Nebraska State-led
O'Neill Unit Alternatives Study

Nebraska Department of Water Resources
Lincoln, Nebraska
January 31, 1985

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NEBRASKA STATE-LED O'NEILL UNIT ALTERNATIVES STUDY

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J. Michael Jess, Director
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The proposed O'Neill Unit, authorized by Congress in 1972, is located in north central Nebraska within the Niobrara River Basin. It was formulated by the Bureau of Reclamation as a multipurpose project serving the functions of irrigation, recreation, fish and wildlife, and flood control. Norden dam and reservoir would be constructed on the Niobrara River to store and divert water. Regulated irrigation releases to a main supply canal, one pumping plant, and the lateral system would supply water to 77,000 acres of land located in Holt and Keya Paha counties. Some 8,000 acres lie in the Springview area; the remainder are located north of Atkinson and O'Neill.

Construction of the project was started in the mid-1970's only to be stopped by litigation in U. S. District Court. Questions were raised as to the safety of the dam, adequacy of the environmental impact statement, and the viability of alternative project schemes. Members of Nebraska's congressional delegation requested the Bureau conduct an evaluation of alternatives to the authorized O'Neill Unit in 1981. A portion of one of the alternatives evaluated at that time was artificial ground water recharge.

The recharge scheme studied by the Bureau consisted of a diversion dam on the Niobrara River downstream from the Norden Dam site near the Rock-Holt county line. Water would be lifted out of the valley by two pumping plants and into a 21-mile-long concrete-lined canal having a capacity of 240 cubic feet per second (cfs). The canal would connect with portions of the authorized canal system and some 209 miles of laterals would be used to fill 304 seepage pits. A total surface area of 203 acres for the pits was specified. A nine-month operation schedule called for one-third of the pit area to be operating at any one time.

While receiving an attractive benefit-cost ratio (2.30 as compared to 1.52 for the authorized project), the ground water recharge alternative raised technical and legal uncertainties. Technical questions dealt primarily with aquifer clogging by sediment contained in the water pumped directly from the river. Other uncertainties included the viability of long term intentional ground water recharge. Legal questions were directed to the lack of authority to recover costs associated with such recharge schemes. As a result of these uncertainties and questions associated with the other studied alternatives, the Bureau concluded that there was no alternative superior to the arrangement of components specified in the authorized project.

In the spring of 1983, the Nature Conservancy, an environmental organization owning property near the Norden Dam site, released a document suggesting that ground water recharge over much of the project lands could be accomplished successfully if one of the methods of water supply studied by the Bureau were altered. Rather than providing the water supply for recharge from the Norden Dam or by direct pumping from the river, it was suggested that it be obtained from wells located in and withdrawing from the Niobrara River Valley alluvium. In doing so, problems associated with recharge of sediment-laden waters could be alleviated. In addition the Conservancy noted that the 1983 Nebraska Legislature passed Legislative Bill (LB) 198. Now codified into law, the bill provides the needed legal mechanism for a project operator to recover costs from project beneficiaries who would utilize surface water to recharge a ground water system.

At the urging of Nebraska's Senator James Exon, Congress in August 1983 authorized $100,000 for a state-led review of the Conservancy alternative scheme. The funds were intended to "pass through" the Bureau to the Nebraska Department of Water Resources for the study. Matching efforts have equaled that commitment. Local officials, state and university agencies, the Bureau, and the private sector participated in the endeavor. The study was done under the general direction of Michael Jess. Lee Becker was study leader.

By substituting several more innovative elements within the proposal, the state-led study has focused upon service to the same 77,000 acres authorized for service by Congress. Five key questions have been addressed.

(1) In the absence of a major reservoir (Norden), can an alternative means be devised for supplying project water demands?

(2) Where recharge is impossible or impractical, by what means would water service be provided?

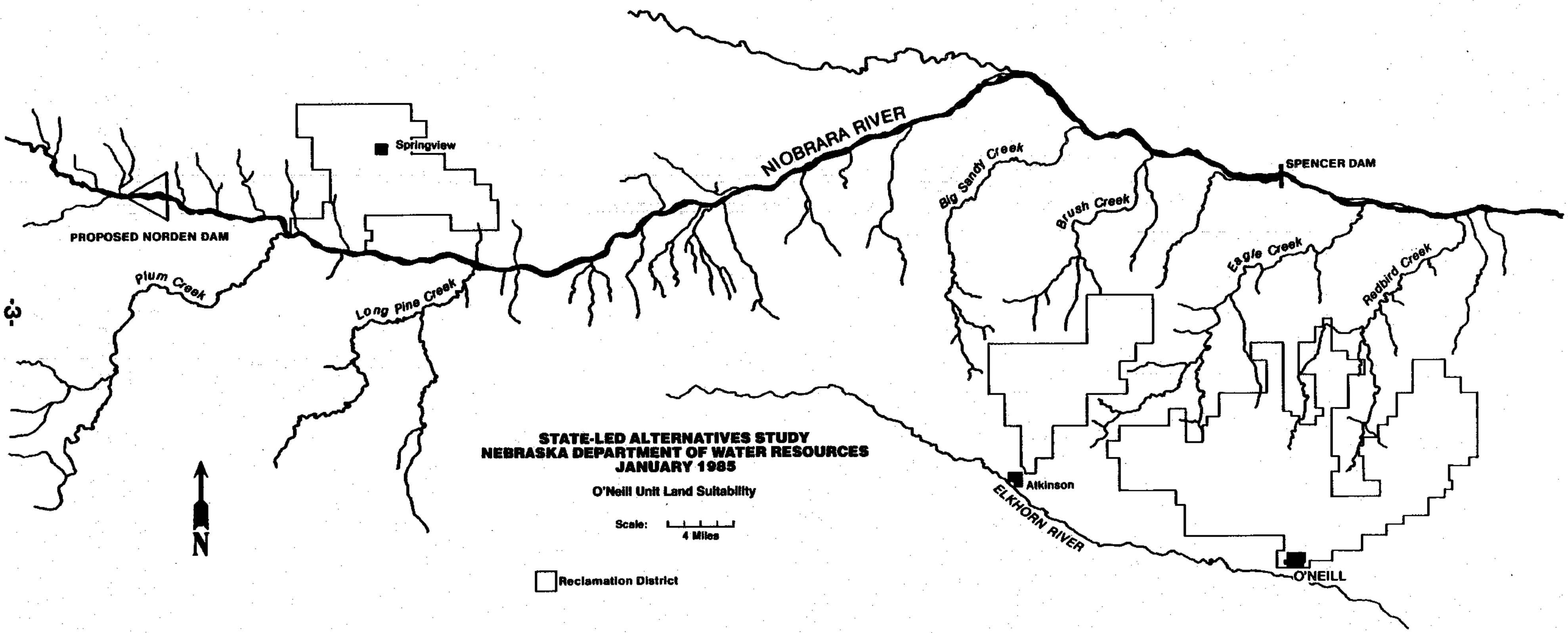
(3) Can ground water recharge be sustained on a large-scale basis?

(4) In terms of out-of-pocket expenses to irrigators as well as federal, state, and local outlays, what are estimated costs for the alternatives investigated?

(5) Are there significant legal, institutional, or environmental considerations which might preclude adopting an alternative proposal?

Water Supply

For the larger, approximately 69,000-acre block lying north of Atkinson and O'Neill (Figure 1), several water supply alternatives were examined. The principal study area was selected along a stretch of the Niobrara River approximately one mile downstream from the State Highway 137 bridge located some 13 miles north of Newport. This location coincides with the diversion site investigated by the Bureau in its 1981 ground water recharge investigation. It is also the same site proposed in the Conservancy study.



O'Neill Unit Project Location

Figure 1

The site investigated is situated northwest of the Atkinson-O'Neill project lands. Topographically, it is a broad, flat flood-plain terrace overlying saturated sediments atop which water collection facilities could be constructed. Water pumped from the valley floor up to the crest of the south side hill may then flow by gravity to the Atkinson-O'Neill area. Well maintained county roads parallel the north and south river banks. They allowed for easy transport of drilling equipment, heavy machinery, and other vehicles used in the study effort.

