp. 33-35.) Terrestrial habitat could be affected by changes in crops and crop diversity.

Technological Impacts

Reduced groundwater withdrawals will increase interest in irrigation and crop water use efficiency. However, the techniques used to achieve increased efficiency will vary according to the amount of ground water allocated. For example, if the allocation is high enough to eliminate waste only, the use of irrigation scheduling and conservation tillage practices may be sufficient to allow the irrigator to continue production of fully irrigated corn. However, if allocations are tight such that cropping pattern shifts will be required, increased emphasis may be placed on growing crops which use less water. For this case, added research for yield improvement in sorghum, for example, would be very beneficial.

Current technology exists such that irrigation conveyance and application efficiencies can be improved greatly. However, crop yield improvements, such that greater yields could be produced with current water application levels, may hold the greatest promise in helping the irrigators to cope economically with reduced water usage.

Increased research and subsequent extension programs related to crop stressing also may be very beneficial for irrigators operating under an allocation system.

Economic Impacts

The economic impacts from several different allocation levels are discussed in Appendix C of the separate Appendix to this report. Generally it was found that the aggregate economic impact from withdrawal limitations is negative for at least the next 40 years, although not as negative as one might have expected. For example, an 80 percent allocation program (allow irrigators to pump 80 percent of expected unregulated pumpage) would decrease statewide returns to land and management by 3.0 to 6.0 percent over the next 40 years. In return for this reduction in income there would be 675,000 more acres in production as of 2020 than there otherwise could be.

A similar relationship holds for a 60 percent allocation program. In this instance it is estimated that there would be a statewide decrease in net returns to crop agriculture of from 11 to 18 percent, with 1,141,000 more acres in production as of 2020 than there would be without the regulation.

In terms of off-farm economic impacts, the implications are similar, meaning reduced income during the next few decades in return for having more economic activity a half century or more in the future. It was estimated that as of the year 2000 the total value of goods and services produced in Nebraska would be reduced by $787,109,000, or 0.9 percent, with an 80 percent

allocation program and by $2,009,624, or 2.3 percent, with a 60 percent allocation program.

Readers interested in more detail or other allocation levels should refer to the seperate Appendix to this report.

Social Impacts

The degree of social impacts would depend upon the level of withdrawal restrictions imposed. If the objective is to eliminate waste only, economic activity and subsequent short-term social impacts will remain largely unchanged. However, tight restrictions which contribute to shifts in cropping patterns could, over the short-term, reduce profits or result in losses to the irrigator. This would affect land values, tax base, farm size, population, etc. (See pages 91-93, of the Appendix.) However, the long-term impacts identified in the Baseline would be reduced or slowed down, since aquifer life would be extended. Factors affected would include population stability and maintenance of community services and institutions.

Legal/Institutional/Administrative Impacts

Alternative 8a would require new legislation. For example, if the DWR were authorized to establish and administer groundwater controls in the absence of NRD action, the DWR would need a method of financing those groundwater control activities.

Implementing Alternatives 8b and 8c would require new legislation, although NRDs may implement these policies in groundwater control areas under the GMPA. Administrative difficulties would include defining what constitutes an irrigable acre regarding Alternative 8c.

ALTERNATIVE 9: Enact Legislation Requiring Groundwater Development To Be Restricted In Problem Areas.

DESCRIPTION

Two variations of this alternative were developed by the work group, and will be presented in turn.

(a). **Enact legislation requiring NRDs to restrict groundwater development in problem areas, and requiring the DWR to restrict groundwater development in problem areas in the absence of NRD groundwater controls.**

The GMPA makes the establishment of groundwater control an NRD option. If it determined that groundwater development should be restricted in problem areas, the Legislature could enact legislation requiring groundwater withdrawals to be restricted in those areas. An important part of this alternative is the legislative definition of what constitutes a problem area: when groundwater depletion exceeds, e.g., one percent per year; when groundwater withdrawals deplete streamflow; etc.

The typical "groundwater management response" to groundwater depletion in the western states has been to prohibit additional groundwater development but to leave current users unregulated. Implementing this alternative would follow this traditional pattern.

This approach gives a considerable economic windfall to those who developed groundwater before regulations were imposed, and correspondingly penalizes those who do not develop groundwater in time. To this point NRDs have not relied significantly on development controls in groundwater control areas. In the three control areas currently designated, the major groundwater management tool to be utilized is controlling groundwater withdrawals. The NRDs thus far have avoided groundwater development controls, perhaps in part because of their perceived inequitable nature.

Where development restrictions are imposed not to address groundwater depletion but to obtain other environmental objectives, the equities of the option are somewhat different. For example, prohibiting irrigation of erodible soils or in areas with high groundwater pollution potential is somewhat different from prohibiting a landowner from irrigation because his neighbors have depleted the local groundwater supply. If irrigation development were prohibited for environmental reasons, landowners could still be given the option of using groundwater for other purposes, including the sale of groundwater. This would be a modification of the alternative suggested above. Another modification of this approach would be to require the compensation of landowners who are prohibited from developing groundwater.

(b) **Enact legislation authorizing NRDs to purchase groundwater pumping rights in control areas.**

The GMPA authorizes NRDs to limit groundwater withdrawals in control areas through withdrawal limitations. If it determined that NRDs should be authorized to purchase the rights of irrigators to withdraw groundwater as an additional method for reducing groundwater with-

drawals, the Legislature could authorize NRDs to purchase and retire groundwater pumping rights in groundwater control areas.

If groundwater withdrawals are administratively restricted, e.g., in control areas, some irrigators may use less of their allocation and be willing to sell pumping rights to neighboring irrigators. This alternative would authorize the buyer to pump more than he could have otherwise, and the seller could not pump as much as he was allocated. For example, if the allocation were 15 acre-inches per irrigated acre, and one irrigator intended to pump only 12 inches, he could sell the right to pump three inches to another irrigator. The buyer could then pump 18 inches that season.

This alternative would not authorize the sale of groundwater from one groundwater user to another. That is, under this alternative a groundwater user would not be authorized to pump water from his well and sell it to another person. Rather, a groundwater user could only sell his right to pump groundwater to another who, as described above, would in turn, be able to pump more water from his well than he otherwise would have been authorized. Similarly, the groundwater user selling the pumping rights would be authorized to pump less water than he originally was authorized.

An advantage of this approach is that if it were combined with development restrictions, the purchase of groundwater pumping rights could allow an NRD to establish a zero groundwater depletion policy by purchasing and retiring sufficient pumping rights to balance withdrawals and net recharge. (A zero depletion policy also could be implemented through Alternative 8c.)

WATER USER RESPONSE

Assuming that a program to restrict development is effective, the response of irrigators would be to halt development activities.

IMPACT ASSESSMENT

Environmental Impacts

Environmental impacts of this alternative could include reduction in the rate of groundwater decline, particularly if a streamflow standard or an aquifer depletion rate is applied. Criteria related to soil type, water level and slope could lead to reductions in leaching of nitrates and other chemicals. Surface water quality effects will be influenced by criteria which reduce leaching of chemicals and which are related to soil loss. Slope restrictions may reduce runoff in areas of fine-grained soils. Wind erosion may be reduced by restrictions related to soil type. Maintenance of terrestrial habitat is possible if grasslands are protected. Aquatic habitat maintenance will depend on criteria related to wetlands and streamflow.

Overall impacts will depend on criteria used and the areas to which they are targeted. Applied on a statewide basis, this approach has moderate effects on several of the factors discussed in the economic analysis. (See the Appendix, pp. 77-78, 82-84.)

Technological Impacts

Irrigation technology impacts probably would be similar to those described under the Baseline; however, dryland cropping technology may improve because of the increased use of dryland techniques.

Economic Impacts

Actions to restrict irrigation development have a very large impact on both farm and off-farm income. A statewise well moratorium implemented in 1985 would reduce net returns to crop agriculture by 5, 13 and 21 percent as of the years 1990, 2000 and 2020, respectively (the Appendix, Appendix C). In return for this sacrifice, the number of acres reverting to dryland production are reduced by 5,586; 104,067; and 788,520 acres as of the years 1990, 2000 and 2020, respectively, relative to the unregulated case.

In terms of total economic impacts, a well moratorium implemented in 1985 is estimated to reduce the total annual value of goods and services produced by the Nebraska economy by $2,882,383,000 as of the year 2020.

