NEEDS ASSESSMENT
WATER AND WASTEWATER SYSTEMS

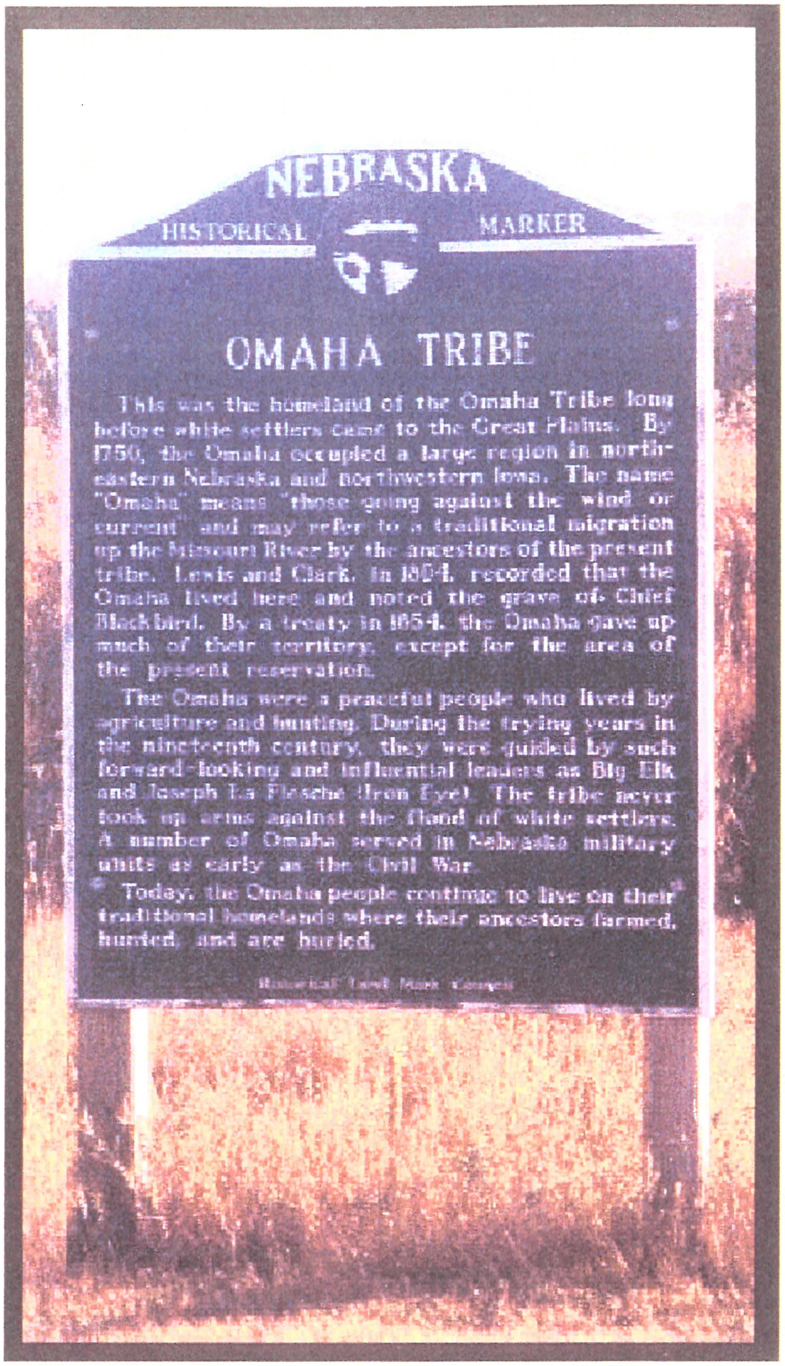
FOR THE OMAHA INDIAN RESERVATION, NEBRASKA

OMAHA TRIBE
OF NEBRASKA & IOWA
HERITAGE FOR PEACE
NI-KAGAHI
HERITAGE FOR PEACE
AGAINST THE CURRENT

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

The U.S. Department of the Interior
Bureau of Reclamation
Nebraska - Kansas Area Office

September 2002



The Mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes.

The Mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

United States Department of the Interior

BUREAU OF RECLAMATION

Great Plains Region
P.O. Box 36900
Billings, Montana 59107-6900

IN REPLY REFER TO:

GP-4500 (Gold)
RES-3.20

OCT 15 2002

MEMORANDUM

To: Area Manager, Grand Island, NE
Attention: NK-100

From: Jaralyn Beek
for Program Manager, Resource Services

Bill Cole

Subject: Transmittal of Report: "Needs Assessment, Water and Wastewater Systems for the Omaha Indian Reservation, Nebraska, September 2000"

Attached are 25 copies of the subject report. Provision of the reports completes work initiated for your office in May 1999 and marks the third in a series of water and wastewater Needs Assessment reports prepared by our Water Resource Services Group for American Indian reservations in northeastern Nebraska.

The reports are provided for your use and for distribution to the Omaha Tribe of Nebraska and Iowa and other participating entities. Please be aware that our tribal contact, Mr. Tony Provost, requested 12 copies of the report. Additionally, Mr. Pat Keatts (GIS Coordinator, Branch of Natural Resources) of the Bureau of Indian Affairs Office in Aberdeen, South Dakota, requested a copy for his retention.

We will mail copies of the report to the team participants at the Denver Technical Services Center and provide copies to the staff in the Regional Office, the Regional Office files, and library.

If you have any questions, comments, or need additional copies of the report, please contact Berril Gold at 406-247-7745.

Attachment - 25 copies

cc: D-8140 (Gesundheit), D-8230 (Jurenka, Walp), D-8270 (Piper), GP-1150 (Zontek), GP-4500 (Cole, Gold Lucero, Phillips), PL-100 (Redhorse), NK-500 (Kube) (w/o attachment) return to Bob Jurek

Preface

The Omaha People

By treaty of 1854, the present day Omaha Reservation was established in a small part of the Tribe's aboriginal territory along the Missouri River. The name *Omaha* means "those going against the wind or current". It may refer to a traditional migration of the Omaha people up the Missouri River. As it had been historically, the Missouri River remains an integral part of the Omaha life and culture.

The Omaha Indian Reservation (Reservation) encompasses approximately 230,000 acres of land that lie almost entirely in Thurston County in northeastern Nebraska (Figure 1-1). The Reservation is bounded on the east by the Missouri River, to the north by its common boundary with the Winnebago Indian Reservation, and to the west and south by the Treaty Boundary of March 16, 1854. The Reservation land emanates from the Missouri river flood plain to the east, climbs westward across steeply wooded bluffs rising several hundred feet above the flood plain, and flattens to rolling farmlands that occupy much of the balance of the Reservation.

The Omaha Tribe of Nebraska is a sovereign nation governed by a seven-member tribal council under a constitution that was approved and ratified in 1936. The Village of Macy, located in the east central part of the Reservation, is the seat of the Omaha Tribal government and home to most tribal members living on the Reservation. It lies approximately 30 miles to the south of Sioux City, Iowa.

Scope of Study

The objective of this Needs Assessment study was to examine the water sources and the water supply and wastewater facility capabilities present on the Reservation in the context of current and future water demands. Fundamental to any such analysis is the accurate determination of current population levels and the formulation of defensible future population trends. For purposes of this report, a forty year planning horizon was adopted, commensurate with the average life span of most water systems. To gain the greatest accuracy, population projections were developed by applying two independent demographic methodologies.

An independent study, undertaken to evaluate the location and setting of Pressure Reducing Valves (PRVs) in the Macy Service Area water system, was initiated by the Bureau of Reclamation's Technical Service Center - Water Conveyance Group, Denver, Colorado, about the same time as this Needs Assessment. Part of the technical information from this parallel study was used directly in the Needs Assessment report to support the discussion of the Macy Service Area water system. The PRV study report is appended in its entirety as Appendix A.

An evaluation of managerial and financial aspects of utility system operations is not typically included in the needs assessment process, and was not done for this study. Additionally, given that Needs Assessments are preliminary investigations using principally existing information, this assessment focused on water supply and wastewater systems serving the Villages of Macy (and surrounding area), Pender, Walthill, and Rosalie due to the fact that base-line information was generally available for these systems and the systems served the greater portion of the

Reservation population. Evaluation of individual and cluster-housing facilities in rural areas of the Reservation was not undertaken due to the lack of available data. Assessment of the rural systems will need to be conducted in an investigation with a specific data acquisition component.

Some of the observations contained in this report evolved from a brief tour of the Reservation communities conducted by Reclamation staff in September 1999. A gallery of photos taken during the tour are provided in Appendix D that illustrate some of the community water and wastewater facilities and vistas that can be seen in the area.

In summary, the purpose of this assessment was to identify the most critical water related deficiencies that could impact the health and welfare of the Omaha people both currently and over the next forty years. The information provided in the report should assist the Tribe in identifying future water needs and could give direction to further water related studies for the Reservation. In line with these overall planning objectives, water supply and treatment system conceptual design plans that illustrate the type of facility enhancements each Reservation community would need to meet Year 2040 projected service demands are provided, along with general construction cost estimates at appraisal or sub-appraisal level (depending on the amount of information available) to accomplish these changes.

With regard to possible future application of information contained in this report, it must be understood that this document does not deal with tribal water rights issues, and the data presented herein was not designed or intended to be used or construed for any estimation, interpretation, or limitation process in this regard.

Authority and Funding

This study was performed under authority of the Federal Reclamation Act of June 17, 1902, as amended. Funding was provided through Reclamation's Native American Affairs and Technical Assistance to States Programs and from the Indian Health Service, Department of Health and Human Services, Sioux City District Office, Sioux City, Iowa, under Public Law 86-121 for Project AB-00-E27.

Acknowledgments

The Nebraska-Kansas Area Office of the Bureau of Reclamation (Reclamation) wishes to acknowledge those individuals who participated in the preparation of this Needs Assessment report. Included are: Doran Morris of the Omaha Tribal Council; Mert Christiansen, Alan Freemont, Art May, and Ben Walker, Jr., of the Omaha Tribal Utility Commission; Wehnona St. Cyr of the Carl T. Curtis Health Education Center, Macy, Nebraska; John Penn, Assistant Chief of Tribal Operations; Tony Provost, Director of Environmental Protection for the Omaha Tribe; Terry Tipton (Village of Walthill, Nebraska); Bob Fendrick (Village of Pender, Nebraska); Christine Baker (Village of Rosalie, Nebraska); David Koski, Ken Esplin and Melvin Clifford of the Indian Health Service, Sioux City, Iowa; and, staff of the State of Nebraska Department of Environmental Quality and the U.S. Environmental Protection Agency.

Preparation of this report was directed and coordinated by Berril Gold of Reclamation's Great Plains Regional Office, Billings, Montana, for Michael Kube, Native American Affairs

Coordinator of Reclamation's Nebraska-Kansas Area Office, Grand Island, Nebraska. Subject matter experts from Reclamation's Technical Service Center, Denver, Colorado, who authored major portions of the report include: Rebecca Redhorse - Social and Demographics; Steven Piper - Population and Economics; Paul Carlson and David Gesundheit - Water Distribution Systems and Modeling; Bob Jurenka, Qian Zhang, and John Walp - Water and Wastewater Systems; and Keith Copeland - Cost Estimation. Report chapters involving Resource Setting and Surface and Ground Water Resources on the Reservation were developed by subject matter experts Mark Phillips and Berril Gold of the Great Plains Regional Office in Billings, Montana.

Executive Summary

Background

The Omaha Indian Reservation (Reservation) encompasses nearly 230,000 acres of land that lie almost entirely in Thurston County in northeastern Nebraska (Figure 1-1). The Village of Macy, located in the east central part of the Reservation about 30 miles to the south of Sioux City, Iowa, is the largest urban center on the Reservation. It is the seat of the Omaha Tribal government and home to most tribal members. Macy is followed in size by the Villages of Pender, Walthill, and Rosalie, in that order.

Demographics

Over the past several decades, the Native American population on the Reservation has increased at an average annual rate of about three percent. In contrast, the non-Native American population has declined at around two tenths of a percent from 1980 to 2000. Based on demographic modeling and trend analysis, it is anticipated that the current Reservation population of 5,667 will more than double in size to about 14,100 by Year 2040. Much of the growth will occur in the Village of Macy Service Area (Village of Macy and surrounding rural areas) where the population is projected to increase from its current level of 3,150 to over 10,000. Population growth on the Reservation will be driven by the youthful profile of the Native American population, high birth rates among women of child bearing age, and high in-migration rates.

Income and Employment

The most important sources of income and employment on the Reservation include: Tribal and Federal government administration including the Omaha Tribe, U.S. Bureau of Indian Affairs, and the Tribal health facility; CasinOmaha; and farming and related services. Considerable income variation exists across the Reservation. According to 2000 Census data, Pender had the highest per capita and median household income levels on the Reservation, $17,672 and $30,990, respectively. Corresponding figures for Macy were $5,640 and $19,500, lowest on the Reservation. Unemployment numbers mirror this same trend. Pender had a 1.1 percent unemployment rate, while Macy registered an unemployment rate of 18.6 percent for the Year 2000 census period.

Economics

Net taxable sales for Thurston County and communities on the Reservation showed little or no appreciable growth over the period 1990 to 1998. On the Reservation, near-term economic growth may be limited to activities and resources unique to the area due, in part, to strong competition from Sioux City, Iowa. Retail trade and services should continue to grow in line with population increases. Recreation and gaming operations may witness some growth. Long term economic trends are almost impossible to foretell.

Land Use

Landform dictates land use patterns on the Reservation. Woodlands are located primarily on bottomlands along the Missouri River or follow stream courses inland. Strongly sloping topography of the dissected and undissected uplands is utilized for pasture and rangeland. Dryland farming occurs on moderate to gently sloping terrain scattered throughout the Reservation area. Irrigated cropland is situated mostly on the flood plains and low terraces along the Missouri River and Logan Creek.

Surface Water Resources

Major water courses impinging on the Reservation include the Missouri River, Logan Creek, and Omaha Creek. Logan Creek and its tributary Big Slough Creek drain much of the western half of the Reservation. Omaha Creek and its tributaries drain the north-central portion of the Reservation. Blackbird Creek and other small tributaries drain the eastern third of the Reservation to the Missouri River. Missouri River water, although categorized as very hard, is considered an excellent source for all domestic use. Water in Logan and Omaha Creeks is generally very hard with manganese levels exceeding the U.S. Environmental Protection Agency (U.S. EPA) Safe Drinking Water Act secondary maximum contaminant level (SMCL). Pesticides, mainly atrazine and alachlor, contributed from non-point agricultural sources, exceed the U.S. EPA maximum contaminant levels during high flow events.

Ground Water Resources

The most significant ground water sources on the Reservation include the Dakota Formation and Quaternary alluvial aquifers adjacent to major streams and buried river channel alluvium. Water quality of the Dakota Formation appears to improve west to east across the study area, although, even in the eastern sector, formation water typically exhibits elevated total dissolved solids (TDS), iron, and manganese. Discontinuous sandstone layers within the formation may impede the development of high yielding wells.

Ground Water Usage

A basal zone of sands and gravels and alluvial aquifers associated with major streams in the area are the most universally accessed sources of ground water on the Reservation. Depending on the nature of the recharge source, water quality varies significantly. Sampling conducted in 1990, 1992, and 1995, in a series of wells completed in Quaternary deposits, indicated that although pesticide concentrations were very low or non-detect, sulphate, manganese, TDS, nitrate-nitrogen, and coliform bacteria exceeded regulatory limits in a significant number of wells. Well yields vary between about 50 to over 1,000 gallons per minute (gpm) depending on the composition of the aquifer.