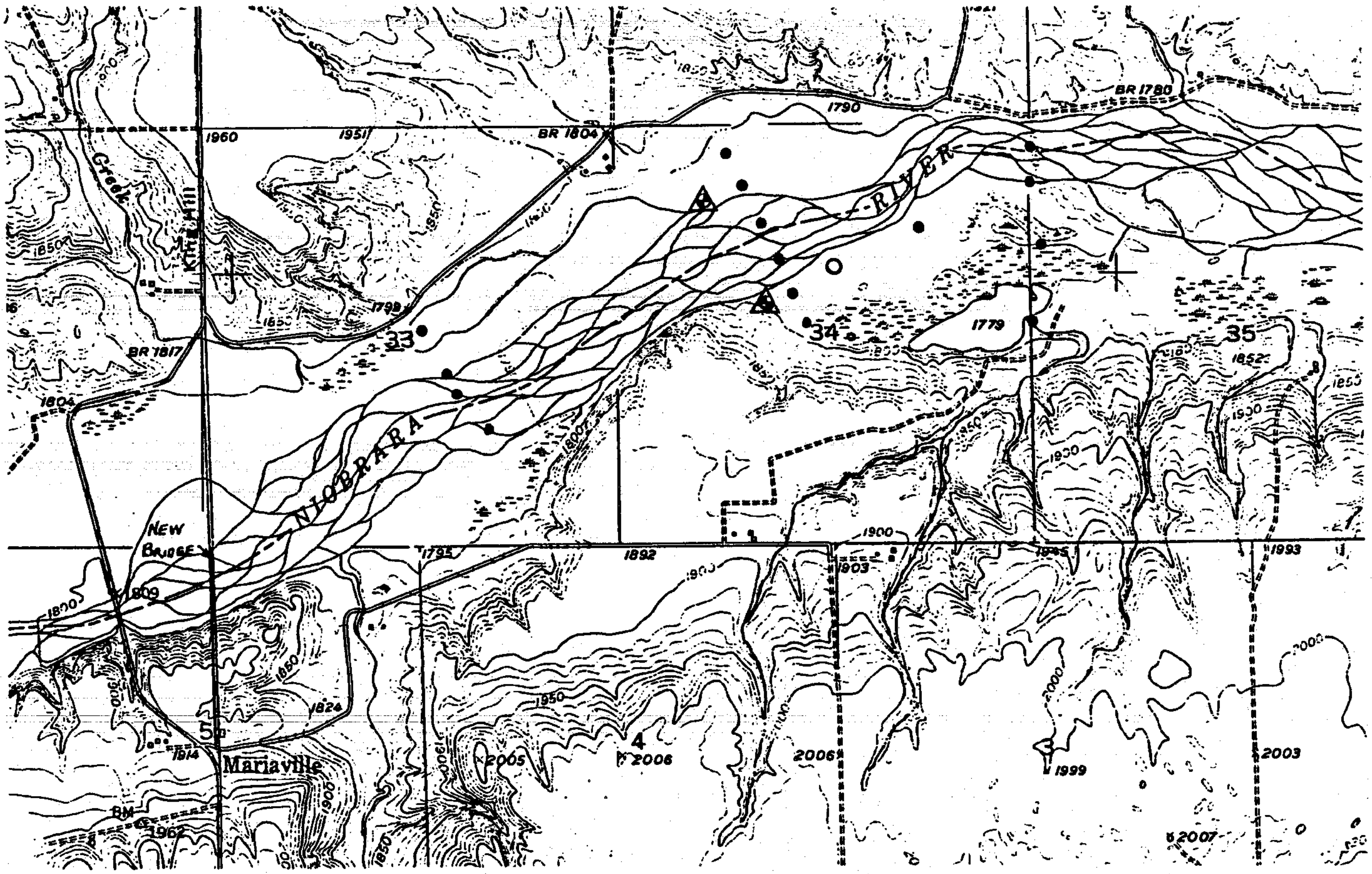
In terms of depth, areal extent, or composition, very little information concerning the valley alluvium, was available prior to this investigation. It was generally assumed that the subsurface alluvial material would be shallow because the Niobrara River is located in a narrow, deeply-incised valley. A poor water yielding formation was anticipated. To better evaluate hydrologic conditions at the site, a test drilling program was planned. It specified drilling to bedrock to determine the thickness of the unconsolidated alluvium in the valley. It also included sample collection to allow visual evaluation and later mechanical analysis which permitted further classification of the materials encountered.

Test drilling within the river valley was completed in late October 1983. Test holes were drilled in three lines transecting the valley (Figure 2). Later analysis provided geologic information about the nature and areal extent of the alluvial deposits. Analysis of data collected from an additional hole provided greater understanding of the more deeply buried alluvial deposits. Presence of an older meander cross-over occurring between the north and south valley walls was revealed. The location and elevation of all boreholes was established by survey in relation to Bureau river station markers. Two State Department of Roads' drilling rigs performed the work.

Depth to bedrock was much greater than expected. Previous borings, completed in the early 1970's for construction of the new Highway 137 bridge upstream, indicated that depth to the Pierre Shale (bedrock) was 25 to 30 feet. The new, downstream test holes revealed depths ranging from 35 to 115(+) feet. The field crew ran out of auger stem (115 feet) before reaching bedrock in several holes. Prior to further testing, the likelihood of a ground water supply greater than previously expected could be anticipated.

In order to quantify the hydraulic properties of the valley alluvium, mechanical analysis and a pumping test were planned and performed. The mechanical analysis and classification of the sample materials indicates they are predominately uniform fine to medium-grained sands with interspersed silt layers at depth.

For the pumping test, a production well was drilled 50 feet away from the south bank of the river. Sixteen shallow observation wells were also drilled so that ground water level changes could be monitored while the production well was pumped. The observation wells were situated in a pattern of eight wells parallel to the river and eight wells perpendicular to it. The pumping well was located at the center. Changes in ground water levels in each well during pumping (time-drawdown data) were used to determine aquifer characteristics and the effective distance to the boundary of recharge. This information formed the basis for the design of several facilities which could be used to extract water from the valley alluvium.



TEST DRILLING LOCATION
Scale 1" = 2,000'

△	USBR Benchmark
○	Production Well
●	Test Hole

Figure 2

During the test, the central well was pumped at a rate of 450 gallons per minute (gpm) for six hours. Water levels in the observation wells were recorded throughout. Preliminary, on-site analysis of the data suggested that shallow silt layers vertically separating the pumping well screen and the screens of the observation wells were present. The silt layers effectively separate the aquifer into two formations. Following the first six-hour pumping test, six deep observation wells were installed and the test performed again. Water level measurements were made in the six deep observation wells and in ten shallower observation wells already in place. At the conclusion of each pumping test, water levels in all observation wells and the pumped well were measured until recovery to the original water level was attained.

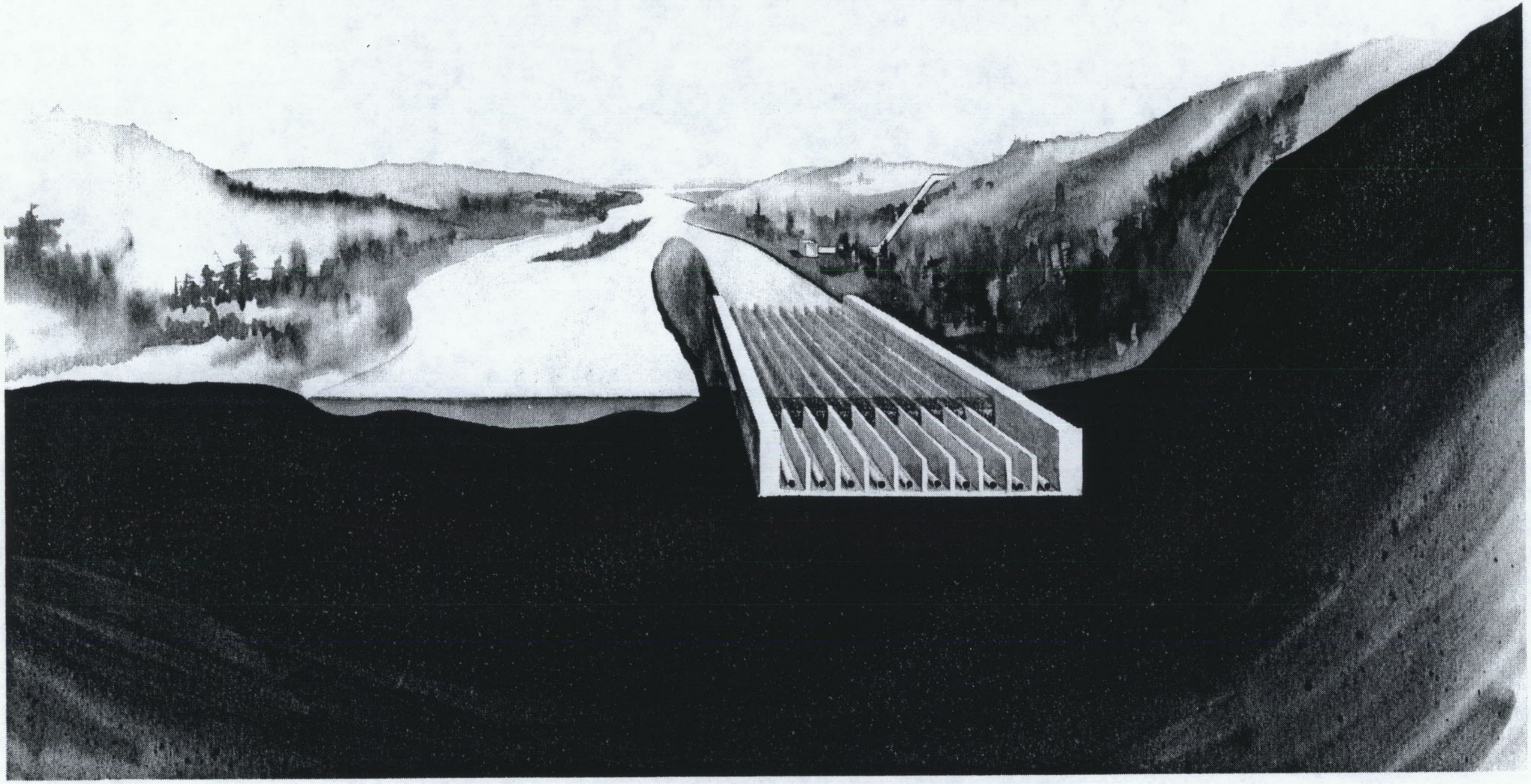
The data obtained from the pumping test were analyzed by the "match-point" technique utilizing type curves for leaky artesian aquifer conditions. The data from the deep observation wells perpendicular to the river indicated aquifer transmissivity in the range of 20,000 gallons per day per foot (gpd/ft) and a storage coefficient of 0.013. Similar results were obtained using both the pumping test data and recovery data. The measured drawdown in the deep observation wells parallel to the river was much less than that observed in the perpendicular line. Results of the pumping test indicate that properly designed and constructed conventional wells could achieve yields exceeding 300 gallons per minute. The results also added further support to the notion that an adequate irrigation supply could be extracted from alluvial deposits in the Niobrara valley.

Instead of the Conservancy suggestion for 196 vertical wells requiring extensive operation and maintenance inputs, several other water extraction schemes were examined. A horizontal infiltration gallery and an adaptation of a rapid sand filter were extensively evaluated.