Another important economic consideration associated with a well drilling moratorium is the distributional impacts. Current owners of irrigable but undeveloped land would be precluded from developing it and accordingly improving their income situation, while current irrigators would gain from extended aquifer life. This equity problem could be mitigated by state or NRD purchase of pumping rights in the areas precluded from development. If pumping rights were purchased with funds collected from irrigation, e.g., a water use tax, the people who gain from extended aquifer life would be compensating those who lose.

Social Impacts

Restricting groundwater development would decrease the value of irrigable land of which pumping rights had been sold. In addition, farmers who purchased land at its "potentially irrigable" price could suffer severe economic hardship if they were prevented from drilling a well. They probably would feel their land had been "taken" if they were not allowed to irrigate. However, if areas of sandy soils were restricted from irrigation development, some landowners could feel that this was a legitimate restriction which would prevent damage to environmentally-sensitive land. Of course, the level of impacts will depend upon the amount and type of land that is restricted from groundwater development.

Long-term social impacts would result in a reduction of those described under the Baseline condition.

Legal/Institutional/Administrative Impacts

Alternative 9a would require new legislation. For example, if it were authorized to establish and administer groundwater controls in the absence of NRD action, the DWR would need a method of financing those groundwater control activities. Alternative 9b would require new legislation, although it could probably be implemented in control areas under the GMPA.

ALTERNATIVE 10: Enact Legislation Establishing A Fee For Withdrawing Groundwater.

DESCRIPTION

This alternative could be implemented by levying a charge on groundwater withdrawals. The charge could be a constant rate or graduated. A certain level of withdrawals could be free with the charge taking effect only when withdrawals met a certain level. The charge could be implemented statewide or in problem areas, e.g., where withdrawals approached recharge or where the aquifer depletion rate exceeded one percent per year.

This alternative could be implemented for a variety of reasons: to cover the expense of groundwater administration, to discourage groundwater use, to provide a fund available for purchasing groundwater development or use rights, to compensate domestic well-owners who must replace their wells because of interference from irrigation wells, or to provide supplemental water where local groundwater supplies are being depleted.

WATER USER RESPONSE

Charging for groundwater withdrawals could cause two types of responses. First, there is the possibility that pumpage would decline because of increased irrigation costs. Secondly, if the revenues generated were used for supply augmentation it would enable more irrigation for a longer period of time.

The likelihood that water charges would appreciably reduce pumpage is remote. Charges of a magnitude which irrigators would afford would not be enough to significantly change the profit-maximizing amount of water to apply.

The prospect of using a water charge to raise funds for supply augmentation is more promising. Even a small charge of perhaps $2.00 per acre-foot withdrawn would raise nearly $20,000,000 per year at the present time. This amount of money would be sufficient to pay for a considerable amount of water resource development.

IMPACT ASSESSMENT

Environmental Impacts

This alternative could have impacts including slightly reduced rates of groundwater decline, related effects on wetlands and streamflow, reduced leaching of nitrates and other chemicals, reduced runoff (with possible effects on streamflow in some areas) and possible reduction in rates of decline of wetland areas, lake levels and associated habitat.

Technological Impacts

Irrigators would need to optimize water use efficiency through the adoption of increased irrigation efficiency practices, reduced tillage, shorter growing season crops, etc.

Economic Impacts

The economic impacts from a water withdrawal charge depend primarily on what the funds are used for. If the money is used for economically efficient water development projects, a water charge would mean less net income for irrigators in the early years, but compensating increases in later years when the surface development projects come on line. One important point to

note, however, is that there might be some unacceptable distributional effects from such a program. If all irrigators were charged for water withdrawals, but only an inevitable few gained from supply augmentation, some irrigators essentially would be subsidizing others.

Off-farm economic impacts would be approximately neutral in the aggregate, as long as the fees collected are reinvested within a reasonable period of time. Again, it is important to note that one area of the state may find itself subsidizing another.

Social Impacts

The degree of social impacts would depend upon the level of fees imposed on groundwater withdrawals. If the goal of a fee is to eliminate waste only, economic activity and subsequent social impacts may be slight. However, higher fees which contribute to shifts in cropping patterns could reduce profits. This could affect household expenditures, local business activity, and population. Long-term social impacts could be a reduction of those discussed under the Baseline condition.

Legal/Institutional/Administrative Impacts

Implementing this alternative would require new legislation. This alternative could be implemented in a variety of ways: locally, in problem areas, in control areas, or statewide. Similarly, it could be administered by NRDs, and DWR, or some other agency. The tax could be based on the amount of water withdrawn (which could require metering of withdrawals), or on the capacity of the well.

ALTERNATIVE 11: Enact Legislation Authorizing Increased State Appropriations Or Issuance of Bonds For Development Of Supplemental Water Supplies.

DESCRIPTION

If the Legislature determined that additional state support should be given to develop supplemental water supplies, principally by the construction of surface water storage reservoirs, the Legislature could authorize increased appropriations or the issuance of bonds for supplemental water supply development purposes. This alternative will be evaluated more thoroughly in the *Supplemental Water Supplies* policy study.

WATER USER RESPONSE

The response of irrigators to supply augmentation programs would be to use the additional water available, assuming the supplemental water is obtainable at a reasonable price. In cases where surface water is obtainable by those who have available groundwater supplies, it is important to keep in mind that irrigators probably would be unwilling to pay more for surface water than the cost of groundwater extraction.

IMPACT ASSESSMENT

Environmental Impacts

Impacts could include factors reflecting expanded or continued use of groundwater at at least a moderate rate; leaching of nitrates and other chemicals, runoff and related soil loss and sedimentation of surface water, possible degradation of aquatic habitat in surface water, and other effects. Principal effects would reflect the means of supply augmentation and the area of the source of water, the means of transport and the means of storage.

Technological Impacts

Irrigation and crop technology impacts would probably reflect the emphasis on water conservation due to energy costs. Therefore, impacts would probably be similar to those associated with the Baseline condition. Increased emphasis would be placed on improved storage and transportation technology of water.

Economic Impacts

The economic impacts from supply augmentation program depend on how economically efficient the projects are. If only projects where no subsidies are necessary are constructed, there is a net gain to the total economy equal to the net present value of the projects involved. On the other hand, if irrigation developments are subsidized from any state source, there is a net loss to the economy equal to the size of the subsidy. The only exception would be federal subsidies. In this case the state could gain from subsidized irrigation projects, because the subsidy would be paid primarily by people from out-of-state.

Social Impacts

Social impacts would probably be a combination of the short-term and long-term impacts discussed in the Baseline. Areas that augment

local groundwater supplies probably would continue to experience economic growth or at least maintenance of an irrigated agricultural economy. Social impacts of this condition would be similar to the short-term impacts of Alternative 1. Areas unable to augment local groundwater supplies may face impacts similar to those discussed under the long-term social impacts of Alternative 1. Of course, the degree of impacts would depend upon the rate and extent of groundwater depletion.

Legal/Institutional/Administrative Impacts

Existing law authorizes the formation of reclamation and irrigation districts to develop surface water irrigation projects. These districts have mill levy and bonding authorities such that they could, with strong local support, finance major irrigation projects if the projects were economically feasible (i.e., could be undertaken without significant subsidies). Water planning services are also made available to local agencies through the NRC. The NRDs have water development and financing authorities similar to reclamation and irrigation districts with the exception of bonding authority, a significant difference. Modest state subsidies for surface water development are available through the Natural Resources Fund administered by the NRC

The legal status quo favors water development to a considerable degree. If the Legislature wished to facilitate water development to an even greater extent but still leave the water development decision basically as a local one, it could authorize NRDs to issue tax free bonds. This would not significantly change the water development picture, however, because water development for irrigation purposes usually requires a large subsidy. If it wished to significantly increase the likelihood of developing additional surface water storage in Nebraska, the Legislature could increase state subsidies of irrigation development. As a practical matter this would require the issuance of state irrigation development bonds, because hundreds of millions of dollars would be required.

If the state did intend to subsidize surface water development it might consider conditioning that subsidy on adopting stringent water management practices. In essence this would substitute a legal requirement for what economics would demand if irrigators were required to purchase unsubsidized irrigation water. It would prevent groundwater irrigators from avoiding the water use discipline of having to live within the constraints of the available water supply.