Average and Maximum Day Water Demands

To generate current and future average day water demands, an average day demand rate of 150 gallons per capita per day (gpcd) was applied to population projections for the Macy, Pender, Walthill, and Rosalie service areas. Average day water demand values were then increased by a peaking factor of 2.0 to determine maximum day demands for these municipal areas. The 150 gpcd value was a summary estimation developed specifically for use in this assessment study. This figure would have to be further refined for more detailed water planning initiatives.

Capability of Water Supply Systems to Meet Current and Future Demands

With average and maximum day water demand figures in place, the capability of the municipal water supply systems on the Reservation to meet current and future potable water supply demands was measured against criteria for water quality, production capacity, and storage capability adopted for this assessment. Criteria used to assess water quality were predicated on compliance with U.S. EPA Safe Drinking Water Act primary and secondary maximum contaminant levels. Production capacity criteria required that the average day demand of the water supply system be met with the largest pump out of service, and the maximum day demand be met with all pumps in operation. Storage requirement criteria stipulated that stored water accommodate system demands under both normal and emergency conditions.

Assessment of the four service area systems follows:

• **Tribal System, Village of Macy Service Area** - The tribal water system serves the Village of Macy and the surrounding rural areas north, west, and south of the Village (Macy Service Area). Source water is drawn from the Dakota aquifer by three wells with a total combined pumping capacity of 896 gpm. Typically, water from the Dakota aquifer is very hard and iron, manganese, and total dissolved solids exceed SMCL criteria. Water treatment is provided by a mechanical treatment plant which uses aeration followed by filtration to remove iron and manganese. An elevated and at-grade steel tank provide storage capacity of 450,000 gallons. The distribution system includes about 87 miles of pipeline and consists of an 8-inch diameter main loop with branches to serve Macy and the rural area. The service area is characterized by hilly topography.

Although current water production meets study criteria, 293 gpm of additional capacity will be needed by Year 2020 and 1,256 gpm by Year 2040. The current storage capacity is about 1.1 million gallons shy of meeting study criteria; this figure increases to approximately 4.6 million gallons by Year 2040. Analysis of an uncalibrated water system hydraulic network model showed that significant portions of the distribution system have deficient pressure and that location and settings of Pressure Reducing Valves need to be changed or the valves removed to rectify this problem.

• **Village of Pender** - Source water for the Village of Pender system is drawn from the Logan Creek aquifer by three wells with a total combined pumping capacity of 780 gpm. Water treatment consists of disinfection by liquid sodium hypochlorite at each wellhouse. Three structures provide a combined water storage capacity of 555,000 gallons.

Treated water is of good quality, albeit, total dissolved solids is borderline and total coliform, nitrate, and arsenic should be monitored. No additional water pumping capacity is needed in the system through Year 2040 to meet either average or peak day demands. The current storage capacity in the system needs to be augmented by about 5,400 gallons to meet study criteria. This figure, however, is less than one percent of the current total storage and no change is recommended unless replacement of the current tanks is undertaken. No need for additional storage capacity is projected through Year 2040. No critical system problems are known to exist.

• **Village of Walthill** - Two metered wells provide the Village system with 550 gpm of production capacity. Similar to the Macy area system, source water drawn from the Dakota aquifer is very hard and iron, manganese, and total dissolved solids exceed SMCL criteria. The Village has one water storage standpipe with a capacity of 250,000 gallons. Water is treated at a 400 gpm filtration plant.

Except for about 39,000 gallons per day (gpd) needed in Year 2040 to meet average day demand, no additional pumping capacity is required in the Village system through the study planning period. At present, about 247,000 gallons of additional storage capacity is needed to meet study criteria; by Year 2040, 815,000 gallons of total capacity will be needed. It is the perception among some residents that water quality and water pressure problems have affected their home water heaters.

• **Village of Rosalie** - Two wells provide Rosalie with a combined pumping capacity of 324 gpm. Like the water systems serving the Macy area and the Village of Walthill, Rosalie draws its water from the Dakota aquifer. Excessive hardness and high levels of iron, manganese, and total dissolved solids impart undesirable use and aesthetic characteristics to the water. The Village has no centralized water treatment system. One elevated steel tank provides 50,000 gallons of storage capacity. According to the Village Superintendent, the water distribution system was installed in 1912.

No additional production capacity is needed to meet average or peak day water demands through Year 2040. Currently, 137,000 gallons of additional storage is needed to meet study criteria; this figure increases to about 141,000 gallons by Year 2040. The water distribution system is experiencing leakage from aged galvanized pipe. Leakage is also occurring from the storage tank valves that need to be replaced.

Conceptual Design Plans to Meet Year 2040 Water Demands

Water system needs stemming from water quality, production capacity, or storage capability deficiencies impact all Reservation municipal systems in varying combination and degree. Depending on the system, some needs are immediate while others may be twenty to forty years out. Various water treatment technologies are available to address water quality problems. In general, the treatment method selected will hinge on source water quality and the desired quality of finished water. Both the Macy Service Area and Village of Walthill systems will need additional pumping capacity to meet Year 2040 average day demands. All municipal storage and distribution systems serving Reservation communities will need to be expanded to meet Year 2040 demands.

Water supply and treatment system conceptual design plans were developed that illustrate the type of facility enhancements each Reservation community would need to meet Year 2040 projected service demands. They include general construction cost estimates at appraisal or sub-appraisal level to accomplish these changes. It was assumed that water distribution system expansion would grow proportionately with the existing village land area, housing, and population density. Given that these estimates are accurate to ±40%, they are useful only for general planning purposes. Underlying assumptions used to formulate the estimates would have to be further refined to obtain greater accuracy. Cost estimates (in current dollars) for the Reservation systems are listed below. The magnitude of the cost associated with the Village of Macy Service Area system reflects a 227% increase in population over the planning period; the greater part of the costs are associated with upgrades of the water distribution system, i.e., water lines and Pressure Reducing Valves.

- Tribal System, Village of Macy Service Area - $34,000,000
- Village of Pender System - $940,000
- Village of Walthill - $4,400,000
- Village of Rosalie - $1,350,000.

Wastewater Services
Expansion of water supply system facilities in a community necessitate increasing wastewater services to the community. Assessment of the four community systems follows:

• **Village of Macy** - The Village wastewater system consists of a collection network with one lift station and a 3-celled wastewater lagoon discharging treated effluent to Blackbird Creek. The collection system is old and the operating staff is small. Problems with infiltration and inflow, broken lines, and lift station problems resulting from flooding persist. The current wastewater lagoons appear to be losing wastewater through seepage which may be preventing proper operation as discharging systems. If the State of Nebraska's 120 gpcd wastewater flow rate is applied, the Macy system should be overloaded at the present time. In view of projected future population growth, planning for system expansion should be expedited.

• **Village of Pender** - The Village wastewater system consists of a collection system, two lift stations, and a 165,000 gpd contact stabilization, activated sludge wastewater treatment plant that discharges treated effluent to Logan Creek. There are also two non-discharging lagoon cells available for treatment if needed or when flows exceed the plant capacity. For the twelve month period ending June 2000, the average day and maximum day flows were 134,100 and 285,500 gpd, respectively. Hence, there may be many days throughout the year that the plant is overloaded. The wastewater facilities appeared to be in good working order as observed during a September 1999 field tour. Because future population increase will place additional demand on the existing facilities, it would appear that the Village should proceed with planning facility expansion.

• **Village of Walthill** - The Village wastewater system consists of a collection system with one lift station and an activated sludge wastewater treatment plant which discharges treated effluent to Omaha Creek. Wastewater treatment is accomplished by a 100,000 gpd activated sludge wastewater treatment plant. No information was available regarding the condition of the collection system or lift station. Comparing maximum day flows reported by the U.S. EPA with plant capacity, it would appear that the treatment plant, on occasion, is hydraulically overloaded.

Lack of recent and complete operational and water quality data make this assessment uncertain. It is known, however, that the wastewater facility had trouble meeting the BOD (Biochemical Oxygen Demand) limitation in 1997 and 1998. It is recommended that the Village monitor flows and treatment plant performance for long term planning purposes.

• **Village of Rosalie** - The Village wastewater system consists of a collection system with one lift station and a facultative 2-celled wastewater lagoon discharging to Big Slough Creek. The two non-aerated lagoon cells have a total volume of 3.5 million gallons. Installed as early as the 1930s, the collection system may be allowing higher than normal infiltration and inflow. The lift station, installed in 1968, was observed to be in good working condition. Information about the current average day flow was not available. Applying the State of Nebraska's recommended design criteria of a 120-day lagoon detention time, the lagoon system appears adequately sized to serve the current population. However, if an ammonia standard is imposed on Big Slough Creek, which would require a 180 day detention time, the lagoon system is at capacity.

Conceptual Design Plans to Meet Year 2040 Wastewater Demands

Wastewater system conceptual design plans that illustrate the type of facility enhancements each Reservation community would need to meet Year 2040 projected service demands were developed, including general construction cost estimates at appraisal or sub-appraisal level to accomplish these changes. Because these estimates are accurate to ±40%, they are useful for only general planning purposes. All municipal systems required addition of sewer mains. The Macy system required one lift station and 104 million gallons of additional capacity in the discharging lagoons. The Village of Pender system needed 90,000 gpd of activated sludge treatment capacity. The Village of Walthill system required one lift station and 0.15 million gpd of activated sludge wastewater treatment capacity. The Village of Rosalie needed one lift station and 9,220 gpd of new discharging lagoon volume. Cost estimates (in current dollars) factored out as indicated below. The magnitude of the cost associated with the Village of Macy system reflects a 227% increase in population over the planning period. About 55% of the costs are associated with wastewater treatment and 45% are associated with wastewater collection.

- Village of Macy - $17,500,000
- Village of Pender System - $980,000
- Village of Walthill - $2,900,000
- Village of Rosalie - $910,000.

Data Needs for Future Studies

The objective of this study was to assess the water resource and water supply and wastewater disposal facility capabilities present on the Reservation in the context of current and future water needs. More detailed data acquisition and engineering evaluation will be needed for future water development planning. Based on insights gained during this study, key types of information that must be obtained include:

- Recent and complete operational and water quality data for water supply and wastewater treatment facilities including, but not limited to, average and maximum day flows, sources and volumes of infiltration and inflow, per capita water usage, lagoon seepage, etc.

- National Pollution Discharge Elimination System (NPDES) permit compliance violations.
- Functional condition and performance of facility infrastructure and remaining design life of equipment.
- Source water and treated water quality specific to each individual potable water system including concentrations of pesticides and other potential carcinogens.
- Availability of alternative sources of good quality water to be used for blending purposes.
- Community development plans and commercial growth initiatives.
- Health related trends appearing in the Reservation population.
- Reduction in future water supply demands that could be achieved by implementing water conservation measures.
- Condition and performance of individual and cluster-housing water and wastewater facilities in rural areas of the Reservation.

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ACRONYMS AND ABBREVIATIONS

BIA	Bureau of Indian Affairs
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biological Oxygen Demand
CFR	Code of Federal Regulations
cfs	cubic feet per second
DEQ	Department of Environmental Quality (State of Nebraska)
EPA	Environmental Protection Agency
ft	feet
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
HUD	Department of Housing and Urban Development
IHS	Indian Health Service
I/I	Inflow and Infiltration
JEO	Johnson, Erickson, and O'Brien
MCL	Maximum Contaminant Level
MGD	Million Gallons per Day
mg/L	milligrams per Liter
NPDES	National Pollution Discharge Elimination System
NPDWR	National Primary Drinking Water Regulations
PCS	Permit Compliance System
PET	Potential Evapotranspiration
pH	hydrogen ion concentration
ppb	part per billion
ppm	part per million
RO	Reverse Osmosis
SDWA	Safe Drinking Water Act
SMCL	Secondary Maximum Contaminant Level
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
μg/L	micrograms per Liter
USGS	United States Geological Survey
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

Chapter One - Social and Economic Setting

This chapter discusses social and economic dynamics on the Omaha Indian Reservation (Reservation). The Reservation communities of Macy, Pender, Walthill, and Rosalie are briefly characterized. Health and welfare and economic conditions are discussed on a Reservation-wide basis.

Background

A series of treaties, primarily during a 50-year period beginning in the early 1800s, caused the Omaha people to relinquish vast amounts of land and dramatically changed their way of life. By treaty of 1854, the present day Omaha Reservation was established in a small part of their aboriginal territory along the Missouri River. As it had been historically, the Missouri River today remains an integral part of Omaha life and culture.

The Omaha Tribe of Nebraska and Iowa (Tribe) is a domestic sovereign nation governed by a seven-member tribal council under the tribal constitution and by-laws that were approved and ratified in 1934. Each resolution or bill enacted by the council becomes part of tribal law. The Tribe has its own court system for resolving disputes involving tribal members on the Reservation and for adjudicating criminal proceedings.

According to a 1997 community profile prepared by the Mni Sose Intertribal Water Rights Coalition, Inc., there are 14,775 acres of individually allotted land, 14,373 acres of tribal trust land, and 2,000 acres of other non-tribal government land within the estimated 310 square miles of the Omaha Reservation. The remaining portion of the Reservation is comprised of non-Indian owned fee land. According to the report, "Phase II Water Resource Inventory, Omaha Indian Reservation" (B&E Engineering, Inc., 1981), approximately 2,900 acres of the 310 square mile Reservation lie in the state of Iowa.

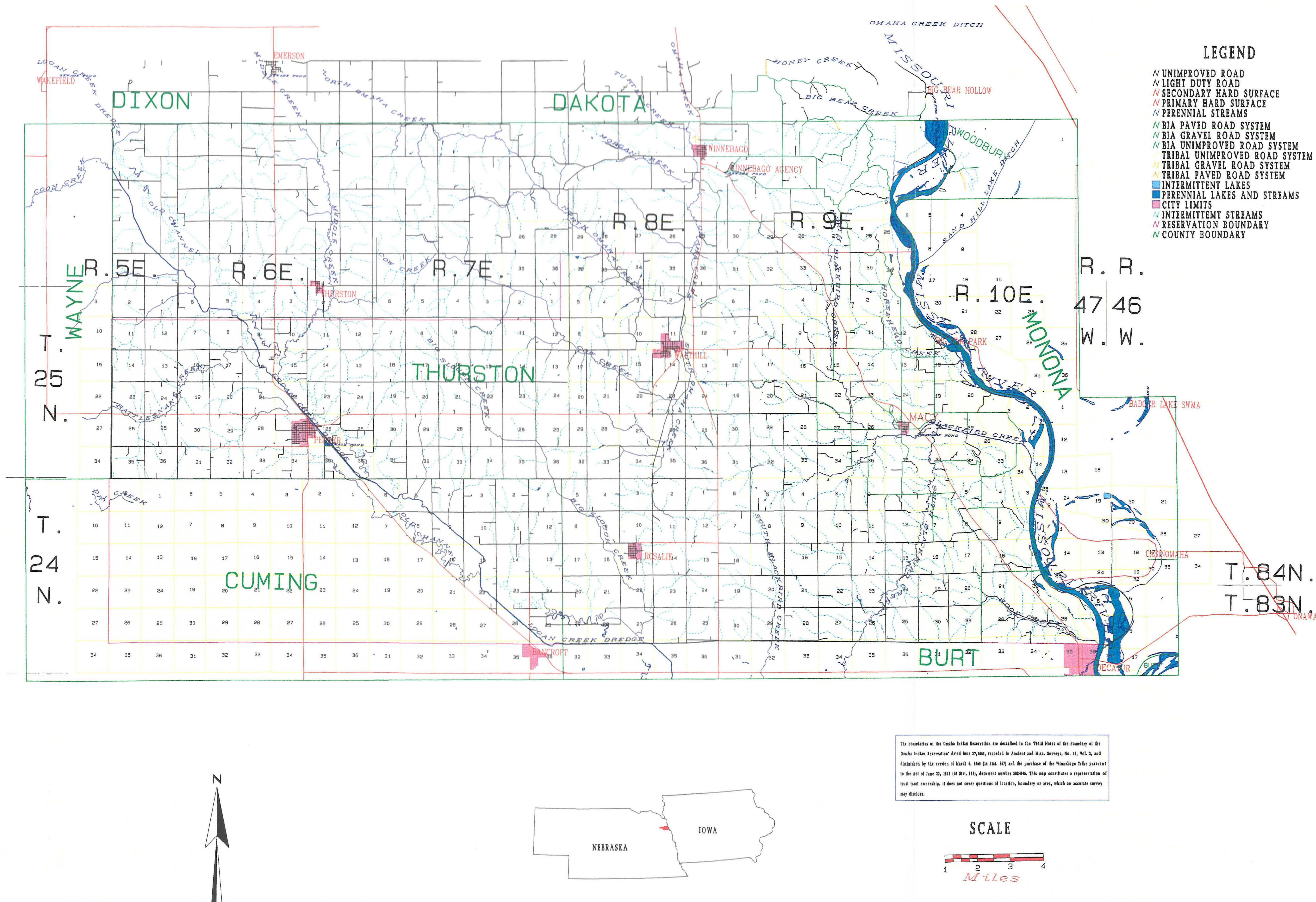
Reservation Communities

Four communities are located on the Reservation: the Villages of Macy, Pender, Walthill, and Rosalie. They are shown on Figure 1-1 and described in the following paragraphs.