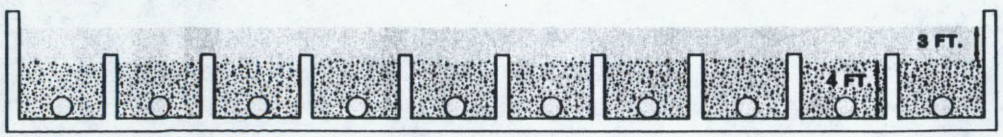
Using the information gained from the pumping test, several designs for a horizontal infiltration gallery were reviewed. One called for the buried, perforated pipe to be placed parallel to the river bank. The other envisioned the facility buried beneath the river bed and perpendicular to the bank (Figure 3). In either case, the perforated pipe would terminate at a central location where all pumping equipment to lift water from the valley would be installed.

The other water supply scheme examined, the rapid sand filter, consists of a rectangular concrete box structure located within an artificial channel constructed parallel to the river (Figure 4). A pile dike would direct raw river water into the channel where it would flow over a chamber consisting of cells filled with specially graded sand and gravel overlying perforated pipes or filter blocks. Similar to the gallery, the water would be collected from each cell and directed to a central location where all pumping equipment would be installed. Periodic backflushing of each cell would remove trapped sediment, thus improving the intake rate.

To determine design and operational considerations for planning a rapid sand filter, a scale model was constructed and operated under laboratory conditions at the Civil Engineering Department, University of Nebraska-Lincoln. The model was constructed in a glass flume. Tests were made using filter media in single and multilayers. Three layers of filter



Typical Rapid Sand Filter Installation



Structure is made of concrete.

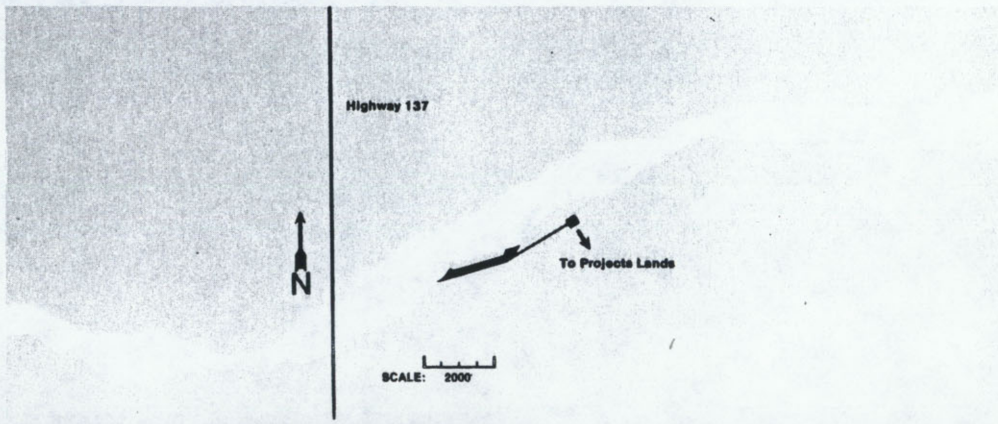
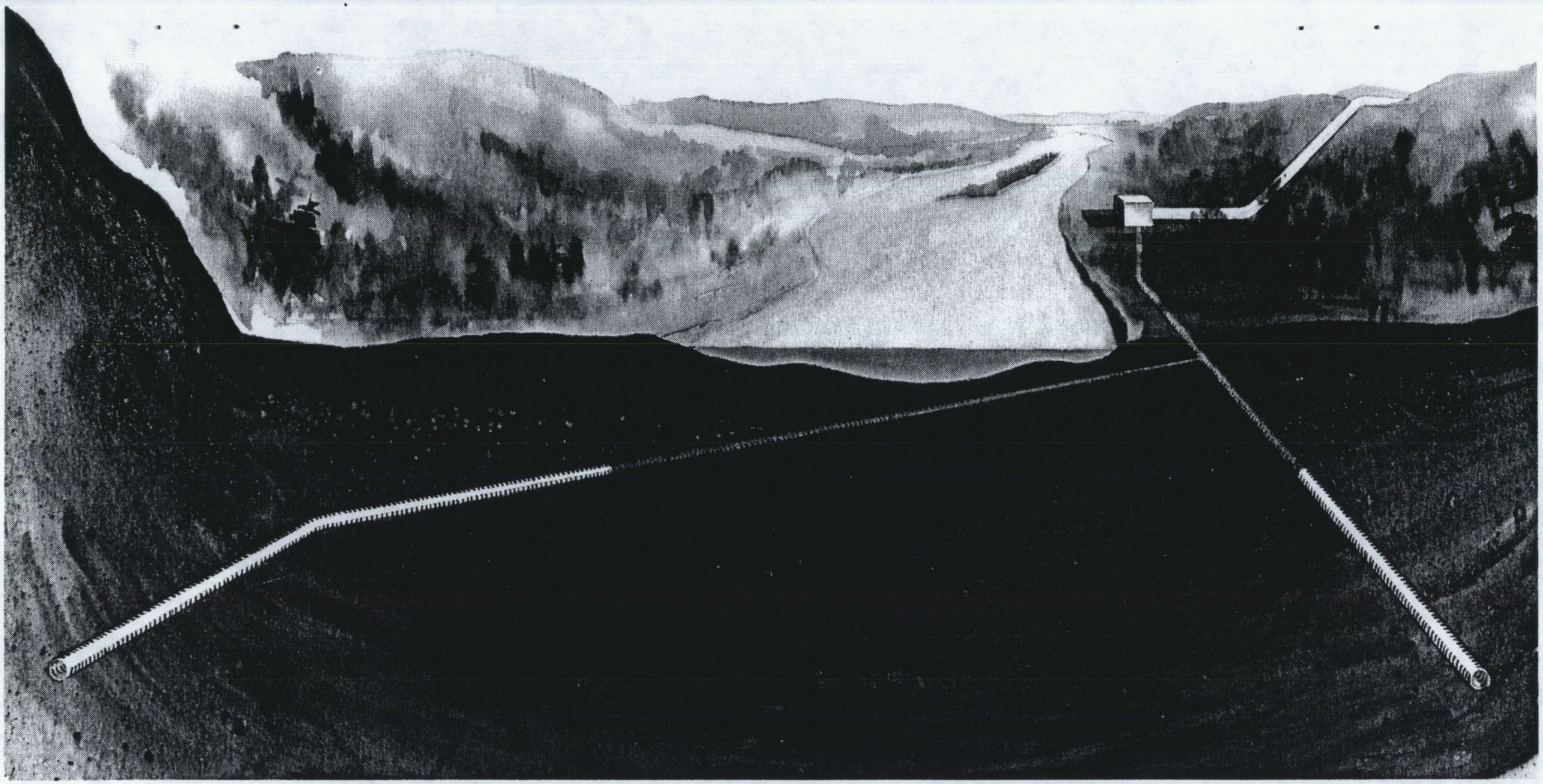
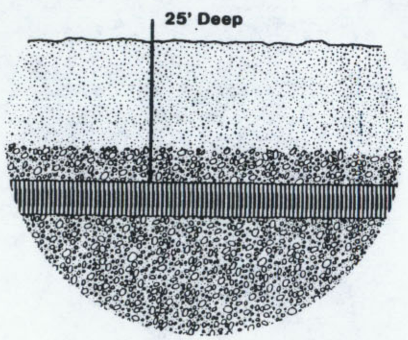


Figure 3



Typical Infiltration Gallery Installation



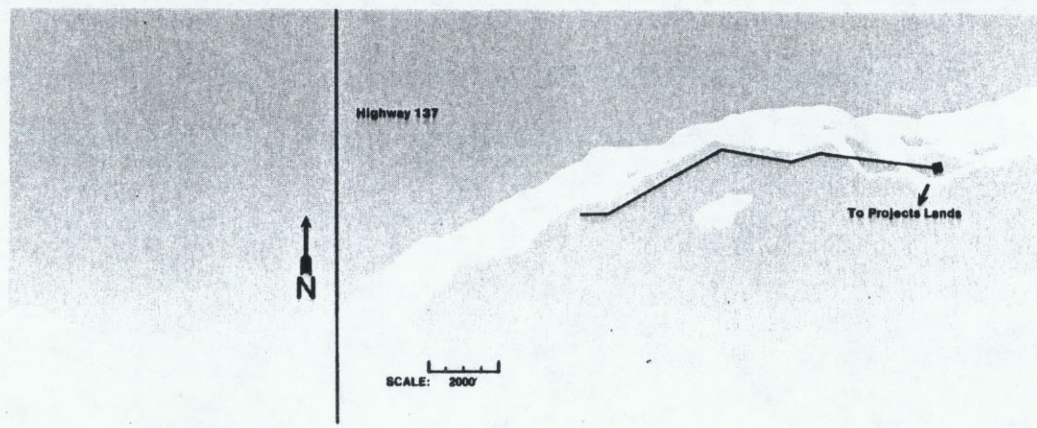


Figure 4

media consisted of coarse, medium, and fine gravel. Ground walnut shells were used to simulate river sediment.

Various river flow conditions were simulated and infiltration rates of the sand filter measured. The laboratory tests consistently demonstrated that an infiltration rate of 20 to 25 percent of the total flow applied to the filter could be expected even when the velocity over the filter was less than required to move incoming sediment. A narrow water velocity range was determined to be optimal.

Although less throughly studied, still other schemes including a Ranney collector and a series of small diameter wells connected by means of syphon tubes to a central caisson were reviewed. Beyond supplying sediment-free water, other advantages exist for these types of systems over the 196 well proposal of the Conservancy. Excepting the rapid sand filter, all are capable of extracting large quantities of water from the alluvial sediments at the test site. In contrast to the 196-well proposal, a centralized pumping facility would be more cost effective by allowing easier access along with reduced maintenance responsibilities.

Each alternative has advantages and disadvantages. An infiltration gallery installed in the alluvium would be affected little by adverse weather conditions and winter ice buildup on the river. Since water would be extracted from the aquifer rather than the river, water temperature fluctuations would be minimal. Once such a system was installed, a long period of service could be expected with minimal operation and maintenance expense. For example, the Des Moines, Iowa infiltration gallery was first constructed in 1888, expanded in 1912, and with moderate routine maintenance is still in use today.