A PERSPECTIVE ON THE ALTERNATIVES

Not all legislative alternatives can be tied directly to a specific management technique and related impacts. Some legislation is implemented by a direct reporting or compliance; other legislation is implemented by administrative action of a state or local agency. Legislation which encourages management by incentives or educational activities could, in differing degrees, relate to nearly all management practices.

Chapter 4 and the separate Appendix establish three potential management objectives: 1) to reduce irrigtion water need, 2) to reduce future groundwater development, and 3) to reduce the amount of groundwater withdrawn. Within the list of legislative alternatives there are obvious actions which would address these objectives. Thus, those impacts anticipated from the management techniques can be correlated with the potential legislative action.

In other instances, the potential legislation may be more directly related to the method of implementation of management rather than the management action. Discussion in Chapter 4 and the separate Appendix assess the impacts of implementing management by 1) research and educational activities, 2) financial incentives/disincentives, and 3) regulation. Those impacts discussed can pertain directly to several legislative alternatives and indirectly to nearly all alternatives based upon the manner of implementation.

The discussion of direct impacts in Chapter 5, the correlation, both direct and implied, with the management techniques in the separate Appendix and the potential for irrigation development summarized in Chapters 2 and 3 should collectively provide a framework for assessing the potential response to and consequences of each of the legislative alternatives for groundwater management. The focus of this study has been on technical aspects of the statewide groundwater reservoir. Implementation of legislation should occur in connection with an understanding of other policy issue studies and an awareness of unique local criteria.

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Relationship Of This Policy Study To Others

No matter how determined the effort, it is impossible to separate water policy issues into ten, twenty, or fifty separate and distinct issues for analysis purposes. Water policy is complex with many overlaps in issues when any system of categorization is used. In designing the original nine policy issue studies for the State Water Planning and Review Process in 1978, an attempt was made to separate issues in as logical a fashion as possible. Still, numerous problems are encountered because of this separation. The separation of ground and surface water issues is of particular concern in this study.

It is still impossible to specify with any degree of certainty what issues will be addressed in most of the policy issue studies. Only the Water Quality and Instream Flow Policy Issue Studies have been completed. Reports have been made on two of the eight subjects to be covered in the Selected Water Rights Study. Reports on Funding Alternatives and Surface-Groundwater Interrelationships have not yet been started. Other studies are in varying stages of development. Until policy alternatives are finalized for those studies and the impacts of these alternatives are assessed, the full relationship of one study to another will not be known. The relationships which are identified in this chapter are therefore based upon the best information available at the time this report was being prepared.

It is important that the relationships between policy issues be identified. Such identification promotes awareness of the fact that any particular water policy action will have greater impact upon overall water policy than just the resolution of the immediate issue at hand. The result of this awareness should not be to delay automatically what may otherwise appear to be a favorable action, although that may be appropriate in some cases. However, such awareness should at a minimum discourage actions which will prevent consideration of new information at a later date.

Based upon the information available at the time of this writing, significant relationships can be identified between Groundwater Reservoir Management and most other policy issue studies can be identified. A discussion of these relationships for each of the other studies follows.

STUDY #1 INSTREAM FLOWS

The report prepared for the Instream Flows Study was approved by the Commission in January and sent forward to the Legislature and the Governor for their consideration. While that study dealt almost exclusively with surface water and this study deals almost exclusively with groundwater, relationships between the two studies do exist. Streams in the State of Nebraska which have fairly constant base flow are dependent upon the discharge of groundwater for the maintenance of that flow. That discharge could be reduced or even eliminated in some streams because of the development and use of groundwater supplies. The extent to which the alternatives addressed in this study would encourage or discourage such groundwater use could affect the realization of instream flow objectives in those streams.

A future policy study is tentatively planned to cover both the physical and legal aspects of the interrelationship between ground and surface water. The complexity of this topic has resulted in only brief treatment of the topic in this study and the Instream Flow study.

Legislative Alternatives presented in the *Groundwater Reservoir Management Study* which could be especially applicable to instream flow policy include Alternatives 8 and 9 (if problem areas are defined in part according to the impacts of groundwater withdrawals on streamflow).

Alternatives 12 and 13 of the *Instream Flow Policy Study* would likewise have impacts on this study. Use of groundwater to supplement natural flow as suggested in Alternative 12 would probably have minimal impacts on groundwater

supple due to the limited usage the alternative would likely receive. However, Alternative 13 "Impose Restrictions on the Use of Groundwater" could have major impacts on groundwater supply and usage.

STUDY #2: WATER QUALITY

The extent of the relationship of this study to the *Water Quality Study* is similar to that identified for the *Instream Flow Study*. That relationship is dependent upon the extent that groundwater alternatives encourage or discourage use of water in areas where contamination by nitrates or other pollutants is a direct result of the application of supplemental water and chemicals. Similarly, many of the water quality management alternatives would have an impact on the rate of utilization of the groundwater reservoir.

STUDY #4: WATER USE EFFICIENCY

Some of the alternatives in this study are also closely related to the *Water Use Efficiency Study* because they would encourage or discourage efficient use of water. For instance, Alternative 5, 6 and 7 would have fairly direct effects on improvement of water use efficiency. The effect would be less direct but possibly even more substantial in Alternatives 8 and 10. Some alternatives would, if implemented, have a tendency to lessen water use efficiency in at least some cases. These alternatives include 2 (e, f, g, and h) and 4.

STUDY #5: SELECTED WATER RIGHTS ISSUES

Drainage of Diffused Surface Water

The only portion of the drainage report significantly related to this report is the portion dealing with wetlands. In some areas groundwater usage can contribute to or cause the loss of wetlands. Any effect of the alternatives in this report on that usage could, therefore, affect the retention of those wetlands.

Preferences in the Use of Water

The relationship of this study to the Water Use Preferences Study was discussed in the *Water Use Preference Study*. Those paragraphs stated:

"Preferences are directly related to groundwater reservoir management and are in fact of the present state policy for that management *Prather v. Eisenmann*[1] indicates that groundwater preferences will have a fairly significant role in that management, at least as related to protection of preferred users' **means of access** to the water supply. There is no reason to believe that a court would find any less significant role in conflicts involving the **adequacy** of that water supply. Preferences are also recognized in present statutory mechanisms for the administrative management of groundwater.

Since preferences already play such an integral part in the state groundwater management policies, any modification in those preferences or in their function will obviously affect that management.

Beneficial Use

The only aspect of the *Beneficial Use Study* related to groundwater reservoir management is application of beneficial use a a method of limiting waste.

Water Right Adjudications

No significant relationships with this study have been identified.

Riparian-Appropriative Rights

No significant relationships with this study have been identified.

Interstate Water Uses and Conflicts

No significant relationships with this study have been identified. However, there are significant groundwater issues related to interstate uses. These will be mentioned in the groundwater property rights report

Transferability of Water Rights

No significant relationships with this study have been identified.

Property Rights in Groundwater

This study is very closely related to the *Groundwater Reservoir Management Study*. In fact the subjects dealt with in the *Property Rights in Groundwater Report* could have been dealt with in this study. The final *Property Rights in Groundwater Report* is scheduled to be completed only a few months after this report. As a result, in the future, policy makers may wish to use the reports in tandem.

STUDY #6: MUNICIPAL WATER NEEDS

Because of the almost exclusive reliance on groundwater as a source of municipal water, decisions affecting the nature of the groundwater reservoir will clearly impact upon municipal water uses. The exact impact of any of the alternatives identified will normally depend upon the nature of the specific situation. For example, alternatives such as 3 or 4 which encourage rapid use of the groundwater reservoir might endanger municipal supplies in some areas either through depletion of supply or water quality problems.

On the other hand, alternatives which encourage efficient use of water, such as 5, 6, or 7 may slow depletion of supply and slow the infiltration of substances which could contaminate municipal water supplies.

STUDY #7: SUPPLEMENTAL WATER SUPPLIES

The nature of the *Supplemental Water Supplies Study* is not yet well defined, but that study will deal with both groundwater and surface water. It is likely that alternatives to recharge groundwater supplies will be included. The feasibility and practicability of recharge schemes could be impacted by some of the alternatives identified in this report. Because many of the alternatives would also affect the extent of groundwater use in the state, they would also affect the need for supplemental water.