Village of Macy

The Village of Macy (Macy) is located in the eastern part of the Reservation approximately 30 miles south of Sioux City, Iowa. It is the largest urban center on the Reservation, seat of the Omaha Tribal Government, and home to about 3,150 people. The majority of the Reservation's Native American population resides in Macy. It continues to be the most rapidly growing population center on the Reservation. The town is governed by the Omaha Tribe, which developed its own constitution and current form of government based on the Indian Reorganization Act of 1934.

Figure 1-1. Study Area, Omaha Indian Reservation



The boundaries of the Omaha Indian Reservation are described in the "Field Notes of the Boundary of the Omaha Indian Reservation" dated June 27,1855, recorded in Ancient and Misc. Surveys, No. 16, Vol. 3, and diminished by the cession of March 6, 1865 (14 Stat. 667) and the purchase of the Winnebago Tribe pursuant to the Act of June 22, 1874 (18 Stat. 146), document number 383-845. This map constitutes a representation of trust tract ownership, it does not cover questions of location, boundary or area, which an accurate survey may disclose.

Source: U.S.D.I.-B.I.A., Branch of Natural Resources, Great Plains Regional GIS, 06/15/01

The Tribal Government is the single largest employer in Macy, with the public school system ranking second. There is no major industry in the town. Most of the Tribal offices are situated adjacent to and in the complex of buildings that include the Alfred Gilpin Community Building. The group of buildings house the Four Hills of Life Wellness Center (opened in April 1995), the Tribal Environmental Protection Department, Tribal headquarters, and community Social Services. A U.S. Post Office is in close proximity. The tribally owned and operated gas and convenience store (the "C" Store) is across the street from the Post Office.

A wide range of outpatient health services are provided to Reservation residents at the Carl T. Curtis Health Education Center. This large facility is located about a quarter mile northwest of the community buildings. The Center includes a 25 bed nursing home; a dental clinic; a dialysis clinic with 12 patient care stations and other support services; and quarters the Tribal Community Health Department. The Tribal Law Enforcement building is situated next to the health center. It houses administrative offices, detention facilities, and the Wildlife Conservation Office.

Kindergarten through Grade 12 is offered at a public school facility in Macy. Enrollment has been increasing at the school. Post high school education is available through the Nebraska Indian Community College just outside of Macy. A youth center equipped with an outdoor swimming pool is located near the K-12 school.

The Bureau of Census estimates that the median number of persons per household across the Reservation is about 3 people. Due to undercounting, this figure is probably closer to four. In the Macy area, the average number of people per household may be as high as six to seven based on tribal estimates. Most recent information from the Tribe indicates that Macy has about 220 homes provided by the Department of Housing and Urban Development (HUD), with about 25 additional non-HUD residences. Tribal housing authorities estimate the current waiting list for housing to be at about 400. Restoring current vacant housing units in Macy is a tribal priority.

With regard to total housing and population, current Indian Health Service (IHS) data shows that there are 492 water service connections in the Macy Service Area (Village of Macy and surrounding rural areas), about 30 of which are businesses. About 250 of the residential connections are located in the town of Macy proper. Assuming a median number of persons per household at six to seven yields a range of between 2,772 to 3,234 people residing in the Macy Service Area. This range of population corresponds closely with the figure of 3,150 provided by the Tribe and is the figure used in this report for the Macy Service Area.

<u>Village of Pender</u>

The Village of Pender (Pender) is located in the west-central portion of the Reservation along the west edge of the Logan Creek drainage. In 1882, 50,000 acres of Indian land in the western portion of Thurston County was sold to land speculators, which started the "Pender Rush". Four years later, Pender was established as the county seat. Currently, Pender is governed by the Village Board of Trustees and is home to approximately 1,148 residents.

Village of Walthill

The Village of Walthill (Walthill) lies in the north central portion of the Reservation just west of the intersection of Routes 77 and 94. It was incorporated in 1906, soon after Thurston County was opened to settlement. Over the past several decades, the Native American population in Walthill has steadily been increasing in what was once a predominantly non-Indian town. Currently, Walthill has a total population of about 1,018 people, about 40 to 50 percent of which is Native American. Walthill's population is expected to grow more rapidly than that of Pender or Rosalie.

A Tribally operated company, One, Inc., is located in Walthill. The company was established around 1992. It performs financial management and accounting services for operating the Tribal farm, utilities (including water), and cable television. The Omaha Tribe would like to build additional housing west of town, but restoring vacant units in Macy remains the highest priority.

Village of Rosalie

The Village of Rosalie is a small, rural farming community of about 200 people. The town mayor anticipates considerable future growth resulting in part from housing demand in Macy.

Public Health and Welfare

Statistics from the IHS for the period 1993 to 1997 list the leading causes of death for persons within the Omaha-Winnebago service area as: heart disease, cancer, chronic liver disease, diabetes, and tobacco and unintentional injuries. The Tribe's Carl T. Curtis Health Education Center provides education and services to help combat smoking, poor nutrition, and alcoholism prevalent on the Reservation.

According to the Tribe, there appears to be no known health related water quality problems on the Reservation. However, there is some evidence that pesticides and stockyard runoff are contaminating surface and groundwater supplies in the area, and concern persists among the American Indian residents that contaminated water could be contributing to cancer rates. Based on IHS figures, however, the mortality rate from cancer appears to be comparable to the national rate. Apart from health related issues, problems with water pressure and mineralization of water heaters detract from the quality of life on the Reservation.

Reservation Economy

Employment

The most recent occupation and employment industry data available for the Omaha Reservation (from the 2000 Census) are shown in Table 1-1 for both the Reservation and Thurston County.

Table 1-1. Industry, Employment, and Occupation - Reservation and Thurston County

Employment Occupation or Industry	Omaha Reservation	Thurston County
Occupation	(% of total)	(% of total)
Management, professional, and related occupations	33.2	31.1
Sales and office occupations	20.8	22.9
Service occupations	19.3	20.6
Farming, fishing, and forestry occupations	2.9	2.5
Production, transportation, and material moving occupations	15.4	14.5
Construction, extraction, and maintenance occupations	8.4	8.4
Industry		
Agriculture, forestry, fishing, hunting, and mining	12.0	10.0
Construction	5.0	4.9
Manufacturing	12.6	11.1
Transportation, warehousing, and utilities	4.3	4.4
Wholesale trade	2.2	2.5
Retail trade	7.6	7.7
Finance, insurance, real estate, and leasing	4.4	3.5
Information	1.1	1.1
Arts, entertainment, recreation, accommodation, and food services	10.9	11.4
Educational; heath and social services	25.8	26.6
Other services (except public administration)	3.3	2.6
Public administration	8.7	11.5
Professional, scientific management, administrative, and waste management services	2.0	2.7

The most important sources of income and employment on the Reservation include: Tribal and Federal government administration including the Omaha Tribe, U.S. Bureau of Indian Affairs, and the Tribal health facility; CasinOmaha; and farming and related services. The tribally operated CasinOmaha currently employs about 247 American Indians. Private commercial businesses on the Reservation include a gas station, two grocery/convenience stores, a bait shop, and arts and handicrafts establishments. There is also a recreational vehicle park in Macy and hunting and fishing areas throughout the Reservation.

Unemployment

As shown in Table 1-2, unemployment was highest in Macy (18.6%) followed by Walthill (8.4%) and the Reservation (7.3%) according to Year 2000 Bureau of Census figures. By comparison, the unemployment rate was 2.5 percent statewide and 3.7 percent nationally.

According to the 2000 Census, the percentage of those 16 years of age and over considered part of the labor force was lowest for Macy, as illustrated in Table 1-2. The larger percentage of people not considered part of the labor force in Macy and the Reservation, compared to the rest of the State and other local areas, indicates that chronic, long-term unemployment is prevalent on the Reservation and concentrated in Macy, and not reflected in traditional unemployment rates. As a result, the actual rate of unemployment on the Omaha Reservation is likely to be significantly greater than estimates provided by the Bureau of Labor Statistics or the Bureau of the Census.

Income

In 1999 (2000 Census), per capita income in Macy was only about half that of other towns and Thurston County, as shown in Table 1-2. Macy also had the lowest median household income at $19,500 per year, and Pender had the highest median household (and per capita) income at $30,990 and $17,672, respectively.

By comparison, the Bureau of Economic Analysis estimated that per capita personal income for Thurston County was $16,507 in 1997, about 70 percent of the state average and 65 percent of the national average. The 1997 per capita personal income for the Reservation should be very similar to that of Thurston County judging by 1989 figures. Personal income is defined by the Bureau of Economic Analysis as labor income, proprietors's income, government transfer payments (for poverty or age related, i.e., Social Security), dividends, interest, and rent.

Table 1-2. Reservation and Community Unemployment and Income Levels

Income Category	Omaha Reservation	Macy	Pender	Walthill	Rosalie
Percent Unemployment	7.3	18.6	1.1	8.4	5.7
Percent in the Labor Force	62	55.3	58.9	58.2	66.7
Per Capita Income (1999 data)	$11,708	$5,640	$17,672	$10,051	$12,249
Median Household Incomes (1999)	$29,063	$19,500	$30,990	$28,750	$26,094

Net Taxable Sales

Although net taxable sales best measure the strength of the retail goods and services sector, they are a useful indicator of overall economic activity and trends can be used to help predict future economic growth. Net taxable sales for 1990 and 1998 for Thurston County and towns on the Reservation are presented in Table 1-3. As shown, little or no economic growth was recorded in the County between 1990 and 1998. Moreover, the Village of Rosalie experienced a sharp decline in net taxable sales over this same period of time.

Table 1-3. Net Taxable Sales for Thurston County and Communities Within the County

Area or Place	1990	1998
Pender	$8,454,463	$8,883,607
Walthill	$1,416,850	$1,163,881
Rosalie	$344,460	$157,322
Rest of County (includes Macy)	$279,386	$322,198
Total for Thurston County	$10,495,159	$10,527,008

Source: Nebraska Department of Revenue.

Economic Outlook

Agricultural activities are a major source of income and employment in the area, mostly among non-Indians, and will continue to be so in the future. Excepting the introduction of high revenue specialty cropping, agricultural production and services should remain relatively unchanged and will probably not contribute significantly to higher levels of future employment and income on the Reservation. Retail trade and services, on the other hand, should continue to grow in line with population increases.

CasinOmaha is an important source of employment for Native Americans on the Reservation. Any growth for the casino, however, will be tempered by competition from other gambling establishments in the near vicinity.

Recreational and cultural activities are an important part of the current economy and areas of potential economic growth. Past economic plans have included the development of tourism coincident with cultural events such as the annual summer Pow-Wow. Good hunting and fishing and other water-based recreational opportunities exist as potential sources of increased employment and revenue in the area.

Near term economic growth on the Reservation, may be limited to activities and resources unique to the Reservation, due in large part to the proximity to Sioux City, Iowa, (less than 30 miles away) a strong competitor for new business and industry looking to locate in the area.

Chapter Two - Demographics

This chapter discusses the population dynamics of the Reservation and the methodology used to develop population trends used in the report. The chapter concludes with a table of population projections that are employed in succeeding report sections to evaluate current and future water and wastewater facility needs.

Population Dynamics

Over the past several decades, the Native American population on the Reservation has increased at an average annual rate of about 3 percent, while the non-Native American population has decreased by about 0.2 percent from 1980 to 2000. Native Americans comprised about 24 percent of the Reservation population in 1980, 37 percent in 1990, and 44 percent in 2000. As a result, the Native American population has become a major determinant for current and future population changes on the Reservation.

As shown in Table 2-1, census data indicate an exceptionally high birth rate (1,486 children ever born per 1,000 women) in the youngest child bearing age category of 15-24 years. This rate is more than double the county rate and over five times the state rate. Although not as dramatic, the same trend holds true in the 25-34 and 35-44 age category. The high birth rate in the youngest child bearing age group is responsible, in large part, for the young age profile on the Reservation. Data from the 2000 census indicate that the median age in Macy was 18.4 years compared to 35.3 years for the State of Nebraska. Over half of the Native American population is under 20 years old, and about 80 percent is under 30 years old. High teenage pregnancy rates, as well as the predominantly young complexion of the Native American population, were noted by the Tribe in its February 1997 "Integrated Resource Management Plan" (interim draft).

A high birth rate in the youngest child bearing age group will foster rapid population growth. Most population and housing development is expected to occur in the Villages of Macy and Walthill and in rural areas west of Macy.

Table 2-1. Fertility Rates

Number of Children Ever Born to 1,000 Women	Omaha Reservation*	Thurston County	Nebraska	All Reservation and Trust Land Areas in the U.S.*
Ages 15-24	1,486	693	257	644
Ages 25-34	2,986	2,319	1,523	2,352
Ages 35-44	3,504	2,975	2,187	3,160

*Indian population only.
Source: U.S. Dept. of Commerce, 1990 Bureau of the Census

Migration and mortality rates are also important determinants of population growth. The Tribe has reported high in-migration of Native Americans to the Reservation resulting primarily from the 1996 "Welfare Reform Act". The Act essentially eliminated financial assistance for many impoverished Native Americans living off the Reservation. Based on Indian Health Service data, mortality rates on the Omaha Reservation is higher than average for Native Americans located on reservations nationally.

Population Projections

Project planning is normally done 20 to 40 years into the future. Since the average life span of most water systems is about 40 years, a 40 year time period was selected as the planning horizon for this study.

Various population projection methodologies may yield different numbers due to differences in the assumptions inherent in each technique. For this study, two methods were used to estimate future population changes of the Omaha Reservation and its urban centers, i.e., the Trend Analysis method and the Cohort-Component Demographic Modeling method.

Trend Analysis involves the use of historical changes in population within the region of interest to project future population changes. It assumes that past age, birth rate, fertility, mortality, and migration trends of the population will continue into the future. However, the trend estimates can be adjusted qualitatively to account for changes in variables that may be expected in the future. Demographic modeling involves the estimation of relationships between demographic characteristics and population levels used to project future population. These characteristics include: mortality, birth rates, and net migration. Although results of both projections were similar, the somewhat higher figures from the trend analysis were adopted for this assessment as they were more in line with the Tribe's perception of current and future population growth.