Taking advantage of being able to specify grain size of the material placed in each cell, the rapid sand filter could be compact in size. However, it would be adversely affected by winter conditions. Ice conditions on the river may limit or even preclude operation during portions of the winter. Water temperature fluctuations, particularly cold temperatures, could affect its operation. In addition, operational problems could develop during times of flooding when more concentrated sediment-laden water would decrease efficiency. During low flow, channel movement could result in the need to rechannel the river in order to direct its flow over the filter chambers.

Of the various water supply schemes examined, the horizontal gallery system is believed superior. Its construction cost, discussed later, compares favorably with the others. Operation and maintenance requirements reported for gallery installations are less than for the other schemes examined in this study. A gallery system would not likely be affected by severe weather conditions common to the site evaluated. Legal and environmental considerations, also discussed later, for the most part are the same for each scheme examined.

For the smaller 8,000-acre tract near Springview, the Bureau originally proposed a diversion dam and pumping station to supply irrigation needs there. During the course of this study, it was concluded that there is no better alternative. That component, with no field or laboratory investigation performed, was included in the overall project configuration.

Lastly, the dependability of the Niobrara River to provide sufficient flow for project needs was analyzed using records of historic flow. A stream gage is not located at the study site. Instead, a synthesized record was developed. Records from gaging stations on the Niobrara River at Spencer (downstream) and Norden (upstream), and on the Keya Paha River near its mouth were used. As expected, the analysis showed that total annual flow of the Niobrara River diminished early in the 1960's when diversions for the upstream Ainsworth irrigation project began. A tendency of further depletions is not evident. A five-year moving average of the synthesized annual flow demonstrates stability. No additional flow depletions having the magnitude of the Ainsworth project are anticipated upstream of the study site. A firm water supply for the O'Neill project is expected.

Service to Project Lands

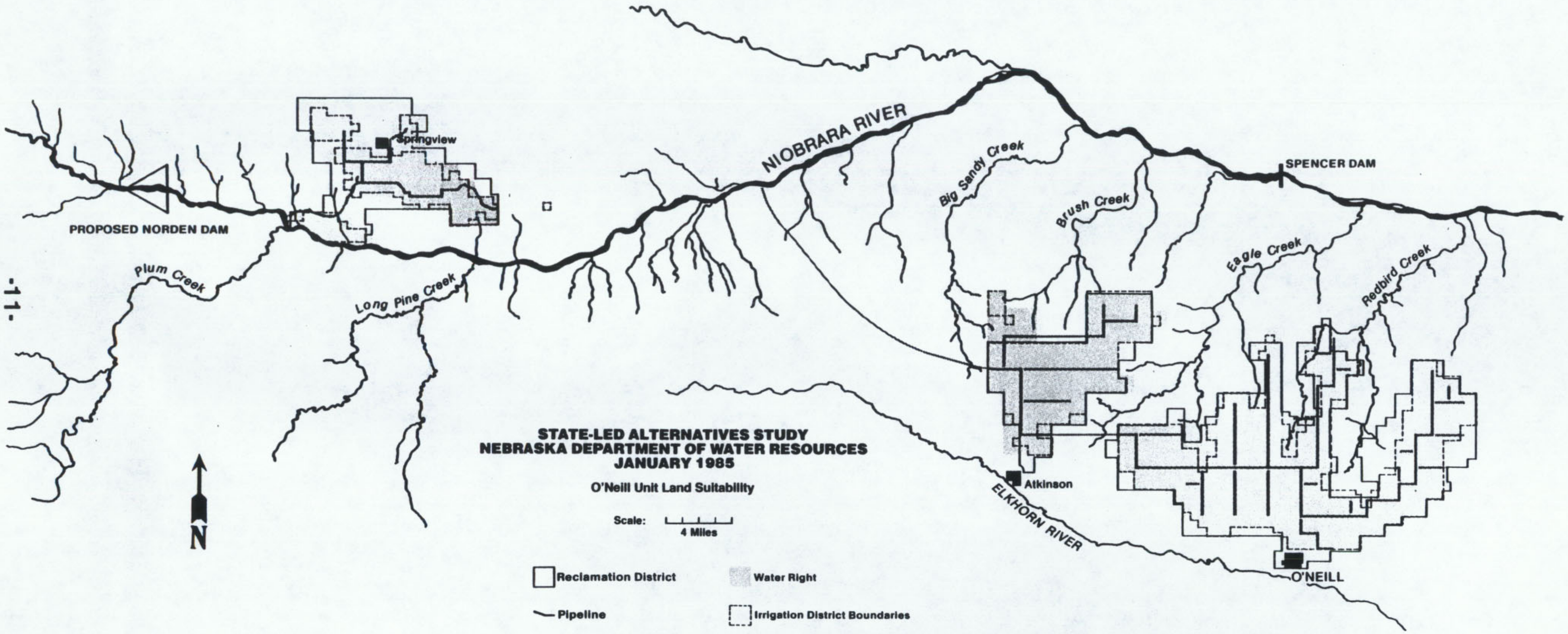
Several boundaries have been established to describe the lands comprising the O'Neill Unit. Both an irrigation district and a reclamation district have been formed with different boundaries. In addition, the project water right includes specifically described lands that make up yet another project boundary. In many locations, the three boundaries do not coincide (Figure 5). For purposes of this study, the project boundary selected was that of the reclamation district. All reference to lands served is in relation to this boundary.

The authorized project calls for the direct, on-demand delivery of surface water. Rather than providing direct, on-demand irrigation delivery with project water to serve those lands that are or could be irrigated using ground water, the maintenance of ground water levels by recharge was examined in part by this study. For those lands not overlying an aquifer system or situated where recharge is considered infeasible, water would be supplied by direct service when needed during the irrigation season. Service to 22,680 acres in the Atkinson-O'Neill area and to the entire 8,000 acres in the Springview area falls into the last category. It would be provided as direct, on-demand delivery (Figure 6).

Sediment-free water is essential to the success of recharge. Rather than conveying and distributing project water through an open canal and lateral system, a pipeline network is envisioned. A pipeline, thought initially more costly, would not arbitrarily segment farm and ranch lands or present hazards to wildlife movement. Once installed, former land use can resume. Maintenance, right-of-way, and land acquisition costs for a pipeline are significantly less than those for a canal.

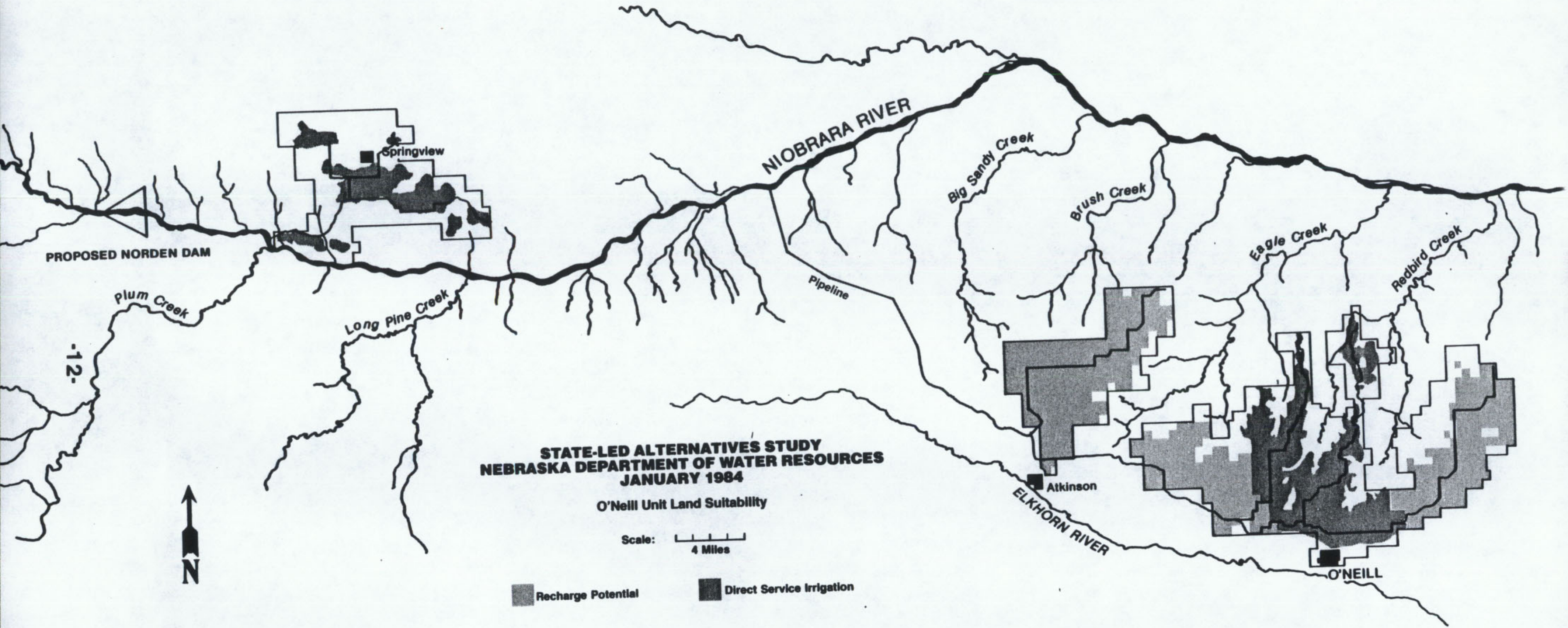
Approximately 62,000 acres have been identified as being potentially suitable for artificial recharge in the Atkinson-O'Neill area. This includes 18,000 acres not obligated by contract. All lands having recharge potential were included in the investigation. Lands obligated and not suitably situated for successful aquifer recharge in the Atkinson-O'Neill area represent 22,680 acres. They extend generally from O'Neill to the north project boundary. They lie between those areas where recharge is envisioned.