WATER - ENERGY WATER DECISIONS FUNDING ALTERNATIVES

These studies are identified in the September 15, 1981, Annual Report and Plan of Work. Work has not begun on any of them, however, and no attempt was made to identify possible relationships with this study.

SURFACE-GROUNDWATER INTEGRATION

A surface-groundwater integration policy study is tentatively planned at this time. Such a study would have a very close relationship to the *Groundwater Reservoir Management Report*. The study would cover both the complex physical interrelationships and various legal mechanisms for addressing that relationship. The study would closely relate to all alterntives in this groundwater study and have at least some bearing on almost all of the other policy studies currently being conducted.

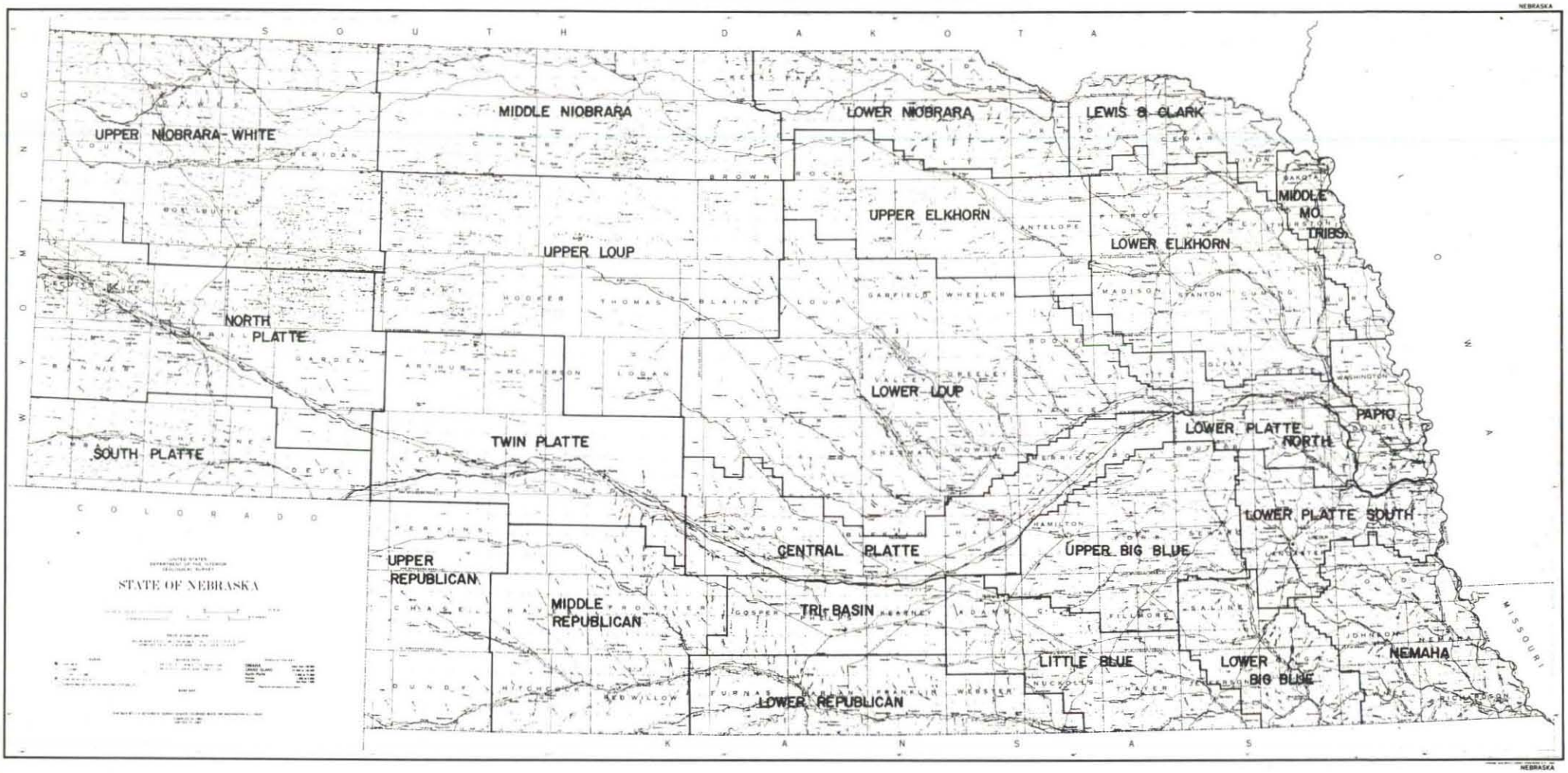

Figure 30. Nebraska Natural Resources District boundaries

Summary Of Hearing
Groundwater Reservoir Management Study

1:30 p.m.
January 5, 1982
Kearney, Nebraska
Holiday Inn

Persons attending:

Gerald L. Abts, Neb. Center Pivot Mfg. Assoc.
Jim Goeke, Conservation & Survey Division
E. T. Lentz, Jr., Middle Niobrara NRD
F. D. Graff, Middle Niobrara NRD
Clinton VonSeggern, NRC Member
Alvin Narjes, NRC Member
Jim Barr
Gerald Chaffin, Game & Parks Comm.
Paul Gessaman, Cooperative Extension Service
Dennis Richters, Neb. Water Coalition & Neb. Livestock Feeders Assoc.
Ron Bishop, Central Platte NRD
Dave Mazour, Little Blue NRD
Bill Umberger, Tri-Basin NRD
Dick Dirmeyer, Central Neb. Public Power District
Paul Madron, Upper Loup NRD
Bill Shreffler, City of Grand Island
Roy Stewart, Public Advisory Board
Bob Lowry, Public Advisory Board
Vance Anderson, Public Advisory Board
Tony Vrana, NRC Staff
Don Thompson, NRC Member
Jim Cook, NRC Member
Bob Gifford, NRC Member
Harold Kopf, NRC Member
Harold Stevens, Dawson Co. Extension Service
Henry Reifschneider, NRC Member
Fred Thomas, Omaha World-Herald
Howard Hardy, NRC Member
Gene Brady, Consulting Engineers Council
Wayne Johnson, NRC Member
Martin Misikke
Harold Nagel
Don Jewell
Bob Warrick, Sierra Club
Alice Heckman, League of Women Voters
DeLynn Hay, UNL Ag. Engineering Dept.
Richard Anderberry
Rose McCullough, Sierra Club
Don McCabe, Nebraska Farmer
David Aiken, Task Force Member
Marv Carlson, Task Force Member
Bob Kuzelka, Conservation & Survey Division
Jack Hart, Executive Coordinator for Natural Resources
Dayle Williamson, NRC Executive Secretary
Jay Holmquist, NRC Staff
Jim Cook, NRC Staff

PUBLIC NOTICE

Legal notice of this hearing was published in twelve newspapers across the state. In addition, press releases were sent to every newspaper and radio station in the state.

HEARING PROCEDURES

Commission member Ervin Lechner presided over the hearing. Bob Kuzelka of the Conservation & Survey Division, UNL gave an overview of the contents of the report followed by a presentation by Dave Aiken of the UNL Department of Agricultural Economics on the legislative alternatives contained in the report. All present were given an opportunity to testify. Following the presentation of testimony an informal question and answer period was conducted and an opportunity for additional testimony was granted prior to the conclusion of the hearing.

TESTIMONY OFFERED

1. **Mr. Gerald L. Abts, Nebraska Center Pivot Manufactures Association.** Mr. Abts comments were directed primarily to Chapter 4 of the *Groundwater Management Reservoir Report*. He agreed that the major policy issue confronting the Governor, Legislature, and Natural Resources Commission is how to extend the life of the state's ground water aquifers. He pointed out that the report demonstrates there are only a few areas in the state that have significant groundwater withdrawal problems. However, these few problem areas will be the focus of legislation and whatever is enacted will affect all areas of the state. He stated any legislation to address problem areas must be compatible with the remainder of the state.

He stated more emphasis is needed on maximizing the benefits to Nebraska by more efficient use of irrigation water and the Legislature should not simply restrict water use under present practices. He stated legislation should focus on economically forcing irrigators to adopt the most efficient irrigation practices applicable to their area.