Accurate estimates of the current population are critical for developing population projections. However, estimating the number of Native Americans on Indian Reservations can be difficult due to the relatively poor data available for this segment of the population. Bureau of Census estimates often under-count the Native American population and estimates available from the Tribe, the Bureau of Indian Affairs (BIA), or Indian Health Service often cover different lengths and/or periods of time and varying service areas. For this study, it was decided to use the most current (Year 2000) Bureau of Census figures adjusted upward by 20 percent to compensate for undercounting.

Results of the Trend Analysis are shown in Table 2-2 in ten year increments for years 2000 to 2040. By Year 2040, the current Reservation population of 5,667 is shown to increase about two and one-half times to 14,102. The average annual increase accelerates as 2040 approaches, primarily because of the compounding effect of the young median age of the Native American population and high birth rates. The Village of Macy area is projected to register the greatest growth on the Reservation, expanding three-fold from 3,150 to 10,327 by Year 2040, due to the dominance of Native Americans and high in-migration rates.

Table 2-2. Omaha Reservation Population Projections

Year	Reservation - Average Annual Percentage Increase from Prior Decade	Reservation Population Total	Macy Service Area	Village of Pender	Village of Walthill	Village of Rosalie
2000	0.1%*	5,667	3,150	1,148	1,018	194
2010	2.1%	6,954	4,239	1,148	1,232	214
2020	2.2%	8,666	5,704	1,148	1,490	236
2030	2.4%	10,978	7,675	1,148	1,803	260
2040	2.5%	14,102	10,327	1,148	2,182	286

* Indian population increased 2.2%, and the non-Indian population decreased 1.6%

The population numbers presented in Table 2-2 are used throughout the balance of the report for all estimating purposes.

Chapter Three - Resource Setting

This chapter of the report discusses the physical resource setting of the Reservation including climate, drainage and land forms, soils, land use, and geohydrology.

Climate

As described by the U.S. Geological Survey (USGS, 1996), the study area has a subhumid climate with warm summers and cold winters. The growing season extends from May through mid-September. July is the warmest month with an average temperature of 75° F, and January is the coldest month with an average temperature of 18° F. Extremes in temperature range from -30 to 110° F. The annual mean temperature for the Reservation area is 40° F.

According to the National Climatic Data Center Year 2000 database compiled by EarthInfo, Inc., of Boulder, Colorado, the mean annual precipitation for the 49 year period from 1949 to 1997 was 27.96 inches as measured at the weather station at Walthill, Nebraska. About 74 percent of the annual rainfall occurs during the months of April to September.

The average annual potential evapotranspiration (PET) for the study area from 1951 through 1980 was 38 inches. PET is the loss of water that would occur from the soil and through plants if the availability of water was not a limiting factor.

Drainage and Landform

As related by the U.S. Geological Survey (1996), the Reservation lies within the Dissected Till Plains Section of the Central Lowland Physiographic Province. The physiography of the area has been affected by glaciation, wind and water erosion, and fluvial and eolian deposition.

The extreme eastern portion of the Reservation lies in the flood plain and terrace system developed by the Missouri River and is collectively referred to as the Missouri Valley. Bluffs rising 300 feet above the flood plain and terraces mark the western terminus of the Missouri Valley and form the eastern border of the dissected uplands which cover the eastern third of the Reservation. The dissected uplands are a glacially formed, old terrace feature mantled by loess with slopes ranging from 20 to more than 30 percent. The western two-thirds of the Reservation consists of nearly undissected glacially developed uplands mantled with loess with slopes ranging from about 3 to 20 percent.

The study area is drained by several major rivers, creeks, and their tributaries (see Figure 1-1). Logan Creek and its tributary Big Slough Creek drain much of the western half of the Reservation. Logan Creek originates in Cedar County and flows southeasterly through Dixon, Wayne, and Thurston Counties before entering the Reservation. It eventually discharges to the Elkhorn River south of the Reservation. Logan Creek drains 1,030 square miles of which 122.5 square miles lie on the Omaha Reservation (B&E Engineering, Inc., 1978). Logan Creek has been channelized, resulting in a stream length that is roughly half the original channel length. Big Slough Creek originates near the northern edge of the Reservation and discharges into Logan Creek near the southern boundary of the Reservation. Big Slough has a drainage area of 25.1 square miles, all of which are in the Reservation (B&E Engineering, Inc., 1978).

The north-central area of the Reservation is drained by Omaha Creek and its main tributaries North Omaha Creek, South Omaha Creek, and Cow Creek. South Omaha Creek originates on the Reservation, flowing northerly and combining with North Omaha Creek to form Omaha Creek. In an unusual fashion, Omaha Creek flows in a northerly direction out of the Reservation to its eventual confluence with the Missouri River. Omaha Creek and tributaries drain 174 square miles above the streamflow gauge at Homer, Nebraska, of which 51 square miles are on the Omaha Reservation.

Blackbird Creek and other small tributaries to the Missouri River drain the eastern third of the Reservation. North Blackbird Creek originates on the Winnebago Reservation and flows southward to its confluence with South Blackbird Creek near the Village of Macy. South Blackbird Creek originates about 3 miles east of the Village of Rosalie, flows south out of the Reservation into Burt County, then returns flowing northward. North Blackbird Creek, South Blackbird Creek, and Blackbird Creek proper drain 32.6, 34.4, and 4.5 square miles, respectively, on the Reservation (B&E Engineering, Inc., 1978).

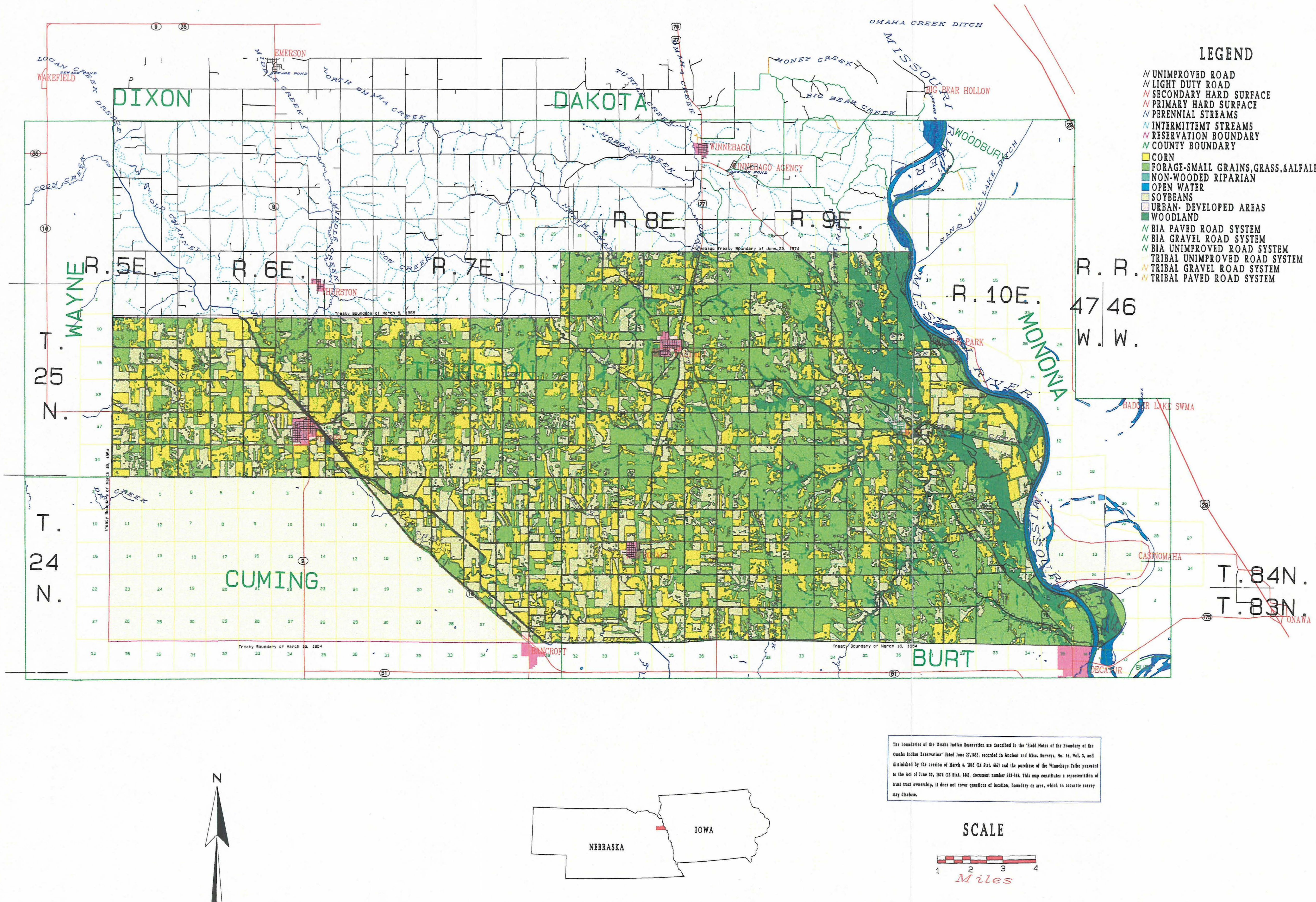
Soils

The predominant parent materials for soils in the study area are alluvium and colluvium on river bottom lands, and loess, silty-colluvium, and eolian sand on the uplands. Soil associations occurring on bottom lands in the Missouri River Valley are subject to frequent flooding. Soils in the uplands areas are generally well drained. Soil characteristics and landscape position determine the hydrologic characteristics of the soil associations found in the study area.

Land Use

Land-use patterns (Figure 3-1) can be related to landform and soils in the study area. Forests are located primarily in the eastern part of the study area on bottom lands along the Missouri River flood plain and tributaries. Pasture and rangeland occur primarily on the dissected and undissected uplands. Irrigated cropland occurs mainly within the Logan Creek flood plain, the Missouri River bottom lands, and some in the uplands in the southwest corner of the Reservation. Non-irrigated cropland is spread throughout the remainder of the study area, mainly on areas of rolling hills with slight to moderate slopes. The 1997 agricultural crop data for Thurston and Cuming Counties shows the largest acreage to be in corn followed in decreasing order by soybeans, hay, and oats (Nebraska Natural Resources Commission, 1997). Relatively small acreages of sorghum and wheat have been harvested in previous years.

Figure 3-1. Land Use on the Omaha Reservation



Source: U.S.D.I.-B.I.A., Branch of Natural Resources, Great Plains Regional GIS, 06/15/01

Geology

The stratigraphy of the study area consists of approximately 1,800 to 2,000 feet of sedimentary Paleozoic, Mesozoic, and Cenozoic deposits which overlie relatively impermeable Precambrian basement rock (USGS, 1996). The sequence of geologic formations is shown in Figure 3-2. The location of generalized bedrock formations on the Reservation are shown in Figure 3-3.

The Paleozoic deposits formed in marine and near-marine environments and consist of inter-bedded limestone, dolomite, dolomitic shales and limestones, and sandstone. Due to their great depth, they are not a viable source of groundwater on the Reservation.

The Mesozoic era is represented by Cretaceous period formations. In descending geologic order they include the Carlile Shale, Greenhorn Limestone, Graneros Shale, and the Dakota Formation. Of these, the Dakota Formation is the only formation known to yield significant potable water supplies. The Dakota Formation consists of inter-bedded sandstones and claystone with about 70 percent of the formation being sandstone. Depth to the top of the formation generally ranges from 100 to 400 feet in the study area and its thickness varies from approximately 250 to 600 feet. Indications are that these formations slope gently to the west. The Dakota Formation underlies the entire Reservation area and outcrops at several locations in the Omaha and South Blackbird Creek drainage basins and along the Missouri bluffs.

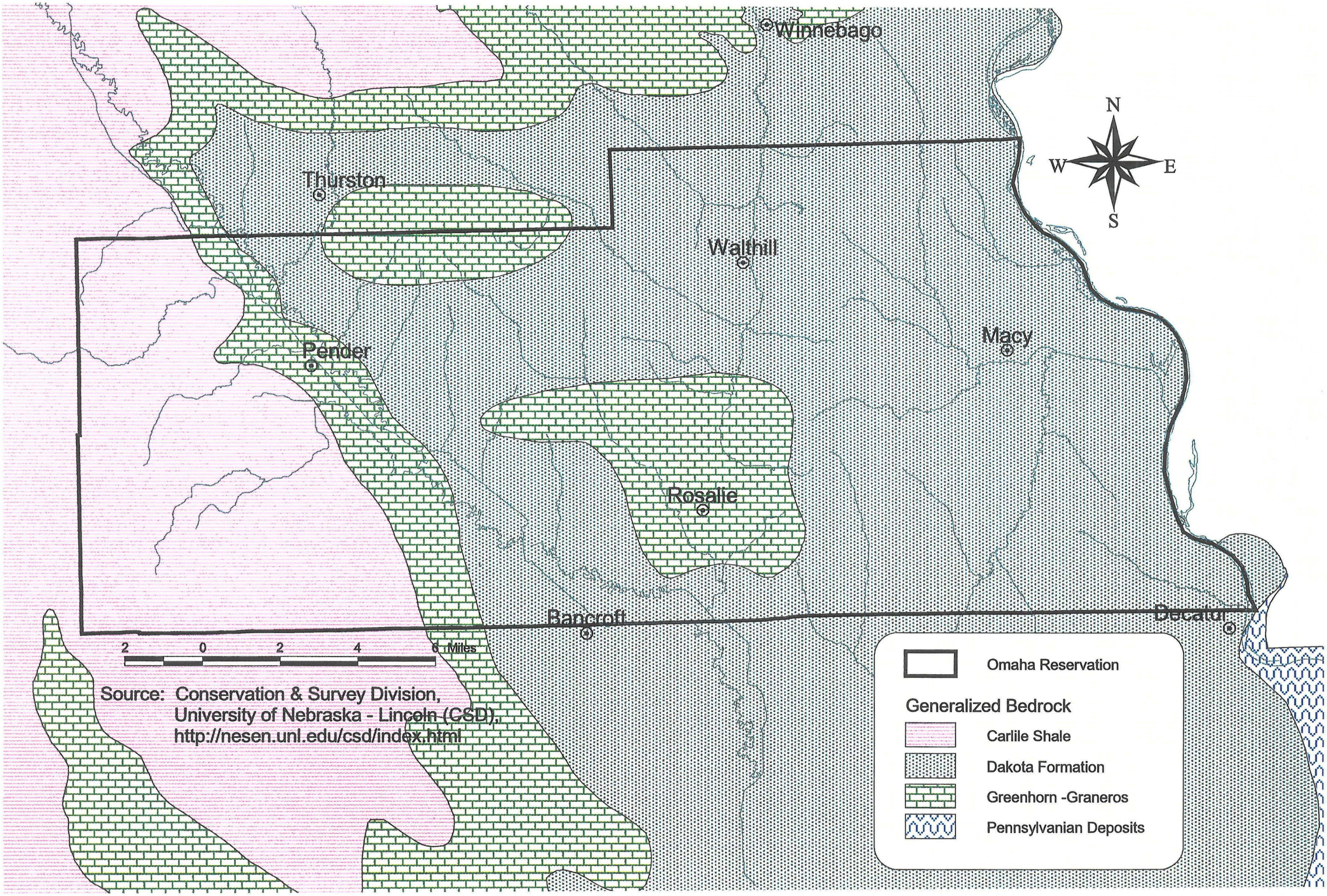
The Cenozoic era is represented by Quaternary glacial, eolian, and alluvial deposits that occur throughout the Reservation. The bedrock for the Quaternary aquifers is the Carlile Shale toward the western portions of the study area; the Greenhorn Limestone and Graneros Shale in the north-central portions; and, the Dakota Formation in the east and south-central portions of the Reservation. Glacial drift and till are found throughout the upland area and consist of poorly sorted silt, clay, shale, and limestone fragments. These deposits have an average combined thickness of about 150 feet. Eolian deposits also occupy upland positions. They consist of silt and clayey-silt ranging in thickness from 5 to 40 feet. The alluvial aquifers consist mainly of unconsolidated sand and gravel deposits with inter-bedded silt and clay. They are associated with recent major stream deposition and buried alluvial channels. These deposits have an average thickness of about 100 feet. Alluvial aquifers are essentially unconfined, but buried stream channels may be confined to semi-confined.