To develop an estimate of project water needs, a Bureau-developed computer model for the ground water system beneath the Atkinson-O'Neill area



O'Neill Unit Boundaries

Figure 5



Recharge and Direct Service Area

Figure 6

was used. Results from the model indicate that the annual difference between ground water pumping and natural recharge (consumptive use) averaged 0.8 acre-foot per irrigated acre. Water supply needs for the lands suitable for recharge were based on replacing the consumptive use. For those lands to receive direct service, the legislative statutory limit of one cubic foot per second per 70 acres was applied. For example, this translates into approximately 1.9 cfs (865 gpm) supplied to each quarter section irrigated by a center pivot (135 acres).

To aid in later locating project facilities, the Bureau's ground water model of the Atkinson-O'Neill area was used to estimate ground water depletions and to identify lands benefited by recharge and direct service. Ground water conditions were simulated for future time periods under three assumptions: without supplemental irrigation water, with the authorized project, and with the recharge-direct service alternative envisioned in this report. Lands were identified inside and outside the reclamation district boundaries in each case. It was noted that a large portion of the authorized project lands already have experienced private irrigation development utilizing ground water.

The future without project simulation categorized lands that are currently ground water irrigated and those presently undeveloped but with the potential for ground water development. Model results showed ground water depletions would result in 40,365 acres within the reclamation district, reverting to dryland conditions at the end of approximately 70 years. For the authorized project scenario, lands were identified as currently ground water irrigated, potentially ground water irrigated, currently ground water irrigated but switching to surface water, and surface water irrigated with no potential for ground water development. The loss of all ground water irrigated lands (8,500 acres) at the end of the simulation were projected to occur outside the reclamation district boundary. Lands were identified in the same manner as the authorized project scenario in the simulation of the recharge-direct service alternative. In addition to the loss of ground water irrigated lands outside the reclamation district boundary, the model predicted 810 acres in addition were lost inside the boundary. A summary of the results of ground water model simulations is shown in Table 1.

Project configuration and expected water demand in the area to be served dictated the "size" of the various components. Meeting the peak, on-demand direct irrigation needs of the 22,680-acre segment established the maximum capacity of many components. In order to meet this two-month demand, facilities providing a flow rate of 324 cfs would be required. If the analysis went no further, at this rate project facilities would provide the potential to greatly expand recharge service to more lands. Alternatively, recharge could be accomplished in a matter of months.

To provide water service within the existing boundaries while minimizing component sizes and resultant costs, it is proposed that water in excess of that required to sustain ground water pumping be temporarily stored in the ground water reservoir near the 22,680-acre direct service tract. During the growing season, water demands for that tract would in part be met from recovery of water previously used to recharge an aquifer system nearby. The project's water supply gallery in the Niobrara valley, pumping station and pipeline between the Niobrara valley and the location of the peak-season

Table 1

COMPARISON OF GROUND WATER MODEL RESULTS

O'NEILL - ATKINSON AREA

	W/O SUPPLEMENTAL WATER		AUTHORIZED PROJECT		RECHARGE ALTERNATIVE	
	* INSIDE	* OUTSIDE	* INSIDE	* OUTSIDE	* INSIDE	* OUTSIDE
IRRIGATED ACRES AT START OF SIMULATION						
CURRENTLY GROUND WATER IRRIGATED	54405	61020	23220	58725	46035	61020
POTENTIALLY GROUND WATER IRRIGATED	24570	30375	8370	30375	24570	30375
GROUND WATER IRRIGATED GOING TO SURFACE WATER	-----	-----	47915	2295	3915	-----
SURFACE WATER IRRIGATED (NO GROUND WATER)	-----	-----	18765	135	18765	-----
TOTAL IRRIGATED ACRES (POTENTIAL)	78975	91395	98270	91530	93285	91395
IRRIGATED ACRES AT END OF SIMULATION						
DIRECT SERVICE ACRES	-----	-----	66680	2430	22680	-----
WELL IRRIGATED ACRES	38610	51840	31590	80595	7830	71145
WELL IRRIGATED WITH RECHARGE	-----	-----	-----	-----	61965	-----
TOTAL POTENTIAL IRRIGATED ACRES	38610	51840	98270	83025	92475	71145
LOSS OF WELL IRRIGATED ACRES	40365	39555	0	8505	810	20250

NOTE:
* - RECLAMATION DISTRICT BOUNDARIES

recovery wells were reduced in size by over 50 percent. A flow rate of 150 cfs would be sufficient to provide the recharge requirements to the 22,680-acre tract and the needs of the remaining lands served by recharge exclusively. This flow rate would be required on a continuous basis during at least ten months of the year.

A preliminary pipeline network was established generally following much of the alignment for the Bureau's proposed canal system. Distribution lines were located in a manner to minimize the distance to the numerous service locations. Upon review of this network, however, it was determined that reductions could be realized by realignment of the distribution system. The main supply line, originally paralleling the southern boundary of the service area, was redirected through the center of the project lands. By reducing the length over 20 miles, construction costs were reduced considerably.

Pipe sizes ranging in diameter from 4 to 108 inches make up the network. When operating, a constant flow rate from the water supply gallery would be pumped. Peak direct service requirements would be supplied by combining that flow with sufficient quantities recovered from ground water previously placed in storage. A 72-inch diameter pipeline would convey water from the river valley to the temporary ground water storage and recovery facilities north of Atkinson. The largest pipe diameter, 104 inches, would be installed for conveyance between that location and the direct service area further east.

Recharge Demonstration

Two sites were selected for demonstration of recharge potential utilizing perforated, plastic materials commonly used in agricultural drainage. Selection was based upon information obtained from recently published Soil Surveys, irrigation well logs, and Bureau geologic cross-sections. One site, northeast of O'Neill, was selected where the soil to a depth of five feet was judged to be highly permeable. Well log and other geological information indicated the absence of intervening silt layers at greater depth. Potential for recharge appeared good. Another site was selected in an area north of Atkinson where shallow silt and clay layers cause a perched water table to exist. Recharge potential there was judged to be more marginal.

A well was installed at each site to provide sediment-free water comparable to that which would be obtained from the Niobrara valley. Each was equipped with a flow meter. A submersible pump capable of supplying 100 gpm was installed in each well. At both sites, 600 feet of six-inch perforated plastic drainage pipe with a fabric filter was installed in a five foot deep trench. The trenches were backfilled to their undisturbed elevation.

Operation at both sites was not without problems. Recharge at the Atkinson site went as anticipated after electrical/mechanical problems encountered in start-up were overcome. Water "exfiltration" from the perforated pipe was at a rate consistent with design assumptions for the soil conditions present. The rate, however, was less than would be required under project operational conditions. To provide volumes sufficient for project operation, it was apparent that water would have to be introduced below the silt layers encountered at depths of 5 to 15 feet.

The second site, again after overcoming electrical/mechanical problems in start-up, operated at less than ten percent of design capacity with land surface seepage occurring near the terminus of the pipe. Site investigation suggested that several factors contributed to the less than satisfactory results. Soil borings indicated that the sand-gravel matrix underlying the site included a clay binder that tended to swell when wet. The swelling of the clays in conjunction with the uniform grain-size distribution in the sand-gravel matrix significantly reduced infiltration capacity. Additional Bureau drilling revealed similar conditions across vast stretches of the Atkinson-O'Neill project area. The slope to which the perforated pipe was installed plus above-normal precipitation during the months of July and August are also thought to have contributed to the poor performance.

A third installation of the perforated pipe system was completed late in the study. This line was intended by design to account for the slower exfiltration rates that had been observed in the earlier two demonstrations. A larger, eight-inch diameter plastic drainage pipe, 900 feet in length, was installed at a location 1½ miles east of the first demonstration site north-east of O'Neill. Test drilling conducted prior to installation indicated more favorable conditions than those at the site 1½ miles west. The third installation also allowed comparison between the cost of installing an injection well and a perforated pipeline each intended for recharge at similar rates.

Initially, an exfiltration rate of 100 gpm was established. After three hours, the rate was reduced to 50 gpm to allow for unattended, overnight operation. Later, the flow rate was again changed several times, and water levels were periodically noted in two standpipes installed with the perforated pipe. Land surface seepage ponding was noted following three days' operation. Further recharge was then discontinued.

To overcome the physical limitations inherent in the native earth materials which made for unsatisfactory recharge performance of the perforated pipe systems, an injection well was installed at the Atkinson site. The six-inch diameter well consists of 15 feet of polyvinal chloride (PVC) casing and ten feet of PVC well screen. Five feet of casing was additionally installed below the screen. The well is finished in the unsaturated zone above the water table. The screen section is located immediately below an upper silt layer and terminates 15 feet above the water table (Figure 7).