Mr. Abts stated the report failed to adequately expand on the relative efficiencies of irrigation delivery systems and what effect that could have on legislation. He stated the authors of the report appeared to assume that there are two distinct types of irrigation delivery systems: gravity, and sprinkler, and that each of these systems needs to be dealt with separately. He stated the Legislature should not adopt a two tier approach to regulating groundwater use but rather should encourage irrigators to maximize their efficiency regardless of the type of irrigation system used.

Mr. Abts also challenged the statement on page 187 of Appendix B of the task force report, that improved irrigation efficiency options will have little impact on water lifts because total pumpage would not change much. In conclusion Mr. Abts stated that technology will continue to play a large role in solving our water problems and our groundwater resources can be spread further than the report assumes because of technological improvements. He stated the Legislature should not pass laws to protect existing users and their inefficiency by preventing the development of irrigation by new users.

2. **Mr. Dennis Richters, Nebraska Livestock Feeders Association and the Nebraska Water Coalition.** Mr. Richters stated that caution should be exercised in offering alterntives to the Legislature this session because one hearing, the day before the session opens does not allow the public time to adequately absorb all the information in the report or respond to the alternatives. He stated the primary issue was how to deal with groundwater mining problems noting that if the estimate that 1,850,000 acres will revert to dry land is accurate then this is a very serious problem that must be dealt with. He stated the organizations he represents are opposed to repealing the Groundwater Management and Protection Act or granting the Department of Water Resources the authority to impose groundwater controls in the absence of NRD action.

Mr. Richters noted the Groundwater Management and Protection Act was not perfect, citing as an example, the authority for NRD's to impose a one year well drilling moratorium. He commented that the threat of a moratorium can influence farmers to drill more wells and increase the pressure on existing water supplies. He also noted a moratorium would be inequitable because it guarantees that those who cause the problem can continue to use water while those that did not cause the problem are excluded.

Mr. Richters stated NRD's should be given additional tools such as those embodied in LB 375. The organizations he represents support requiring NRD's to present information regarding the aquifer in a problem area and establish goals and objectives it has in mind prior to setting up a management area and requiring allocations to be made on the basis of irrigated acres. He noted that requiring allocations to be based on irrigated acres was the only equitable way to set allocations and would lead to the most efficient cropping and farming methods. He noted that many of the positive alternatives contained in the Groundwater Reservoir Management Report could be implemented with enactment of LB 375.

Mr. Richters opposed allowing an income tax credit for irrigation development or groundwater depletion payments. He stated this would lead to more mining and perhaps attract more investors. This would increase competition for land and cause harm to small farmers.

Mr. Richters opposed granting the Department of Water Resources authority to restrict groundwater development and withdrawals and providing compensation for the retirement of pumping rights because it would bypass local control and impose a substantial burden on Nebraska tax payers. Establishing a fee for the use of groundwater was also opposed on the ground that landowners have already paid for the right to use the water through the purchase price of the land and through increased property taxes.

On the subject of increased state funding for research on improved irrigation practices and funding for the development of supplemental water supplies, Mr. Richter stated that only a

small percentage of any economic gain from such expenditures would be retained by irrigators and much of the ultimate benefit would go to the economic growth and future of the entire state.

3. **Mr. Bob Warrick, Nebraska Chapter of the Sierra Club.** Mr. Warrick stated that while the Sierra Club appreciates the benefits of irrigation development and many members are irrigators, his organization is concerned about the severe problems caused by irrigation development, particularly the impact on streams and wetlands. He stated these problems are unacceptable to many people in the state. He stated the Sierra Club recommends the Legislature adopt the strictest alternatives contained in the *Groundwater Reservoir Management Report* and specifically mentioned Alternatives 8 and 9. He stated the Department of Water Resources should have the authority to act if a natural resources district fails to do so when problem areas develop.

4. **Mr. E. T. Lentz, Jr., Middle Niobrara NRD.** Mr. Lentz stated that the main concern of the Middle Niobrara NRD is the conservation of an adequate groundwater supply to insure that current and long range goals are met. He stated the point of attach of the Groundwater Reservoir Management Task Force was misdirected. Many legislative alternatives to alter or to repeal the existing law were offered and while he agreed that some of our water laws must be changed, the alternatives outlined by the Task Force were ambiguous. He was especially concerned over the absence of a definition of what constitutes a "problem area".

He noted that the state's natural resources districts have been assigned a variety of responsibilities including the regulation of groundwater use. He stated when a NRD is subject to control by the Department of Water Resources it cannot opperate as an efficient local entity. The disapproval of the Lower Loup NRD's request for groundwater control area by the Department of Water Resources was cited as an example. He stated that rather than increasing state control, NRD's should be given additonal authority to allow them to effectively formulate groundwater management standards within their districts. With proper authority NRD's could formulate groundwater policy for the district that would precisely define and eliminate groundwater problems. He noted that under existing law this approach is impossible.

In conclusion Mr. Lentz recommended that in consort with the NRD's, the Groundwater Reservoir Management Task Force recommended legislative action to give a NRD proper authority to manage groundwater within its boundaries. The NRD could define problem areas and solutions thus freeing the Department of Water Resources to concentrate on important areas of its assigned responsibilities such as surface water problems.

5. **Lower Platte South NRD.** Written testimony of the Lower Platte South NRD was entered into the hearing record. The district's testimony noted that the report clearly indicates in many areas of the state there are large amounts of groundwater available and projected maximum irrigation development would not have a significant negative impact on the principal aquifer. However, there are other areas in the state including the Lower Platte South NRD, where the potential for groundwater mining problems is significant and local management decisions will need to be made in order to properly use the available water. The NRD recommended support for Alternative 1, "Enact no new groundwater management legislation" with the additon of supporting an amendment to include authority to establish groundwater management areas at the option of the NRD. The NRD board recommended opposition to all the sub-alternatives under Alternative 2 with the exception of Alternative 2g which would require a statement of groundwater management goals., objectives, and implementation methods as part of a NRD's request for a control area designation hearing.

Alternative 3, "Establish state income tax credits for irrigation equipment and development costs" was also opposed as was Alternative 4, "Establish groundwater depletion payment." This latter alternative was opposed on the basis that it would tend to discourage conservation and encourage waste.

Alternative 5, "Increase state funding for research and educational programs" was supported. Alternatives 6, 7, 8, and 9 were opposed. The district opposed providing financial incentatives for improved irrigation practices on the basis that these improved practices have been shown to be of economic benefit to the irrigator.

The district supported Alternative 10, "Establish fee for groundwater use" but did not take a position on Alternative 11, "Authorize increased state appropriations and the issuance of bonds for development of supplemental water supplies" pending a more thorough review of this issue following completion of the *Supplemental Water Supplies Study.*

The hearing adjourned at 3:15 p.m.