Figure 3-2. Stratigraphic Section of the Omaha Reservation

	ERA	SYSTEM	SERIES	GROUP	FORMATION	EST. THICKNESS (FEET)	GENERAL DESCRIPTION
MANTLEROCK	CENOZOIC	QUATERNARY	RECENT		SOIL	2-5	SOIL WITH SOME ALLUVIUM AND LOESS
			PLEISTOCENE		PEORIAN LOESS	5-40	LOESS, SILT, CLAY, AND SOME SAND AND GRAVEL
					LOVELAND LOESS	5-30	LOESS, SILT, CLAY, AND SOME SAND AND GRAVEL
					YARMOUTH FORMATION	0-10	INTERGLACIAL ELASTICS AND GUMBOTIL
					KANSAN TILL	10-60	BOULDER CLAY (TILL)
					AFTONIAN FORMATION	0-5	INTERGLACIAL ELASTICS AND GUMBOTIL
					NEBRASKAN TILL	10-80	BOULDER CLAY (TILL)
BEDROCK	MESOZOIC	CRETACEOUS	UPPER	MONTANA GROUP	NIOBRARA FORMATION	125	SHALY CHALK TO MASSIVE LIMESTONE IN BASAL PART
				COLORADO GROUP	CARLILE SHALE	85	SHALE, LOCALLY LIMY AND SANDY
					GREENHORN LIMESTONE	20	SOFT LIMESTONE INTERBEDDED WITH SHALES
					GRANEROS SHALE	50	SHALE, LOCALLY LIMY AND SANDY
			LOWER	DAKOTA GROUP		280	SANDSTONES AND SHALES
	PALEOZOIC	PENNSYLVANIAN				65	INTERBEDDED LIMESTONES AND SHALES, AND SOME SANDSTONE
		MISSISSIPPIAN				140	LIMESTONES, DOLOMITES
		DEVONIAN AND SILURIAN				250	SHALES AND DOLOMITES
		UNDIVIDED ORDOVICIAN				230	LIMESTONES, SHALES, SANDSTONES, AND DOLOMITES
		CAMBRIAN				55	DOLOMITES AND SANDSTONES
	PRE-PALEOZOIC	PRECAMBRIAM ROCKS					

Source: Taken from Figure 2-G (Stratigraphic Section of the Winnebago and Omaha Reservations) of "Technical Aspects of Phase I, Water Resource Inventory - Winnebago Indian Reservation", 1978, B&E Engineering, Inc., Yankton, South Dakota.

Figure 3-3. Generalized Bedrock Formations on the Omaha Reservation



Chapter Four - Surface Water Resources

As described in Chapter 3, major streams crossing the Reservation include Logan, Big Slough, Cow, North Omaha, South Omaha, Omaha, Blackbird, and the Missouri River (Figure 1-1). In this chapter, the three largest streams, the Missouri River, Logan Creek, and Omaha Creek are discussed in greater detail. Additional information is provided for Blackbird Creek as well.

Missouri River

For the period 1938 to 1998, the Missouri River had an average of the mean-daily discharge of 30,200 cubic feet/second (cfs) with a maximum mean daily discharge of 441,000 cfs in 1952, and a minimum mean daily discharge of 2,500 cfs in 1941 at the USGS streamflow gauge at Sioux City, Iowa. For the period 1987 to 1998, the river had an average of the mean-daily discharge of 32,300 cfs with a maximum mean-daily discharge of 99,900 cfs in 1997, and a minimum mean daily discharge of 7,100 cfs in 1990 at the USGS streamflow gauge at Decatur, Nebraska. The flow in the river is closely regulated by upstream reservoirs, with Lewis and Clark Lake (formed by Gavins Point Dam) being the closest upstream reservoir to the Reservation. B&E Engineering (1978) presents graphs and tables analyzing river flow at several locations in close proximity to the Reservation, including releases from Gavins Point Dam; flow at Sioux City, Iowa, and Omaha, Nebraska; and flow durations from Yankton, South Dakota, to Omaha, Nebraska. They also estimated natural flow available using flow depletions estimated by the Corps of Engineers in 1976. The reader is directed to this reference for further information.

B&E Engineering (1978) concluded that Missouri River water, although categorized as very hard, is an excellent supply source for all domestic use. Typical water quality for the river is shown in Table 4-1.

Table 4-1. Water Quality Analysis for the Missouri River at Decatur, NE

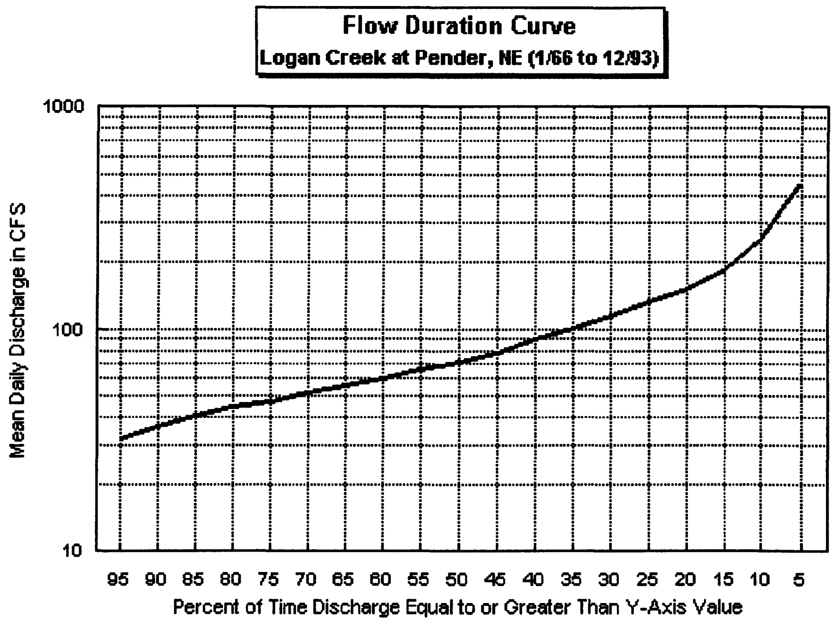
Parameter	Mean Value	Measurement Period
pH	8.0	'69 - '81
Specific Conductance	742 umhos/cm	'69 - '85
Total Dissolved Solids	483 mg/L	'72 - '73
Hardness (as $CaCO_3$)	245 mg/L	'69 - '73
Sodium	57.6 mg/L	'76 - '79
Calcium	57.0 mg/L	'75 - '79
Magnesium	24.2 mg/L	'75 - '79
Manganese	46.7 μg/L	'71 - '73
Iron	555 μg/L	'72 - '73
Chloride	11.4 mg/L	'70 - '79
Sulfate	198 mg/L	'69 - '79
Fluoride	0.47 mg/L	'71 - '73
Nitrate-Nitrogen	0.42 mg/L	'69 - '70

Source: STORET Data Retrieval, Station Number 06601200, U.S. Geological Survey Data

Logan and Omaha Creeks

Flow-duration curves for Logan Creek at Pender, Nebraska, Omaha Creek at Homer, Nebraska, and Blackbird Creek near Macy, Nebraska, are shown graphically in Figure 4-1. Data used to generate these graphs was mean daily discharge for the periods January 1966 through December 1993 for Logan Creek, October 1945 through September 1998 for Omaha Creek, and October 1978 through October 1980 for Blackbird Creek. The graphs indicate the percent of time over the period-of-record that mean daily discharge was at or above a given value. Since Blackbird Creek has only two years of recorded data, the accuracy of the flow duration curve for that station is problematical. Since the Pender gauge is located part way into the Reservation, more flow should be available in Logan Creek near the southern Reservation boundary than at the Pender gauge. Since the Homer gauge is located approximately seven miles downstream from the Reservation, it is likely that less flow is available on the Reservation than would be registered at the gauge.

Figure 4-1. Flow Duration Curves for Logan, Omaha, and Blackbird Creeks



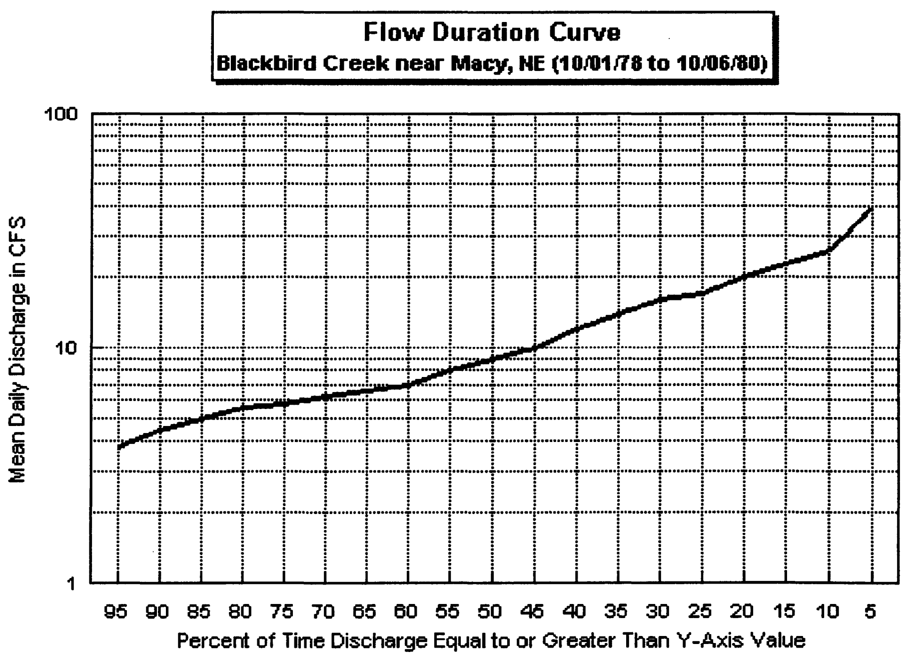
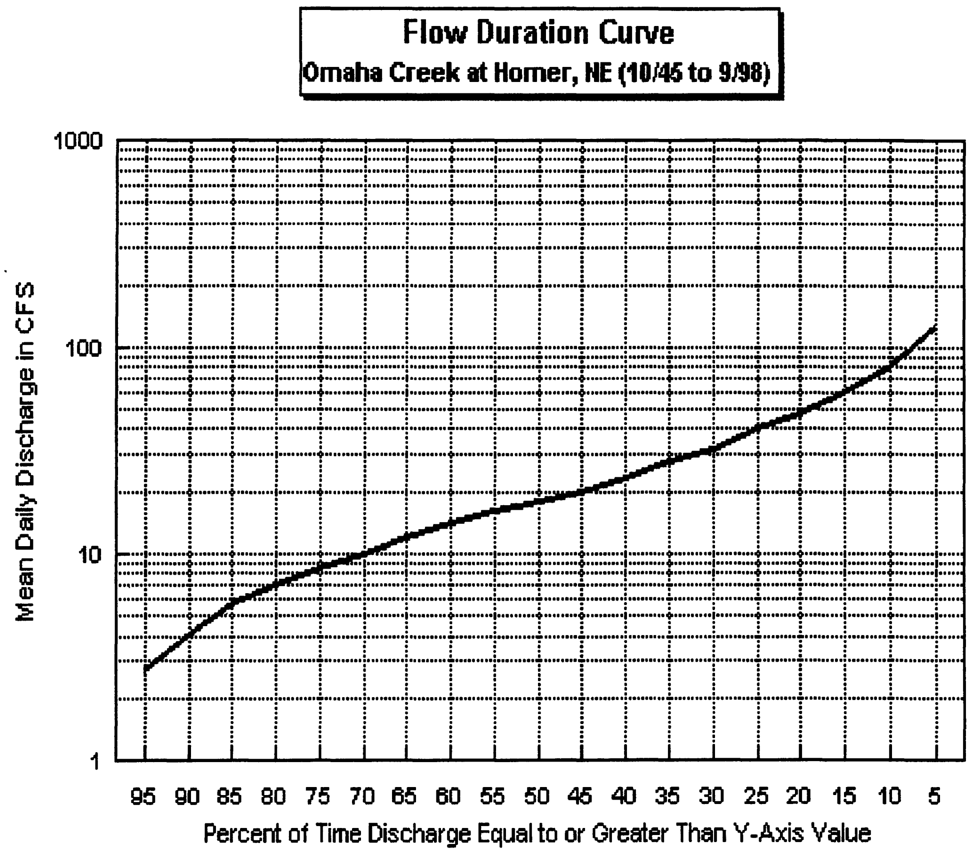


Figure 4-1 (cont.). Flow Duration Curves for Logan, Omaha, and Blackbird Creeks



The USGS has also analyzed historic data for Logan Creek at Pender, Omaha Creek at Homer, and Blackbird Creek near Macy to derive monthly mean discharge along with the standard deviation for these streams. Results are shown in Table 4-2.

Table 4-2. Monthly Mean Discharge and Standard Deviation, Logan, Omaha, and Blackbird Creeks

	Logan Creek at Pender (1966-1990)		Omaha Creek at Homer (1946-1990)		Blackbird Creek near Macy (1979-1980)	
Month	Mean Discharge cfs	Standard Deviation	Mean Discharge cfs	Standard Deviation	Mean Discharge cfs	Standard Deviation
Oct	85.1	59.3	16.8	13.8	15.4	14.2
Nov	78.7	45.0	15.2	10.3	14.6	10.1
Dec	72.0	37.0	13.7	10.8	12.4	8.5
Jan	80.5	50.6	14.2	14.7	8.1	2.9
Feb	236	395	46.0	74.9	15.2	12.3
Mar	255	249	66.7	60.9	64.3	52.7
Apr	231	299	51.2	73.1	21.3	2.8
May	208	190	51.7	50.8	30.7	20.1
Jun	350	477	81.7	90.4	13.5	1.2
Jul	139	127	43.6	40.1	7.1	1.9
Aug	79.3	55.2	24.6	22.7	10.3	2.0
Sep	71.6	42.5	19.6	19.2	6.2	2.7
Annual	157	169	37.0	21.2	18.3	3.1

Source: U.S. Geological Survey, 1996, Table 8.

As shown in the above table, discharge in the Logan Creek drainage is considerably greater than discharge in the Omaha or Blackbird Creeks drainages. This is a result of the larger drainage basin area of Logan Creek relative to Omaha and Blackbird Creeks. The USGS (1996) has also performed and tabulated other statistical analyses of flows in these streams (refer to the USGS report for this additional information).

Surface Water Usage

The Nebraska Natural Resources Commission's surface water rights data bank lists 17 surface water diversion rights within the boundaries of the Reservation. Sixteen rights are for pumped irrigation diversions and one right is for storage. Eleven of the irrigation rights obtain their water from Logan Creek. The remaining irrigation rights are on Rattlesnake Creek, Cow Creek, Omaha Creek, and the Missouri River. The storage right is for up to 4.8 acre feet per year from Omaha Creek by the Northern Natural Gas Company Reservoir No. 2. The 1978 B&E Engineering report indicated that there were 83 diversions or erosion control reservoirs located on the Reservation. Ten of these are Native American owned with a total storage capacity of 26.44 acre feet.