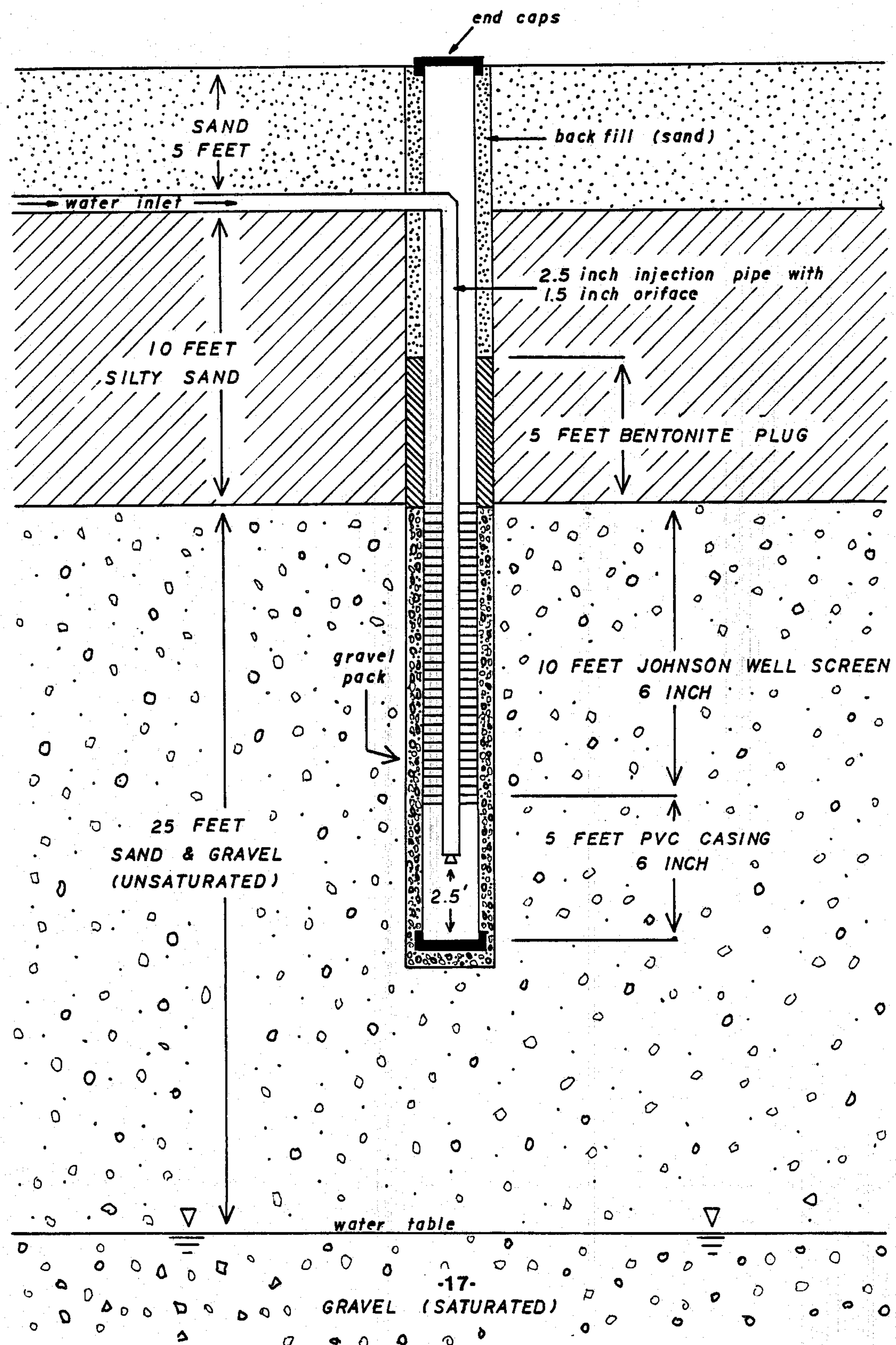
The injection well is 300 feet from the water supply well and connected by a small diameter pipeline. Injection of water through this installation began on November 7, 1984. Five observation wells were constructed nearby. A continuous flow rate of 100 gpm was established. At this rate, 0.44 acre-feet per day is injected into the ground water reservoir. Pumpage has continued uninterrupted to this date. The injection well will be operated beyond the conclusion of the study period.

Measurements of water levels in the observation wells indicate that the mound (or rise) in the water table resulting from injection stabilized soon after operation began. A computer model utilizing finite-difference techniques and methods first developed by M. A. Hantush was used to simulate changes in ground water levels during operation. Computed changes in ground water levels due to the influence of the pumping well, when subtracted from

INJECTION WELL

ATKINSON, NEBRASKA

Figure 7



the computed rise associated with the injection well, results in a net change in ground water levels for the system. Comparison of the computed and observed net changes in ground water levels in the observation wells exhibit agreement within the limits of measurement accuracy (Figure 8).

While exfiltration was initially successful with the third installation of perforated pipe, the surface ponding that occurred at the reduced rate indicated that an even larger perforated pipe installation would be necessary to operate at the rate required. Added expense and uncertainty of success raise serious doubts for using perforated pipe for recharge. To add further doubt is the notion recently expressed by the Conservation and Survey Division, University of Nebraska-Lincoln that across much of the project lands, recharge applied at or near the surface may not be effective. Experience gained in this study implies that ground water recharge using buried, perforated pipeline systems is unsatisfactory for conditions existing within the O'Neill project area. The same conclusion is presumed for the use of pits as envisioned by both the Bureau and the Conservancy. Therefore, the use of injection wells is recommended for recharge within the project. Just as was envisioned with the "leaky" pipe network, however, intentional raising, lowering or stabilizing of ground water levels can be achieved through controlled operation of a system of injection wells.

Use of injection wells for recharge is not without need for rehabilitation and maintenance. The single most important drawback to their use is the potential for clogging of the screen opening. It is acknowledged that some clogging may occur when using even the best quality drinking water. Reported experience in cleaning injection wells seldom results in restoring them to their original capacity. At some point, rehabilitation may yield to construction of a new injection well.

Several specific causes have been identified for the clogging of injection wells. Design of injection wells proposed for those lands suitable for recharge is based on these considerations. Entrained air, the presence of minute quantities of suspended sediment, biological growth, and chemically formed precipitates are all sources of clogging which were "factored" into the injection well specifications. Provisions and recommendations for routine maintenance were developed to address those causes that cannot be minimized.

Project Costs

Various components when blended together would deliver irrigation water to project lands near Springview and in the Atkinson-O'Neill area. They can be categorized as the water supply, main supply pipeline and distribution system, and mode of service for project lands. Preliminary design for each component was developed and construction cost estimates prepared.

All costs were tabulated according to the method and location of the service. A 10 percent factor to cover contingencies was applied to the total basic field construction costs. The detail to which individual component costs were estimated, particularly service to the Atkinson-O'Neill area, supports the selection of this factor for contingencies.

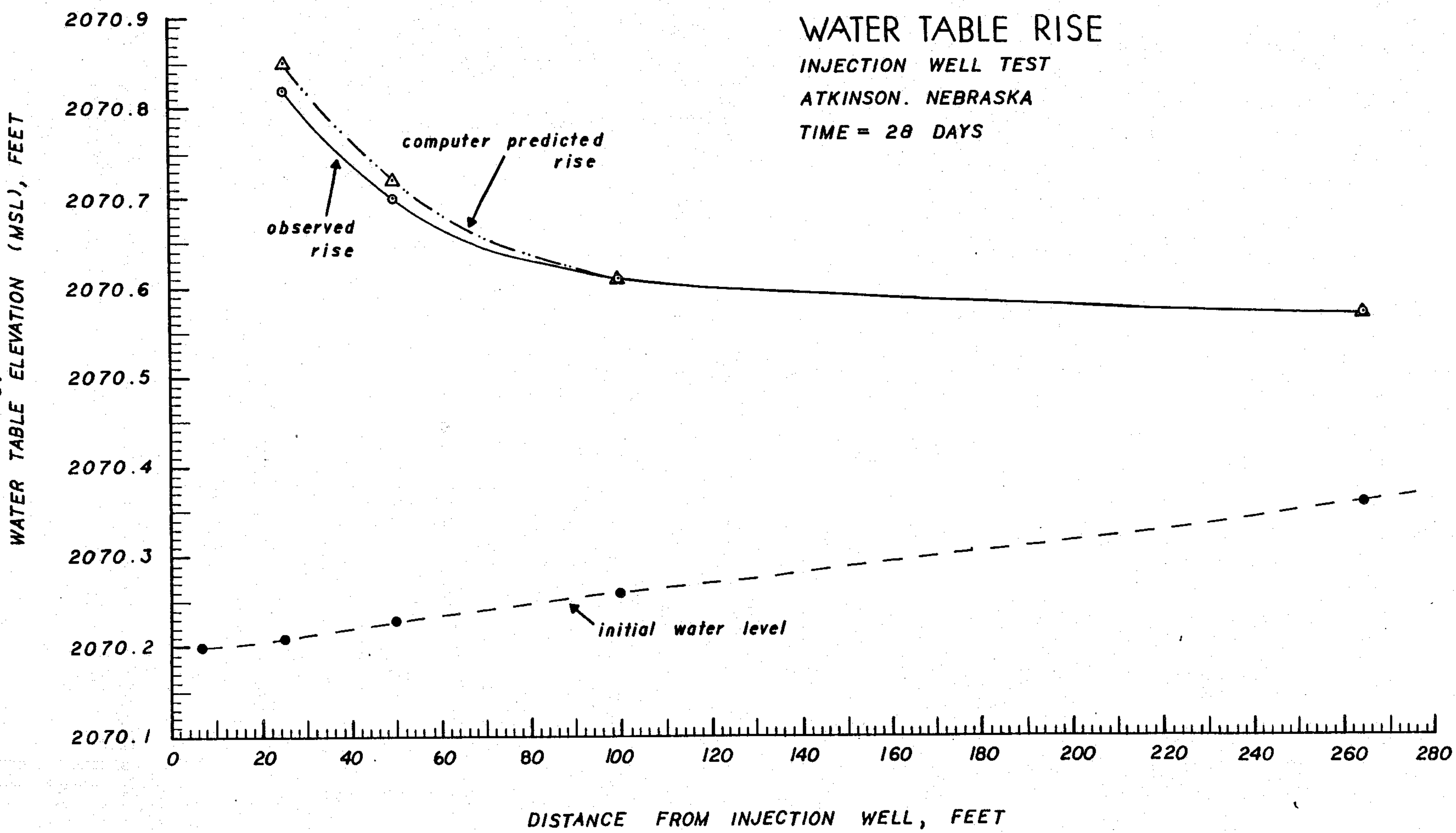

WATER TABLE RISE
INJECTION WELL TEST
ATKINSON. NEBRASKA
TIME = 28 DAYS
computer predicted rise
observed rise
initial water level
WATER TABLE ELEVATION (MSL), FEET
2070.9
2070.8
2070.7
2070.6
2070.5
2070.4
2070.3
2070.2
2070.1
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
DISTANCE FROM INJECTION WELL, FEET

Figure 8

Another five percent was allocated for project management. Inspection of construction activities included with engineering services was excluded from the overall project management responsibilities. This fee, reflecting contracted services for management of a project of this complexity, was selected after discussion with several engineering consulting firms, staff of the Construction Management Department, University of Nebraska-Lincoln, and review of suggested professional practice.