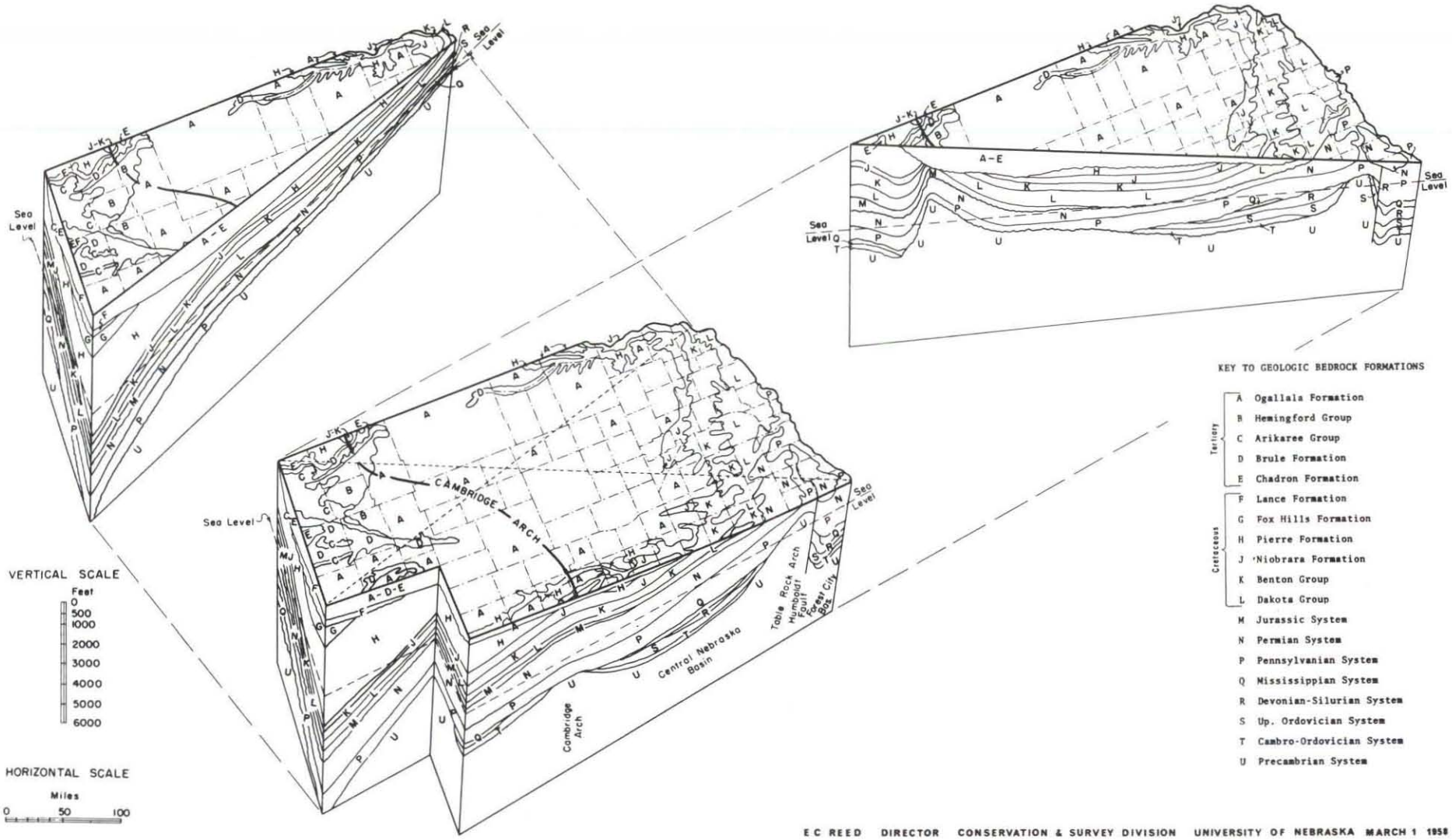

Figure 1 - Block Diagram Illustrating the Extent and Thickness of Geologic Units

Figure 1

BLOCK DIAGRAM OF THE BEDROCK GEOLOGY

The block diagram provides several perspectives of the distribution and thickness of the major sedimentary rock units which overlie the Precambrian rocks in Nebraska. The Precambrian (Unit U) under most of the state is composed of dense crystalline igneous and metamorphic rocks. The overlying sedimentary rocks range in thickness from over 10,000 feet in western Nebraska to less than 500 feet in eastern Nebraska. All of these sedimentary rocks contain groundwater but in differing amounts and of differing quality.

The oldest aquifers are of Cambrian and Ordovician age (Unit T and S). These sandstones and sand carbonates are major aquifers in Iowa and together with carbonate rocks of the Silurian and Devonian Systems (Unit Q) were an important source for industrial use in the Omaha area in the late 1800s and the first half of this century. The Mississippian system (Unit R) is mostly carbonate rock but does have permeable zones. Very little water quality data are available for these older rocks. The Pennsylvanian and Permian systems (Units P and N), where tested, have yielded water of poor quality.

The Dakota Group (Unit L) is the best groundwater reservoir within the Cretaceous System (Units L-F) and sandstones within the Dakota are an aquifer in parts of eastern Nebraska. However, in much of the state, water in the Dakota is moderately to highly saline. Most of the other Cretaceous units have low permeability. Fracture zones in the Niobrara Formation (Unit J) yield groundwater in northeastern Nebraska and in Nuckolls and Fillmore counties. The Greenhorn Limestone and sandstones in the Benton Group (Unit K) and the Pierre, Fox Hills and Lance formations have all supplied low-yield wells. The Cretaceous and older rocks have not been thoroughly evaluated as aquifers due to the cost and other more readily available supplies.

All of the Tertiary units (E-A) serve as aquifers in various areas of the state. The Ogallala (Unit A) is the most widely distributed and is a major unit of the principal aquifer. Not illustrated on this diagram are the youngest rocks, the Quaternary System, which mantle nearly all of the state and comprise the remainder of the principal aquifer.

Figure 2

CONFIGURATION OF THE BASE OF THE PRINCIPAL AQUIFER

The base of the principal aquifer in Nebraska usually is defined as the lower limit of those permeable Tertiary and Quaternary age rocks which comprise the major groundwater reservoir. These unconsolidated and semiconsolidated deposits are underlain by fine-grained materials which have a much lower water yield to wells. For mapping purposes, this lower limit is usually adjusted to a recognizable lithologic or geologic boundary in the rock sequence.

The base of the Arikaree Group of Tertiary age (Figure 1) was defined as the base of the principal aquifer for much of the panhandle portion of Nebraska. The base of the Ogallala Group of Tertiary age (Figure 1) is the mapping horizon for much of the central portion of the state. In eastern Nebraska the base of the Quaternary generally is the base of the aquifer. Locally, this reference plane is adjusted to the base of the more permeable deposits within the Quaternary. The rocks immediately underlying the principal aquifer range in age from Pennsylvanian to Quaternary. In extreme southeastern Nebraska, Paleozoic rocks form the bedrock surface. For much of the eastern half of the state, Cretaceous rocks are at the base although some fine-grained Quaternary materials are excluded from the aquifer in southcentral Nebraska. The White River Group (Brule and Chadron formations) and Arikaree Group, both of Tertiary age, underlay the principal aquifer in the western portion of the state. The Brule Formation (in Lodgepole and Pumpkin Creek valleys) and the Chadron Formation (in North Platte and White River valleys) are a source of water to wells where the principal aquifer is absent.

A series of quadrangle maps showing the configuration of the base of the principal aquifer was published at a scale of 1:250,000 a a part of a cooperative agreement with the Nebraska Department of Environmental Control. The primary source of data for these maps was the hydrogeologic test-hole drilling program conducted by the Conservation and Survey Division and the U.S. Geological Survey (Figure 15). Supplementary information from wells drilled for water, minerals and oil also was utilized. The amount and reliability of data vary from area to area within the state. The information from these quandrangle maps was compiled to illustrate the configuration for the entire state.

Figure 3

CONFIGURATION OF THE WATER TABLE - SPRING 1979

The water table defines the top of the zone of saturation and is illustrated by contours connecting points of equal elevation of water levels. These water levels are derived from the depth to water measured in wells, most of which are completed in the principal aquifer. More than one water table can occur in an area as a perched water table occurring where percolating groundwater is held above the regional water table by impervious materials. Multiple water levels may also occur where the groundwater in deeper aquifers is under a pressure head as the result of being confined below impervious materials. Contours east of the dashed line on Figure 3 were often based on the water level measured in shallow wells and in some areas represent the perched water tables common in eastern Nebraska.

From a regional perspective, groundwater in Nebraska moves slowly southeastward at right angles to the contours. Local changes in slope as may be caused by large withdrawals may influence the direction of movement. The rate of movement will range from several feet per day in continuous coarse gravel deposits to as little as a few inches per year in fine-grained material. The slow movement of groundwater common to most areas in Nebraska would not allow lateral groundwater flow to replace the amount withdrawn in a local area. Most recharge results from infiltration of part of the precipitation falling within the area.

A series of quandrangle maps of the configuration of the water table was published at a scale of 1:250,000 as a part of a cooperative agreement with the Nebraska Department of Environmental Control. These maps were a revision of an interpretation by G. W. Freethey in 1971. Revision was made using data from the cooperative water-level monitoring program of the Conservation and Survey Division and the U.S. Geological Survey (Figure 16), irrigation well registrations, and hydrogeologic studies of specific areas in Nebraska. Spring water levels for 1979 were used where available as most representative of the regional water table. These quadrangle maps were compiled to illustrate the configuration of the water table for the entire state.

Figure 4

THICKNESS OF THE PRINCIPAL AQUIFER

This map was prepared by superimposing the configuration map of the base of the principal aquifer and the contour map of the water table for spring 1979. The water table map illustrates the top of the saturated zone which is the upper surface of the aquifer. It should be noted that the base of the aquifer in any local area was defined as a recognizable geologic horizon closest to the base of the more permeable rocks.