Surface Water Quality
In April 1990, the USGS collected water-quality samples from a total of ten sites located on the Winnebago and Omaha Reservations (USGS, 1996). Of the ten sites, eight (SW1 through SW8, USGS, 1996) were located on or immediately adjacent to the Omaha Reservation. Two samples were from Logan Creek, two from North Blackbird Creek, and one each from South Omaha , Cow, Middle, and Omaha Creeks. The samples indicated that stream water is generally very hard, with levels ranging from 250 to 360 milligrams/Liter (mg/L) as $CaCO_3$. The samples also indicated a high level of manganese with levels ranging from 0.06 to 0.91 mg/L, i.e., above the U.S. Environmental Protection Agency (EPA or U.S. EPA) secondary maximum contaminant level (SMCL) of 0.05 mg/L. Total dissolved solids (TDS) ranged from 289 to 480 mg/L, i.e., below the EPA SMCL for TDS of 500 mg/L. The USGS (1996) tabulated additional data showing temporal changes in water quality for Logan Creek at Pender, Nebraska, for the period of 1983 to 1985.

Davis et al., 1995, obtained surface water samples from seven sites in the Reservation during 1994. The data demonstrated that waters of the Reservation are generally of a calcium bicarbonate to calcium bicarbonate-sulfate type. Nitrate-nitrogen levels ranged from 0.9 to 7.0 mg/L, i.e., below the EPA maximum contaminant level (MCL) of 10.0 mg/L. Sulphate and chloride levels did not exceed the EPA SMCL of 250 mg/L for each constituent. Iron and manganese levels exceeded their respective EPA SMCLs (0.3 and 0.05 mg/L) in Logan and Cow Creeks during high-flow events. At all seven sites, atrazine concentrations briefly exceed the EPA MCL of 0.003 mg/L during high flow events. Alachlor, with an EPA MCL of 0.002 mg/L, exhibited a similar pattern. Davis concluded that pesticides are a direct result of nonpoint source runoff from agricultural application within or adjacent to the Reservation.

Bioassessments to characterize aquatic life conditions in the creeks on the Reservation were performed in February 1998 and May 1999 (Wright Water Engineers, Inc., 1999). Results of those studies indicated that the benthic community was relatively pollution tolerant at the sites sampled. However, the number of species found and dominant taxon at each site varied between the two studies. Additional work to identify reference conditions, additional water quality sampling in the Walthill area, and identification of potential pollution sources were recommended.

Chapter Five - Ground Water Resources

This chapter discusses the overall ground water resources occurring on the Reservation associated with the major geologic deposits described in Chapter 3. Information is included on yield capability, water quality, and location of these resources.

Paleozoic Deposits

Paleozoic deposits consist of inter-bedded limestone, dolomite, dolomitic shales and limestones, and sandstones. These deposits have not been extensively explored in the study area and therefore their water quality and yield capabilities are not well known. Yields are estimated to range from 50 to 200 gallons per minute and formation water probably has a high TDS. The great depth to these formations, and probable poor water quality, preclude their development as a viable source of water on the Reservation.

Mesozoic Deposits

Mesozoic era formations include the Carlile Shale, Greenhorn Limestone, Graneros Shale, and the Dakota Formation. Much of the Carlile and Graneros formations consists of low permeability materials that cannot serve as ground water sources. The Greenhorn Limestone, on the other hand, may have some secondary permeability capable of yielding greater volumes of water, but the water is likely to have high levels of TDS. The sandstone layers of the Dakota Formation are the only deposits known to yield significant supplies of potable water in the area. Characteristics of the formation and its water are described as follows.

The Dakota Formation is generally a confined aquifer, although, it may be hydraulically connected to overlying Quaternary deposits where younger confining Cretaceous layers are absent. Where sufficiently confined, the formation has the potential to produce artesian wells in the study area. The sandstone layers within the Dakota appear to be discontinuous (Davis and Pederson, 1992) which can impede the development of high yielding wells. Well yields generally range from 50 to 500 gpm.

Water composition varies from a calcium-bicarbonate to a calcium-sulfate type (Lawton and others, 1984). In general, water quality of the formation appears to improve west to east across the Reservation. This is probably due to overlying Cretaceous shales present in the western part of the area, but absent in the east. The low permeability of the shales impedes the downward movement of fresher water to the aquifer.

Total dissolved solids content of the Dakota Formation water ranges from 400 to 1,550 mg/L. Typically, iron and manganese levels are high. During 1990, the USGS (1996) sampled ten wells completed in the Dakota Formation within the Omaha Reservation and the adjacent Winnebago Reservation. Those wells had a median TDS of 601 mg/L. The median iron level was 1.0 mg/L and the median manganese level was 0.17 mg/L. One of the wells sampled exceeded the 20 mg/L MCL for uranium radio nuclide.

Quaternary Deposits

Quaternary deposits include glacial, eolian, and alluvial deposits occurring throughout the Reservation. Typically, glacial till and eolian deposits overlie a basal zone of discontinuous sand and gravel. The glacial till deposits contain a lot of fines that impart a low permeability to these materials; typically, well yields are less than 10 gpm. Similarly, well yields from the relatively fine-grained eolian deposits (consisting of silt and clayey-silt) are expected to be less than 10 gpm.

The basal sand and gravel zone was deposited in fluvial environments during previous glacial advances and retreats. This basal zone, and recent alluvial aquifers associated with major streams, are the most universally accessed sources of ground water in the study area. Depending on the composition of the aquifers, well yields from these deposits can vary significantly (from about 50 to over 1,000 gpm). It should be noted that the alluvial sand and gravel of the Missouri River are not continuous with glacial sand and gravel deposits in the upland areas (Davis and Pederson, 1992).

Depending on the nature of the contributing inflow from adjacent formations and overlying streams, water quality can vary significantly. In 1990, the USGS (1996) sampled three Missouri River alluvial wells and 16 wells completed in Quaternary deposits to the west of the Missouri valley on the Winnebago and Omaha Reservations. The three Missouri alluvial wells had a median TDS of 828 mg/L and the 16 Quaternary wells had a median TDS of 437 mg/L. The median iron level for the Missouri alluvial wells was high at 6.2 mg/L. Manganese levels were high in both the Missouri wells and the Quaternary wells with median levels of 0.49 mg/L and 0.37 mg/L, respectively. One of the Quaternary wells exceeded the MCL for nitrate plus nitrite-nitrogen of 10 mg/L.

Davis and Pederson (1992) examined previous studies of nitrate contamination on the Reservation and adjacent areas. In one study involving 35 domestic wells on the Reservation, thirty-seven percent of the wells exceeded the nitrate plus nitrite MCL, with six of the wells having concentrations above 20 mg/L.

Davis et al. (1995) sampled forty-two wells completed in Quaternary deposits and determined the water to be predominantly a calcium bicarbonate to calcium bicarbonate-sulfate type. Pesticide levels were very low; many analyses were non-detect or just above detection limits. Ten percent of the wells exceeded the EPA SMCL of 250 mg/L for sulphate. Sixty-two percent of the wells sampled approached or exceeded the EPA SMCL of 500 mg/L for TDS. Twenty-four percent of the wells had nitrate-nitrogen concentrations which exceeded the EPA primary MCL, and the same percentage of wells had excessive coliform bacteria. Davis et al. (1995) concluded that the high nitrate-nitrogen levels, in conjunction with high coliform bacteria levels and absence of any significant pesticide contamination, suggests that contamination may be coming from runoff related to livestock feeding operations or septic systems.

Since many diseases potentially can be contracted from drinking water contaminated by animal wastes, or by direct contact with animal wastes, the U.S. EPA is implementing regulations on centralized animal feeding operations (CAFOs). These regulations apply to farms with dairy cattle, sheep, swine, poultry, or slaughter cattle operations. Since such farms exist on the Omaha Reservation, the Tribe would be well advised to review the regulations, National Pollution Discharge Elimination System permit requirements applicable to the farms, and to be cognizant of the potential for contamination of surface waters from these sources.

Ground Water Occurrence on the Reservation

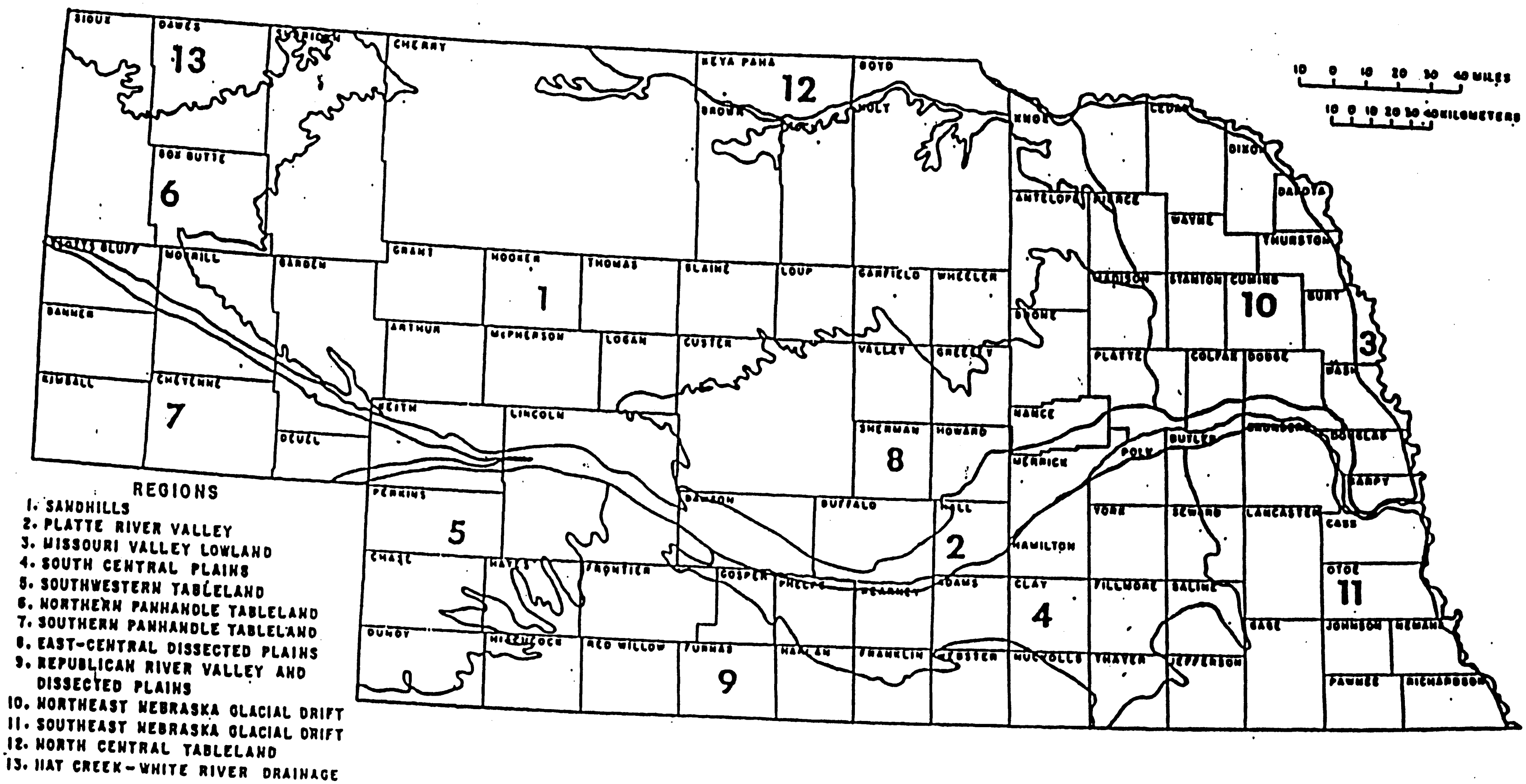
The State of Nebraska is divided into thirteen different ground water regions. As shown in Figure 5-1, the far eastern portion of the Reservation is located in Region 3 - the Missouri Valley Lowland, while the balance of the Reservation lies in Region 10 - the Northeast Nebraska Glacial Drift.

The principal aquifer in Region 3 is composed primarily of alluvial sands and gravels occurring in the Missouri River flood plain. Yields from the alluvial aquifer adjacent to the Missouri River are expected to range from 500 to 1,500 gpm. According to the USGS (1996), this aquifer has potential for further development as a potable water source if recharge is induced from the river.

The uppermost deposits of Region 10 consist of Pleistocene and Pliocene age glacial, eolian, and alluvial deposits. Some of these deposits occur in paleo-channels cut into the underlying bedrock. In this position, they can form aquifers capable of supplying moderate to large quantities of good quality water. Evidently, this is the case with the alluvial aquifer in the flood plain of the Logan Creek drainage. It is the most extensively used of the Quaternary deposits on the Reservation and can provide yields in excess of 1,000 gpm. Ground water from this area is not as highly mineralized as water from Region 3; TDS ranges from 400 to 600 part per million (ppm).

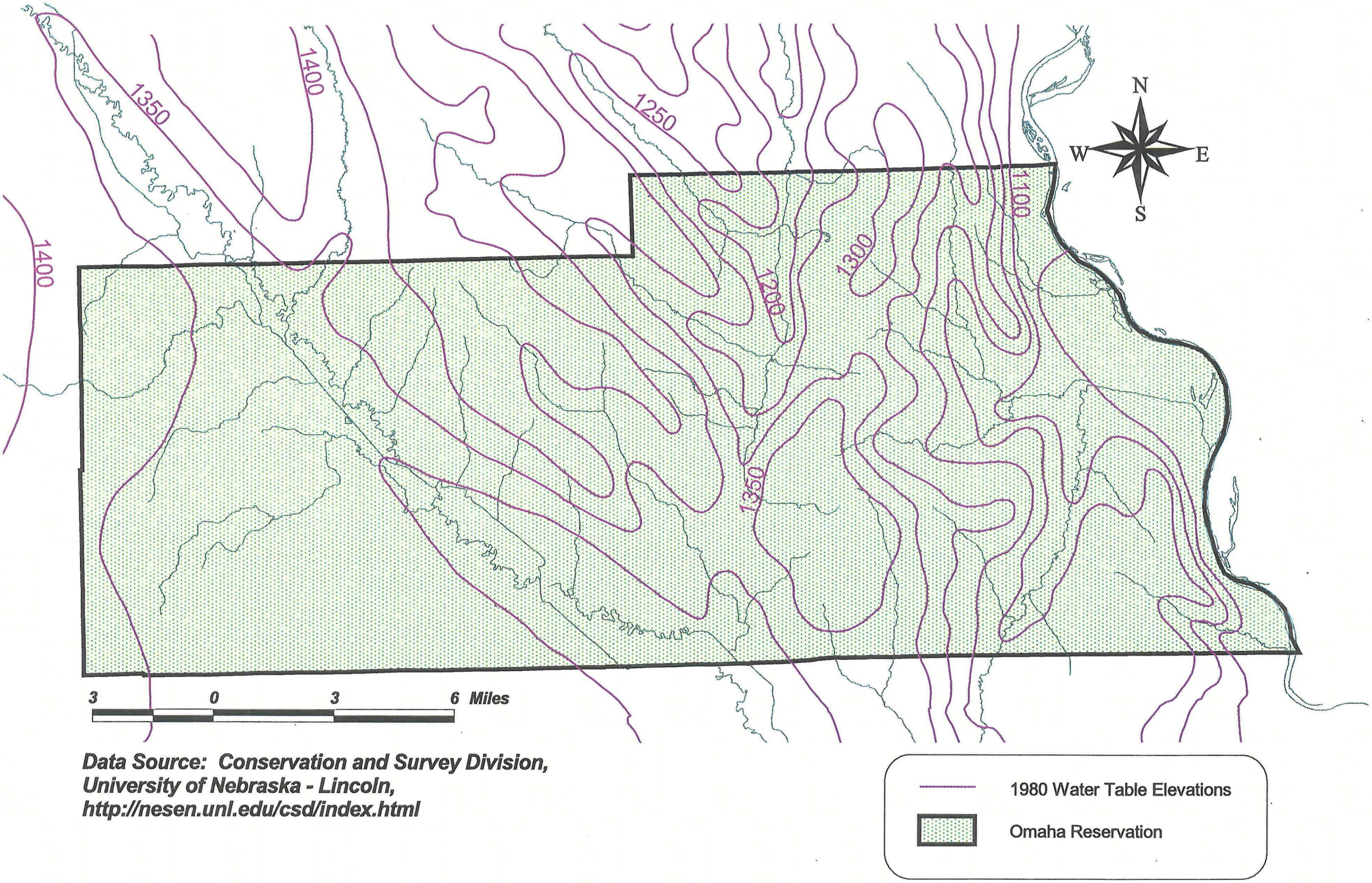
Depth to ground water on the Reservation ranges from less than 10 feet on bottom lands to more than 150 feet in upland areas (USGS, 1996). The State of Nebraska Conservation and Survey Division prepared a generalized map in 1980 showing the elevation of the top of the saturated zone of the principal aquifer (Figure 5-2). The map indicates that, generally, the water table slopes to the east and southeast. Locally, however, the water table slopes towards the major drainages indicating that water is discharging from the aquifers to the streams.