Cost estimates for service to the lands in the Springview area were provided by the Bureau. These estimates were indexed to reflect costs as of October, 1984. The indexed costs used are the Bureau's estimated field costs less its assigned contingencies. Costs associated with land acquisition and road improvements are not listed as separate items. Instead, they are included in the major component classification. Total construction cost for service to Springview lands is estimated to be $24,580,000.

Configuration and design of the infiltration gallery amounts to 12,500 feet of perforated concrete pipe installed in a 25-foot deep trench. The diameter of the pipe varies from 12 to 96 inches. Pipe lengths for each diameter were determined by limiting axial velocity to three feet per second. Construction cost estimates for the infiltration gallery system includes excavation, shoring, dewatering, clearing and grubbing. Total gallery basic field construction costs are estimated to be $7.5 million.

Design estimates for the water conveyance system included the pump station, and the main supply pipeline and distribution network. For the Atkinson-O'Neill area, design assumptions for these components included recharge water provided to 459 quarter sections at a rate of 100 gpm for eight months' time. Supplemental recharge and recovery to partially meet direct service demands of 168 quarter sections were added to that portion supplied directly from the gallery. The pipe unit cost was based on delivery from an existing manufacturing plant. (If the project were to be constructed with the pipeline envisioned, a local manufacturing plant would likely be constructed with a resultant cost savings.) The pumping plant design includes one backup pumping unit. Total estimated basic field construction costs for conveyance are approximately $100 million.

Rather than installing an injection well for each quarter section, lands were clustered and larger injection wells specified. Injection wells with capacities ranging from 100 to 400 gpm were specified. Costs computed for each unit include drilling the well, PVC screen and casing, gravel pack, pitless adapter units, drop pipe assemblies, valves, and meters. In addition to the injection wells, the pipeline for connection with the distribution system is included. Where necessary, manholes or pits for access are included.

Ranney collector wells have been included for the recharge/recovery system to meet direct service, peak needs. Five installations (15,510 gpm each) are proposed for location north of Atkinson. During eight months of the year, water would be provided for recharge to replace pumpage during the irrigation season. Two spur lines of the main distribution system were increased in size to accommodate the increased flow rates required for supplementing direct service. Delivery of direct service water would be provided to the location of use. Access facilities, valves, flow meters, and pipe have been included in the cost estimates for that portion of the distribution network serving the direct service lands.

Additional cost estimates for each service area include power lines, substations, road improvements, and land acquisition. Two project power line routes were examined. One would tie project pumping facilities directly to the federal power line north of O'Neill. The other would be approximately $20 million less costly to construct. It would be tied to the commercial line near Atkinson. Because of "wheeling" charges payable for transmission over commercial lines, the first alternative resulting in lower annual operating expenses is best from the standpoint of project irrigators. Estimated total cost for the first alternative using federal transmission lines is $200 million.

The main supply pipeline network requires approximately 850 acres of right-of-way. Less than 150 acres would be required for the water supply gallery system. A well maintained county road is accessible within one mile of the proposed water supply location. Road improvement costs have been included only for providing access to the existing county road.

The basic field cost estimates for the components serving the Atkinson-O'Neill area were adjusted to include expenses incurred for engineering, surveying, test drilling, and other technical services. In addition, the various costs were allocated between recharge and direct service. This allocation, shown in Table 2, was based on the incremental cost difference of adding the direct service components to the recharge system.

The components of the project configuration could be constructed independently and together are estimated to require four years for completion. The first year, 20 percent of the project could be completed; 25 percent the second year; 33 percent the third year; and 22 percent the fourth year. Interest charged was determined by using the discount rate for the authorized project (3.25 percent) and compounded during construction for the percentage completed in any one year.

The current rate of allocation of the costs for federal (Pick-Sloan) power, with interest during construction, was assigned to the respective methods of service. These costs were assigned only to the project cost analysis assuming the use of Pick-Sloan power and were based on the installed kilowatts of pump capacity. For both the alternative being recommended and the Congressionally-authorized project, Table 3 summarizes costs for project components, costs for interest during construction, and Pick-Sloan costs assigned to the project for supplying power to pumping facilities.

Annual Operation Costs

The North Central Nebraska Irrigation District has agreed to repay the federal government $45,000,000 of the total construction cost for the O'Neill Unit. According to a Bureau spokesman, following an initial ten-year period, this repayment would be spread over 40 years with no interest charged. The annual repayment was allocated to the various methods of service based on the distribution of the total construction cost for the respective service

Table 2

TOTAL CONSTRUCTION COST (FEDERAL POWER)[1]
(THOUSANDS OF DOLLARS)

COMPONENT COST	ATKINSON-O'NEILL AREA		SPRINGVIEW AREA	TOTAL
	DIRECT SERVICE[2]	RECHARGE[3]	DIRECT SERVICE[4]	COMBINED SERVICE
WATER SUPPLY	3500	4000	3029	10529
PUMP STATION	5464	6244	10917	22625
DISTRIBUTION SYSTEM	45410	42758	4152	92320
INJECTION WELLS FOR RECHARGE		2295		2295
INJECTION/RECOVERY FOR PEAK DIRECT SERVICE	6020			6020
POWERLINE AND SUBSTATION FOR RECHARGE/RECOVERY	1400			1400
POWERLINE AND SUBSTATION FOR RIVER PUMPING	2567	2933	3183	8683
ROAD IMPROVEMENTS	467	533		1000
LAND ACQUISITION	298	682		980
TOTAL BASIC FIELD COST OF LISTED ITEMS[5]	65126	59445	21281	145852
CONTINGENCY - 10 PERCENT	6513	5945	2128	14585
PROJECT MANAGEMENT - 5 PERCENT	3582	3270	1171	8022
TOTAL FIELD CONSTRUCTION COST	75221	68659	24580	168459

NOTE:
1. ASSUMES FEDERAL PICK-SLOAN POWER ($0.0025/KW-HR ATKINSON-O'NEILL, $0.00634/KW-HR SPRINGVIEW)
2. 22,680 ACRES SERVED
3. 61,965 ACRES SERVED
4. 8,000 ACRES SERVED
5. INCLUDES ENGINEERING, SURVEYING, SUB-SURFACE EXPLORATION, AND OTHER TECHNICAL SERVICES
6. BASED UPON CURRENT CONTRACTED REPAYMENT ($45,000,000)

methods. The estimated annual operating, maintenance, and replacement costs were allocated in the same manner.

The annual energy costs for pumping water to the project lands was determined for each service method. Three power rates, all federal, federal power carried on a commercial line, and all commercial were considered. As suggested before, power obtained from an all-federal system would be most advantageous to project irrigators. Table 4 summarizes annual costs for both the alternative recommended and for the Congressionally-authorized project. Compared to an all-commercial system, combined annual energy costs are estimated to be less by nearly 15 times. Annual energy costs for the combination federal/commercial line fall between the two extremes.

Legal and Institutional

Several issues were examined in a legal and institutional analysis done for this investigation. They pertain to the laws governing water supply sources, use of water, transportation of water, and assessment of project capital and operation costs. There is no disputing the notion that traditional application of present water laws would prevail for operation of the Springview area diversion facilities. An appropriation to divert surface water from the Niobrara River for the O'Neill Unit has previously been granted by the Department of Water Resources. The point of diversion could be changed administratively from the Norden Dam site to different locations downstream. Water extracted from either a rapid sand filter or an infiltration gallery (located within 50 feet of the river's bank) could be administered by the state as a traditional water diversion. A water appropriation having a priority date and a limitation in terms of an instantaneous rate and annual quantity is envisioned. There are no administrative hindrances preventing water extracted from the Niobrara River Valley to be transported many miles before its use in the Springview or Atkinson-O'Neill areas.

The federal reclamation laws, requiring a local sponsor be organized before the construction of a project can be initiated, have been satisfied. A reclamation district and an irrigation district have formed and contracted with the federal government for construction and operation of the O'Neill Unit. If deemed necessary, minor legislative amendments to "harmonize" several provisions of state law would clarify the district's authority to collect user fees from direct service customers and from those enjoying both intentional and incidental recharge.

Environmental

Various project components envisioned in the investigation were configured in a fashion to minimize environmental impacts. In comparison, the total water supply requirement for the recharge-direct service portion serving the Atkinson-O'Neill area is less than two-thirds that of the Congressionally authorized project. By design, extending the total water demand over a longer time period further diminishes adverse river flow impacts. Nonetheless, some detrimental impact on fisheries at times may remain.

Table 3

PROJECT COST ANALYSIS
(3.25 PERCENT DISCOUNT RATE)

Item	Atkinson-O'Neill Area		Springview Area	Alternative Study	Authorized Project[1]
	Recharge	Direct Service	Direct Service	Combined	Combined
Investment ($1,000)					
Total basic field construction cost	68659	75221	24580	168460	321090
Interest during construction	5590	6124	2001	13715	25770
Assigned to P-SMBP pumping investment (includes IDC)	4980	6346	5562	16888	2860
Total Project Cost	79229	87691	32143	199063	349720
$ per acre	1279	3866	4018	2149	4542
(Acres Served)	(61965)	(22680)	(8000)	(92645)	(77000)

NOTE:
1. DOES NOT INCLUDE SEPARABLE COSTS FOR RECREATION, FISH AND WILDLIFE, AND FLOOD CONTROL (1981 USBR ESTIMATE)

Table 4

ANNUAL IRRIGATION COST ALLOCATION

Item	Atkinson-O'Neill Area		Springview Area	Alternative Study	Authorized Project
	Recharge	Direct Service	Direct Service	Combined	Combined
Annual cost ($1,000)					
Pumping energy (E)	75	71	60	206	24
OM&R	398	441	161	1000	766
Construction Repayment	448	496	182	1125	1125
Total Annual Costs to the Irrigator	921	1008	403	2331	1915
(Cost per acre)	$14.46	$44.43	$50.37	$25.16	$24.87

Installation and operation of the infiltration gallery system would damage nearby riparian woodland and wetland habitat. This installation would affect only those wetlands closest to the river and generally be confined to the length of the gallery. When considering the region in a broader context, those impacts would not likely be significant.