In many areas near the borders of the state, the principal aquifer is very thin or absent. Within some of these areas, however, local or isolated aquifers may be present which can provide for limited development. In eastern Nebraska, a considerable thickness of the principal aquifer is fine-grained material that yields water very slowly. This thickness map is only one source of information that should be used when considering aquifer potential and well yield.

Figure 8

DEPTH TO WATER

The depth-to-water map was prepared by superimposing the water table configuration map for spring 1979 and the U.S. Geological Survey topographic quadrangles at a scale of 1:250,000. The numerical difference between the two sets of contours equals the depth to water. The areas on the map indicate the approximate depth at which water would occur in a well, not necessarily the depth to the groundwater reservoir. In the eastern portion of the state, perched water tables are common and the depth to water can be characteristic of a very local area.

As would be expected, depths to water are less then 50 feet along the major drainages and throughout a large part of the sandhills. In many of these areas, there is an active interface between the surface and the groundwater table. In the western sandhills, dune topography is highly variable and causes a similar variability in the depth to water. In any shallow water area, the impacts of a changing water level on surface features should be considered during development of the aquifer.

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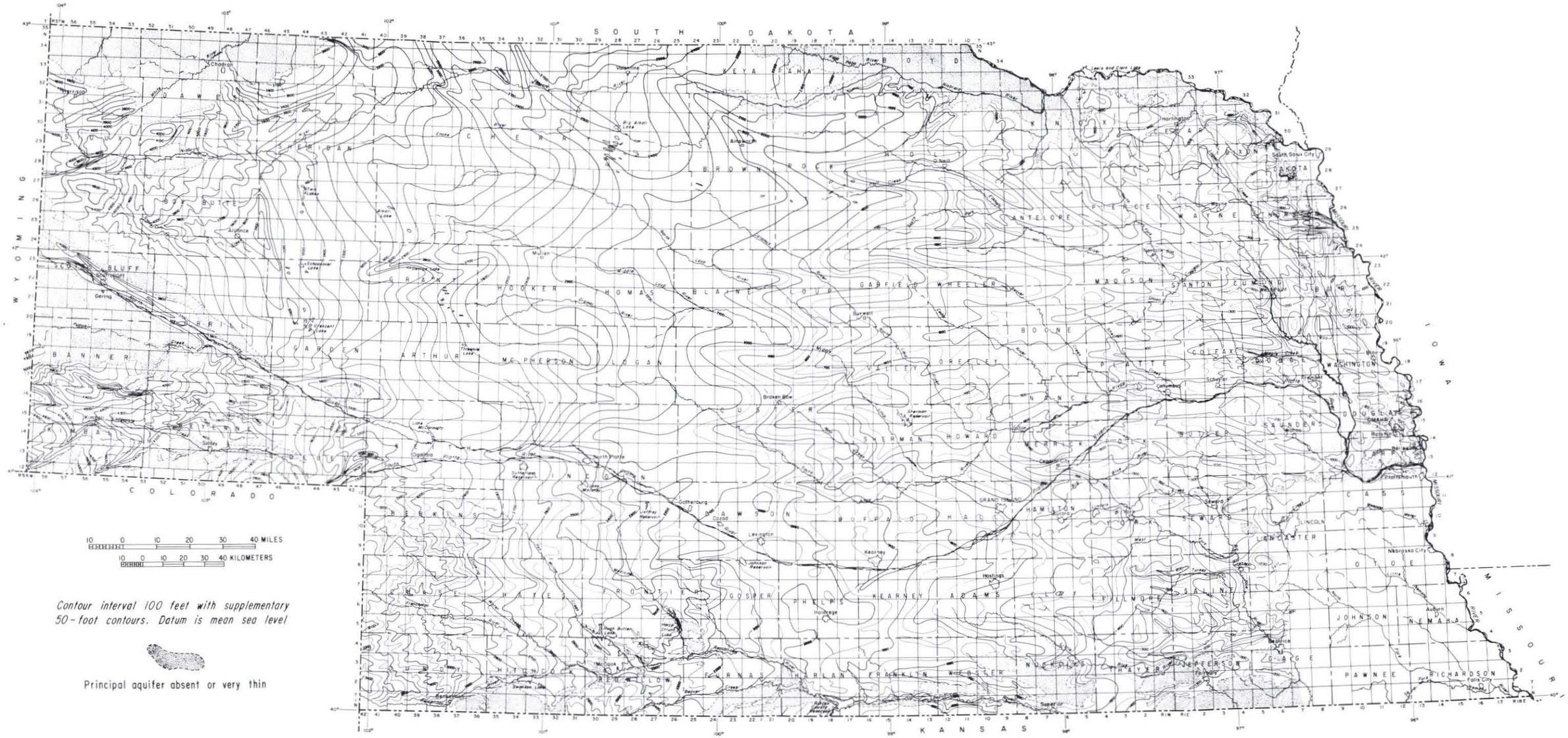