Figure 5-1. Ground Water Regions in Nebraska



Source: 1994 Nebraska Ground Water Quality Report, December 1994; Water Quality Division, Nebraska Department of Environmental Quality.

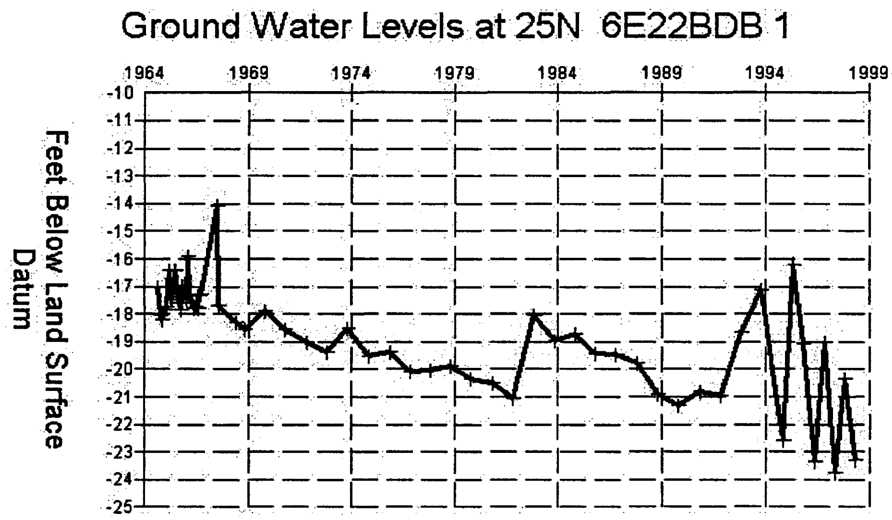
Figure 5-2. Configuration of the 1980 Water Table on the Omaha Reservation (elevation in feet)



Data Source: Conservation and Survey Division, University of Nebraska - Lincoln, http://nesen.unl.edu/csd/index.html

Recent published maps showing significant ground water-level changes indicate that ground water levels for most of the Omaha Reservation have not changed significantly since the pre-development period of 1950[1]. There is a relatively small area, however, in the Logan Creek drainage within the Reservation that has had a 5 to 10 foot decline in water levels since pre-development. The hydrograph of well 25N-6E-22BDB1, located in this area, demonstrates this decline (see Figure 5-3).

Figure 5-3. Well Hydrograph



Ground Water Use on the Reservation

Ground water is used throughout the Reservation for domestic, stock watering, irrigation, and municipal purposes. The Nebraska Natural Resources Commission's database of registered ground water wells[2] (see Figure 5-4) lists 165 registered active wells on the Reservation including, in part, twelve domestic wells, 104 irrigation wells, and eleven public supply wells. The registered domestic wells have yields ranging from 10 to 20 gpm with well depths from 45 to 370 feet. The registered irrigation wells have yields ranging from 300 to 1,500 gpm with well depths to 320 feet. Most of the irrigation wells are located in the western portion of the Reservation close to or in the flood plain of Logan Creek.

Of the eleven registered public supply wells, five wells are associated with the Village of Pender, two wells each are associated with the Villages of Walthill and Rosalie, and two wells are registered with the Omaha Tribe in Macy. The Village of Pender wells are completed in Quaternary aquifers (Davis et al., 1995) with yields ranging from 210 to 345 gpm and well depths

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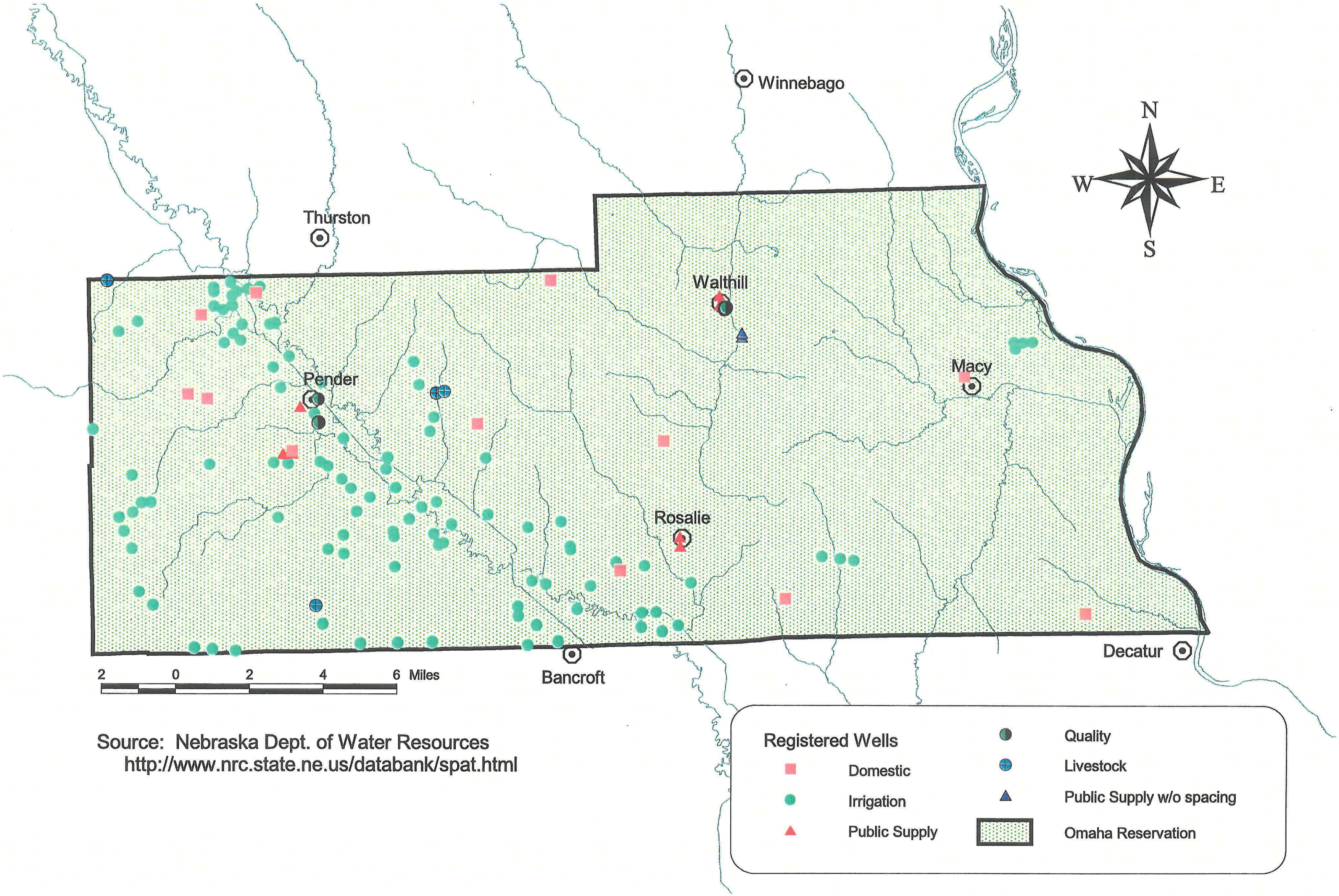
[1] Data source: http://nrcnt3.nrc.state.ne.us/scripts/esrimap.dll?name=gwlMap&Cmd=Map&chglayer=pre.

[2] Source: Registered well data from Nebraska Department of Natural Resources at http://www.nrc.state.ne.us/databank/spat.html.

Figure 5-4. Registered Wells on the Omaha Reservation



Source: Nebraska Dept. of Water Resources
http://www.nrc.state.ne.us/databank/spat.html

varying from 90 to 120 feet. The wells for the Village of Walthill range in yield from 200 to 350 gpm and range in depth from 155 to 200 feet. The wells for the Village of Rosalie yield from 154 to 170 gpm and have a depth of 160 feet. The two wells registered to the Omaha Tribe in Macy are listed as yielding 350 gpm each with well depths ranging from 176 to 227 feet. The wells serving Macy, Walthill, and Rosalie are completed in the Dakota aquifer (Davis et al., 1995). Additionally, there is a registered well serving the dialysis clinic in Macy that provides 25 gpm with a well depth of 332 feet, probably drawing from the Dakota aquifer. More detailed discussion of municipal wells is provided in Chapter 6 of this report.

Data collected by B&E Engineering (1978) indicated a total of 79 wells on the Omaha Reservation that are individually, Native-American, or tribally owned. Seventy-two of the wells are for domestic use and the remaining seven wells for livestock. The wells have a mean yield of 6.3 - 7.3 gpm, with well depths of 30 to 70 feet. B&E Engineering (1978) noted that many of the shallow wells encounter recharge problems when pumped at high discharge rates.

Ground Water Versus Development on the Reservation

The most important ground water sources on the Reservation include the Dakota Formation, Quaternary alluvial aquifers adjacent to major streams, and buried river channel alluvium - most notably, the buried alluvial channel adjacent to the Logan Creek drainage in the western portion of the Reservation.

Depending on locale, ground water from the Dakota Formation can sustain individual, cluster housing development, or additional municipal demands throughout the Reservation. As discussed, water quality appears to improve west to east across the study area, although even in the eastern sector, formation water typically exhibits elevated TDS, iron, and manganese levels. Additional study would be needed to establish the most desirable locations for future ground water development. The USGS (1996) suggested that wells tapping the Dakota Formation may need to be analyzed for gross-alpha concentration.

In many locations throughout the Reservation, Quaternary alluvial deposits are fully capable of sustaining both individual or cluster housing development. Water quality, however, varies throughout the study area, and yield is dependent on thickness and areal extent of the source aquifer. In general, water derived from Quaternary deposits has less total dissolved solids than Dakota Formation water, yet, elevated iron and manganese levels are not uncommon. Because of their position at or near the ground surface, Quaternary deposits are more susceptible to contamination from point and non-point sources than Dakota Formation water. Detailed geologic exploration would be needed to locate and inventory the best alluvial aquifer sources.

The buried alluvial channels near Logan Creek stand out as potential ground water sources for single resident, cluster type, or community systems. High yielding irrigation wells and municipal supplies for the Villages of Pender and Thornton (located just to the north of the Omaha Reservation) bear this out. Similar geohydrologic conditions may exist in the Omaha Creek drainage basin, but no published data was found to substantiate this.

Section 303d Impaired River Reaches

As of 1998, the Missouri River along the edge of the Reservation is listed by the state of Nebraska[3] as an impaired river reach. The parameter of concern is pathogens with sources from urban runoff, storm sewers, and agriculture. This reach has a low priority for development of Total Maximum Daily Loads (TMDL) by the State of Nebraska.

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[3]Source: http://www.epa.gov/surf2/303d/10230001_303d.html.

Chapter Six - Water Supply and Treatment Systems on the Reservation

This chapter examines the configuration and performance of the water supply, storage, and treatment systems serving Reservation communities. The chapter opens with a recap of the population projections from Chapter 2 and follows with the development of average and maximum day water demands for the Reservation communities through the Year 2040 planning horizon using the population figures. It concludes with a summary assessment of the community systems in table form.

Water Demands

Population Base

Table 6-1 displays the population figures used in this chapter to generate potable water demands for Years 2000, 2020, and 2040. The population figures in Table 6-1 represent the projections for these years from the trend analysis modeling results discussed in Chapter 2. Figure 6-1 illustrates current and projected population estimates for the Village of Macy Service Area and the Villages of Pender, Walthill, and Rosalie in graphical form.

Table 6-1. Population Projections Used to Estimate Future Water Demands

Year	Macy Service Area	Pender	Walthill	Rosalie	Omaha Reservation
2000	3,150	1,148	1,018	194	5,667
2020	5,704	1,148	1,490	236	8,666
2040	10,327	1,148	2,182	286	14,102

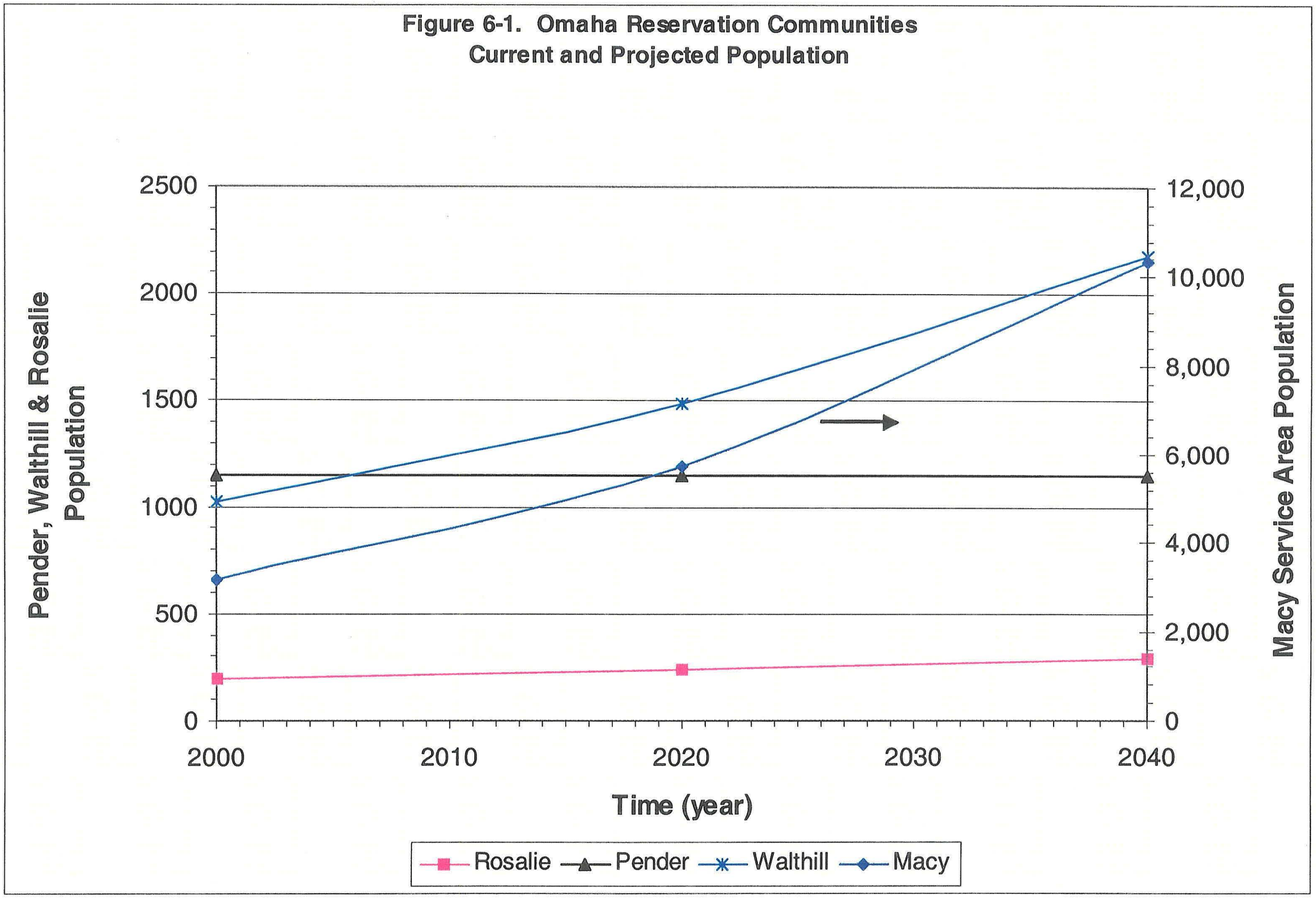


Figure 6-1. Omaha Reservation Communities
Current and Projected Population
Pender, Walthill & Rosalie Population
Macy Service Area Population
2500
2000
1500
1000
500
0
12,000
10,000
8,000
6,000
4,000
2,000
0
2000
2010
2020
2030
2040
Time (year)
Rosalie
Pender
Walthill
Macy