The use of a pipeline for distribution does not present a barrier to wildlife movement as would an open canal. Where possible, the location of the pipeline has been specified to avoid sensitive locations such as wetlands.

The use of injection wells to recharge the ground water reservoir is regulated by the Nebraska Department of Environmental Control. As long as the injection does not endanger public health or cause pollution, all that is required is registration of the wells with that agency. The use of high quality injection water may well result in enhanced ground water quality.

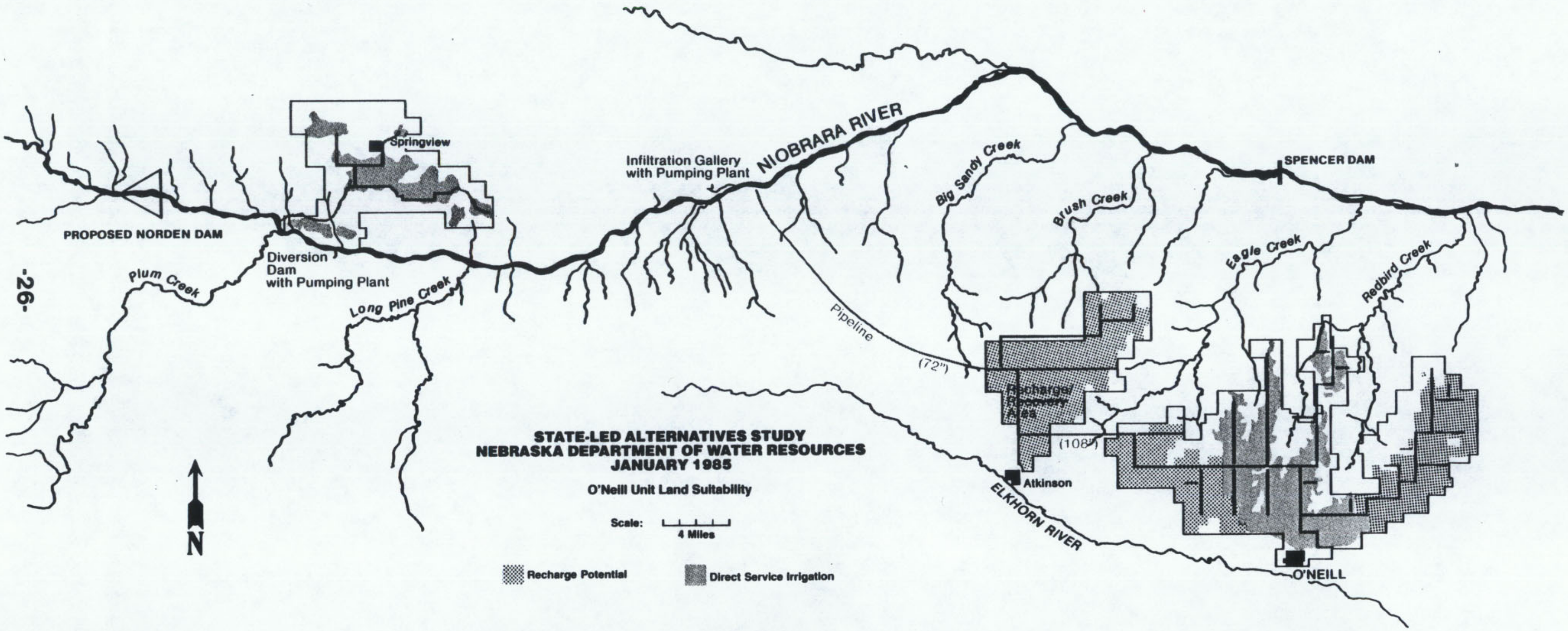
Summary

Beyond evaluating the feasibility of providing an adequate water supply to the O'Neill Unit with facilities other than the Norden Dam reservoir and the other factors mentioned previously, one other goal was established. If possible, we sought to lay out an efficient, less costly alternative scheme. Keeping in mind that some lands could not be served by artificial recharge while other tracts could be served in that manner, made the goal challenging. The scheme finally devised (Figure 9) is of optimum size and capable of fulfilling project needs. With minor modification, it could also provide water supplies for additional irrigation or for municipal or industrial purposes in nearby communities.

The use of recharge/recovery to meet peak direct service needs reduces the maximum instantaneous water supply demand. Thus, a sustained flow rate can be provided continuously during project operation. This flow rate can be provided in any number of ways, including the Nature Conservancy's 196 well field proposal. Based upon our finding in this study, however, we have concluded that a horizontal infiltration gallery can be substituted for the well-field supply. Such a system would result in reduced construction, operation, and maintenance expense.

The Bureau's ground water model of the Atkinson-O'Neill area indicated that with the applied rates for recharge and direct service, ground water levels, and the number of irrigated acres can be maintained within the project boundary. In order for recharge to be effective we believe that water must be introduced below clay or silt layers, the presence of which is known to exist over much of the area. Use of injection wells, therefore, is the best method for providing effective recharge. Use of sediment-free water and particular injection well design criteria have been "factored" into overall project configuration in order to lengthen the service life of the recharge system. Similar to conventional water supply systems, periodic maintenance, including eventual replacement, will be required for the system.

Construction cost estimates were prepared with the assumption that all design and project management would be provided by contract with the private sector. Component and construction activity costs reflect those costs



O'Neill Unit Configuration of Project Components

Figure 9

prevailing during the fall of 1984. The least costly proposal, from the standpoint of the individual irrigator, utilizes federal power (Pick-Sloan) carried on federal power lines. The estimated construction cost is nearly $200 million. (By comparison, the entire cost of the Congressionally-authorized project is said to exceed $380 million.) Averaged over the entire lands served, the annual operating, maintenance, replacement, energy and construction repayment costs are estimated at $25.17 per acre. These costs may be prorated to the method of service and thereby reflect the additional pumping cost borne by ground water irrigators.

Project components were developed to minimize environmental impact. Total water supply requirements have been reduced with this configuration. Nonetheless, some detrimental impact on fisheries at times may remain. Maintaining wildlife habitat was a consideration for the location of the distribution system and the infiltration gallery.

We believe there are no major legal or institutional impediments to the alternative suggested. Both a reclamation and irrigation district have been formed with the authority to contract with the United States. Provisions exist in State statutes to assess project costs to beneficiaries, both direct service and recharge. If deemed necessary, minor legislation amendments to "harmonize" several provisions of State law would clarify the district's authority.

STUDY PARTICIPANTS

Numerous local officials, state and university agencies, the Bureau of Reclamation, and the private sector participated in the State-led study of alternatives to the O'Neill Unit. Their input was greatly appreciated.

The legal and institutional review was provided by Annette Kovar of the Natural Resources Commission. The Department of Roads provided drilling equipment and personnel for geologic exploration. Environmental impacts of the project configuration were evaluated by Gerald Chaffin, an employee of the Game and Parks Commission.

Geologic assistance was provided by the Conservation and Survey Division, University of Nebraska-Lincoln. In addition, Bruce Hanson with the Division evaluated water supply needs and recharge potential of lands in the Atkinson-O'Neill area. The Civil Engineering Department, University of Nebraska-Lincoln, constructed and tested a scale model of a rapid sand filter system under the direction of Professor Ralph Marlette. Dr. Raymond Suppala performed the project economic analysis.

Materials and technical assistance for recharge demonstration were provided by Advanced Drainage Systems, Inc., Iowa City, Iowa. Cost estimates for the water supply, pumping equipment, and distribution system were prepared by Dr. Gary Lewis and James Haney, consulting engineers with Henningson, Durham and Richardson, Inc., Omaha and Austin, Texas, respectively. Project wells were installed by Beck Drilling Company, Ainsworth and Grosch Irrigation, O'Neill. Tom Mathers, Grosch Irrigation, provided technical assistance for the well installations and the injection well test.

Glen Haugen and Don Jamison of Newport permitted access to their Niobrara River valley lands for test drilling activities. Don Focken, Newport allowed access to his land for test drilling and the installation of a well used for the pumping test. Paul Zakrzweski and Dick Grosch, O'Neill and James Frerichs, Atkinson provided access to their land for the recharge demonstration.

Test drilling, analysis and interpretation of soil samples, cost information, and computer simulation of the recharge alternatives were provided by the Grand Island Office of the Bureau of Reclamation. Particular assistance was provided by Marion Thacker, Fred Otradovsky, Larry Cast, and Roger Andrews.

Craig Savage, graduate student with the University of Nebraska-Lincoln Geology Department, assisted with test drilling, geologic interpretation, pump test analysis, and the recharge demonstration. Department of Water Resources staff from the Lincoln, Norfolk, and Ord offices assisted with data acquisition during the pumping test.

The Department specifically recognizes the participation and interest of Alfred Drayton, President of the North Central Nebraska Reclamation District as well as the directors of that district and the directors of the Niobrara Basin Irrigation District.

APPENDICES*

A. Legal and Institutional Analysis

B. Economic Analysis

C. Project Component Costs

D. Rapid Sand Filter Laboratory Model Study

E. Environmental Assessment

F. Artificial Groundwater Storage Potential

G. Pump Test and Geologic Evaluation of Water Supply Alternatives

* Available upon request from the Department of Water Resources.

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