Figure 2 - Configuration of the Base of the Principal Aquifer

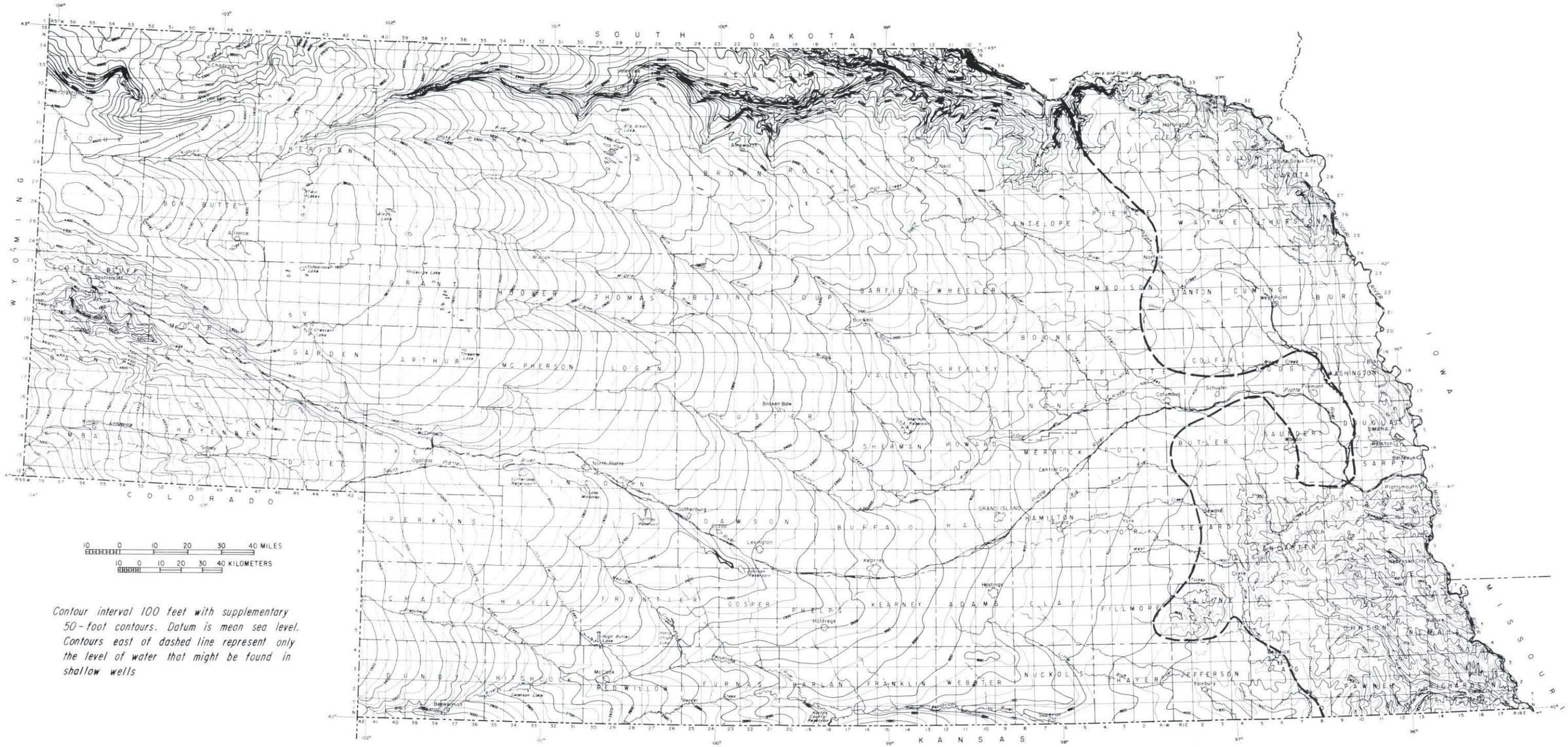

Figure 3 - Configuration of the Water Table - Spring 1979

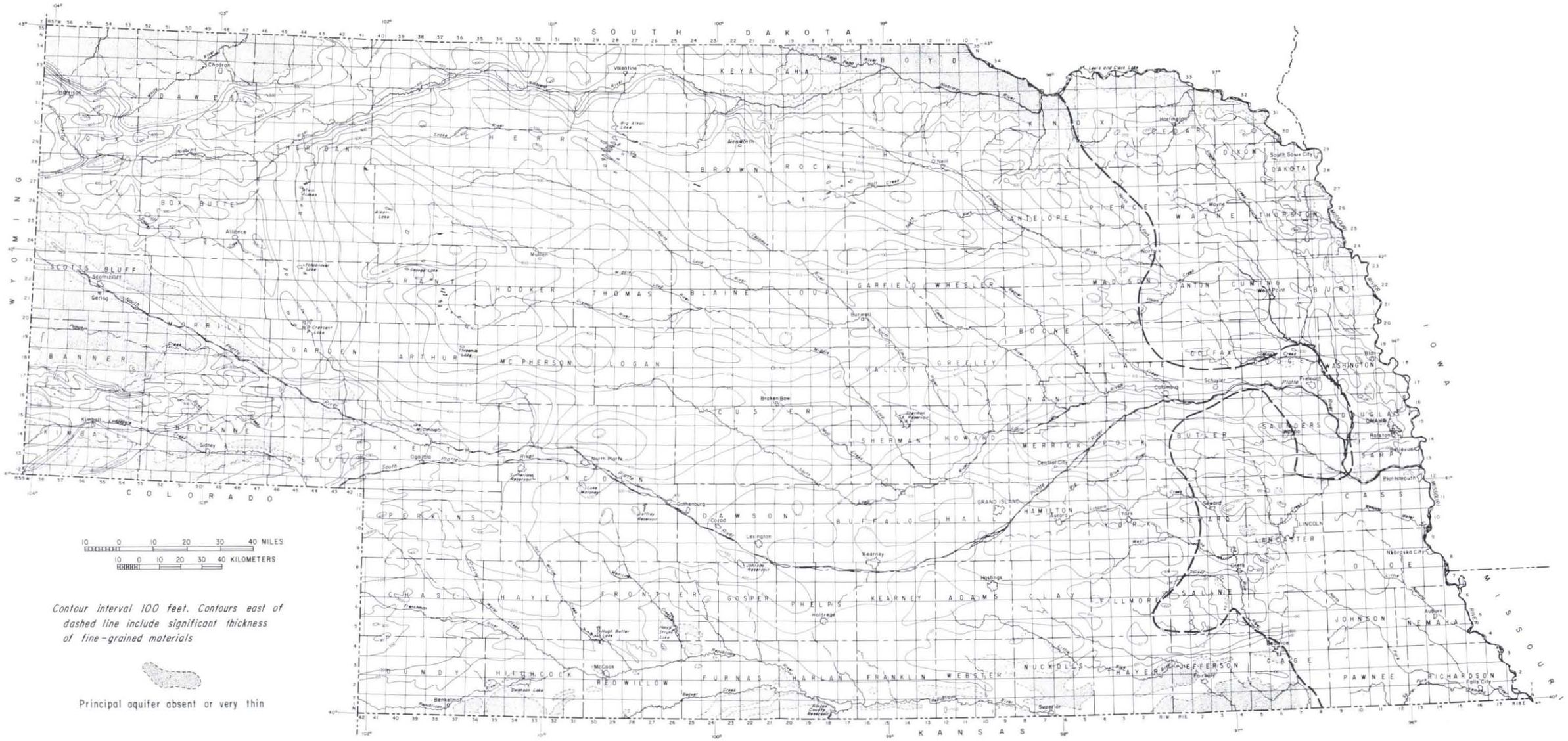

Figure 4 - Thickness of the Principal Aquifer

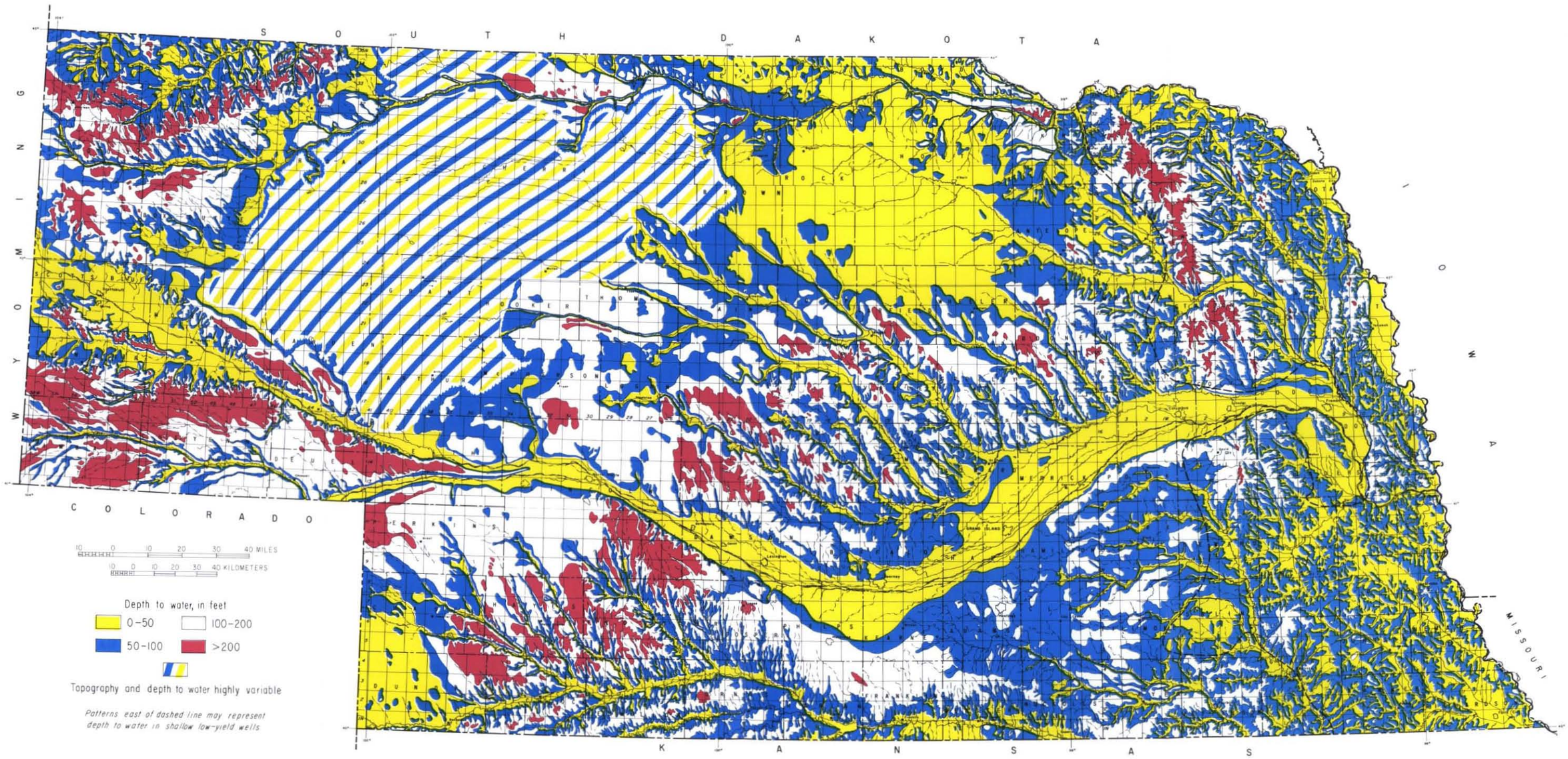

Figure 8 - Depth to Water