Average Day Demand Through Year 2040

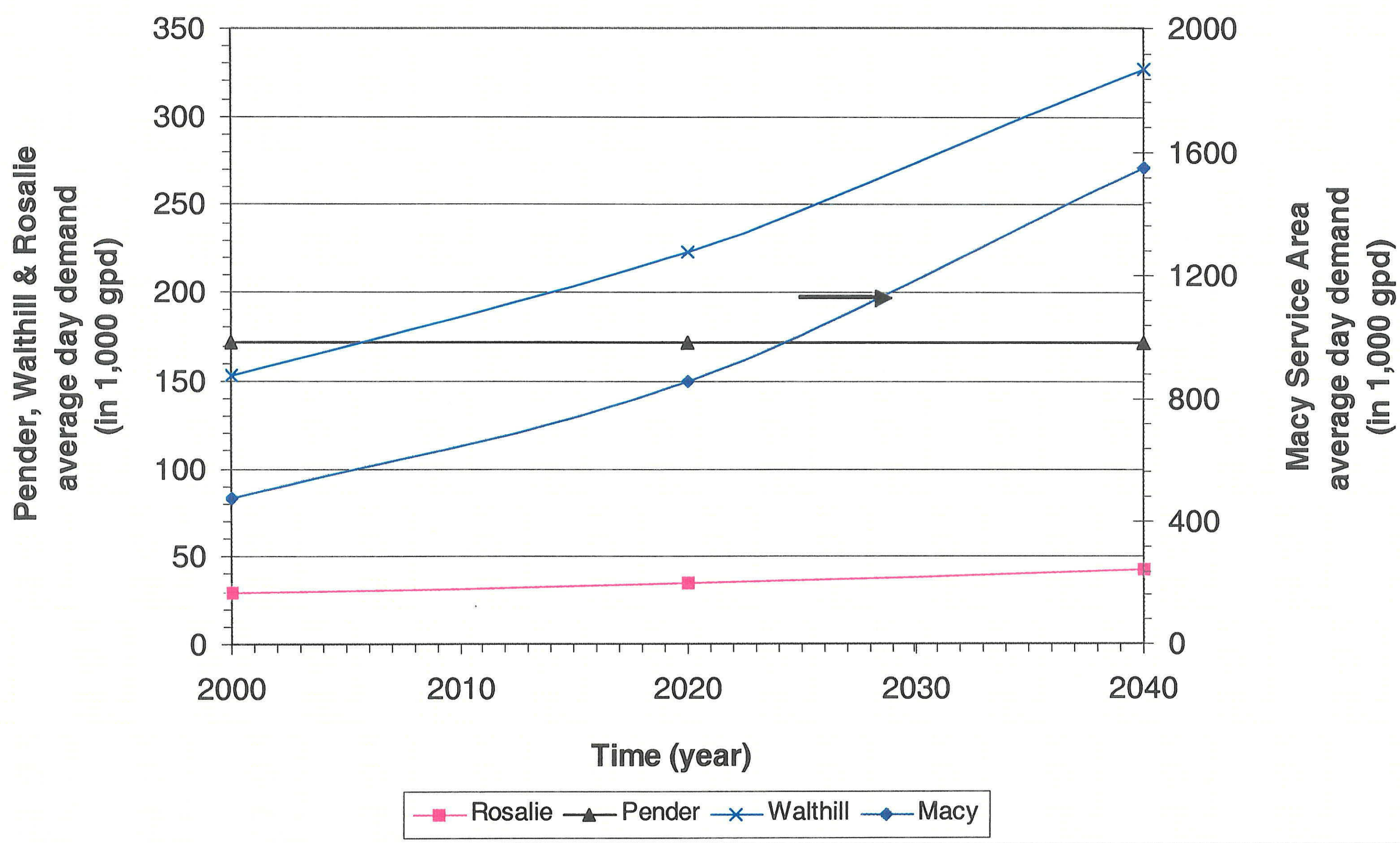
An average day demand rate of 150 gallons per capita per day (gpcd) was applied to the population values in Table 6-1 to generate the current and future water demands presented in Table 6-2, below. The demand rate includes 100 gpcd from residential usage and 50 gpcd from commercial/industrial usage, irrigation of lawns and gardens, and system leakage. This water consumption estimate equates well with the State of Nebraska's Department of Environmental Quality average day wastewater flow standard of 120 gpcd when water loss is taken into account and accords with the value utilized for a Needs Assessment completed for the neighboring Winnebago Reservation. With regard to any future water planning initiatives, it is recommended that this demand rate be closely re-examined as it was only generally formulated for this study. Figure 6-2 illustrates the current and projected potable water average day demand for the Omaha Reservation communities in graphical form.

Table 6-2. Potable Water Average Day Demand Estimates in Gallons per Day

Year	Macy Service Area	Pender	Walthill	Rosalie	Omaha Reservation
2000	472,500	172,200	152,700	29,100	850,050
2020	855,600	172,200	223,500	35,400	1,299,900
2040	1,549,050	172,200	327,300	42,900	2,115,300

At present, none of the communities on the Reservation have a formalized water conservation plan. It has been demonstrated that 10 to 20 percent water savings can accrue from a properly conceived water conservation program.

Figure 6-2. Omaha Reservation Communities
Current and Projected Potable Water Average Day Demand



Maximum Day Demand Through Year 2040

Water use varies with time of day and fluctuates from one day to the next. Peaking factors are used to account for these variations and take into consideration the number of housing units, climate, industry, and type of residences in the area being served. Average day demand rates are increased by the peaking factor to calculate the maximum (peak) day and hourly demand. For this study, the maximum day peaking factor was estimated to be 2.0 (Reclamation, D. Gesundheit). Table 6-3 displays the maximum day demand for Reservation communities and the Reservation as a whole for Years 2000, 2020, and 2040. Figure 6-3 illustrates the current and projected potable water maximum day demand for the Omaha Reservation communities in graphical form.

Table 6-3. Potable Water Maximum Day Demand Estimates in Gallons per Day

Year	Macy Service Area	Pender	Walthill	Rosalie	Omaha Reservation
2000	945,000	344,400	305,400	58,200	1,700,100
2020	1,711,200	344,400	447,000	70,800	2,599,800
2040	3,098,100	344,400	654,600	85,800	4,230,600

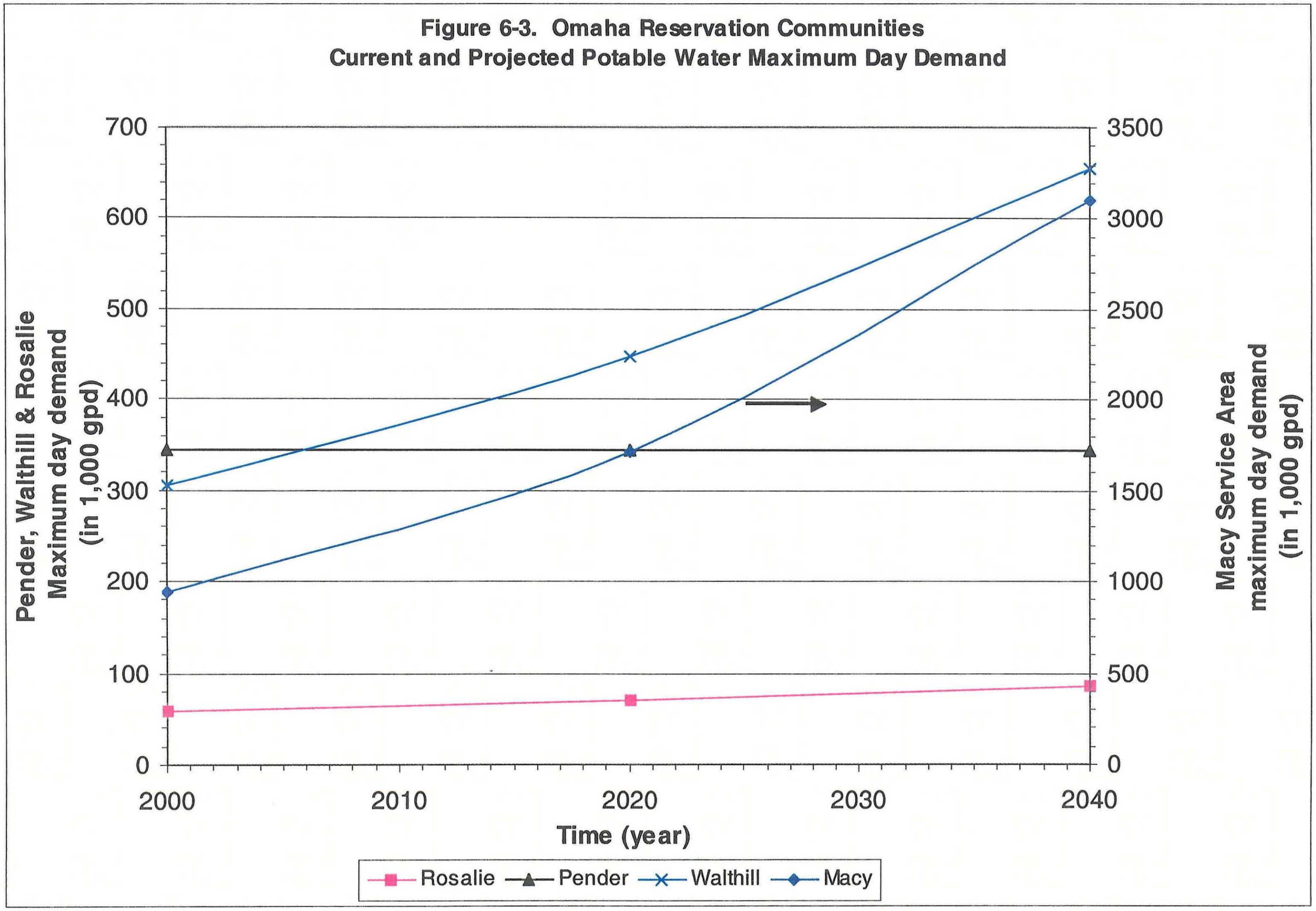


Figure 6-3. Omaha Reservation Communities
Current and Projected Potable Water Maximum Day Demand
Pender, Walthill & Rosalie
Maximum day demand
(in 1,000 gpd)
700
600
500
400
300
200
100
0
3500
3000
2500
2000
1500
1000
500
0
Macy Service Area
maximum day demand
(in 1,000 gpd)
2000
2010
2020
2030
2040
Time (year)
Rosalie
Pender
Walthill
Macy

Criteria Used to Assess Water Supply Systems

The criteria used to assess the capability of the public water supply systems on the Reservation to meet current and future (Year 2040) water supply needs are listed below:

• Water Quality - Water quality meets U.S. EPA Safe Drinking Water Act (SDWA) primary[1] and secondary[2] Maximum Contaminant Levels (MCL) for treated water.

• Production Rate - Raw water is deliverable to treatment and storage facilities in sufficient quantity to accommodate system demands under normal and emergency conditions. The average day demand must be met with the largest pump out of service and the maximum day demand must be met with all pumps in operation.

• Storage Requirement - Sufficient quantities of treated, potable water are stored to accommodate system demands under normal and emergency conditions. The total storage requirement is defined as the summation of volumes needed for equalization and the larger of fire flow or emergency storage.

Equalization, Fire Flow, and Emergency storage are defined below:

> **Equalization for peak day demands** - Volumetric fluctuations in a storage tank due to variances in water consumption throughout the day. The result is approximately 183 gallons of storage required per one gallon per minute of maximum day water demand (American Water Works Association, 1989; Manual 32).
>
> **Fire Flow Capacity** - Based on the 1997 Uniform Fire Code. For Pender, Walthill, and Rosalie: Treated water storage capacity adequate to provide a stored volume of 180,000 gallons per 1,500 gallons per minute (gpm) for two hours. For The tribal water system: Fire flow requirements are defined for the Carl T. Curtis Health Center (333,000 gallons per 2,750 gpm for two hours) and the Tribal Administration Building (540,000 gallons per 3,000 gpm for three hours).
>
> **Emergency storage** - An amount of storage equal to three days of the village's average day water demand.

---

[1] National Primary Drinking Water Regulations (NPDWRs), or primary standards, are legally enforceable standards that apply to public water systems. Primary MCLs apply to constituents that can adversely affect public health.

[2] Under the U.S. EPA National Secondary Drinking Water Standards, MCLs are concentrations of constituents above which cosmetic (tooth or skin discoloration) or aesthetic (taste, odor, or color) problems may occur. Secondary MCLs are non-enforceable federal guidelines relating to constituents that do not threaten human health.

Municipal Systems

Tribal System, Village of Macy Service Area

Overview

The tribal water system serves the Village of Macy and the surrounding rural areas north, west, and south of the Village (Macy Service Area). Macy is located in the east central part of the Reservation and is home to approximately 3,150 people including the surrounding rural area which is approximately 10 miles wide by 11 miles long. Potable water is supplied by three wells with a total combined capacity of 896 gpm. The distribution system includes about 87 miles of pipeline and consists of an 8-inch diameter main loop with branches to serve Macy and the rural area. Hilly topography makes it difficult to provide consistent water pressure. Water treatment is provided by a mechanical treatment plant which uses aeration followed by filtration for iron and manganese removal.

The tribal system is administered by the Omaha Tribal Utility Commission, Mr. Mert Christiansen Superintendent and certified operator. Mr. Christiansen is assisted in the operation and maintenance of this system by two operators. On occasion, the Indian Health Service is enlisted to provide engineering services.

Water Quality and Treatment

The tribal system draws its water from the Dakota aquifer. Raw water is pumped from three groundwater wells to a water treatment plant manufactured by General Filter where air oxidizes iron and manganese to an insoluble form for removal by filtration. The final treatment process is disinfection by chlorine.

In July 1990, the U.S. Geological Survey sampled ten wells in the Dakota aquifer in the Omaha Reservation area (USGS, 1996). The mean water quality values for the ten wells is presented in Table 6-4 along with treated water quality data from the August 1999 annual drinking water quality report for the tribal system. In all likelihood, source water quality for the tribal system is comparable to the water quality displayed in this table. As shown, the raw water meets all primary drinking water standards. With regard to secondary standards, the water is very hard (448 mg/L as $CaCO_3$, reference Table 6-5); iron and manganese concentrations of 1.2 and 0.17 mg/L exceed their respective SMCLs of 0.3 and 0.05 mg/L; and the TDS of 649 mg/L exceeds the SMCL of 500 mg/L. None of the several treated water quality components recorded in Table 6-4 exceeded regulatory levels.

Table 6-4. Dakota Aquifer and Tribal System Treated Water Quality

(--, no data or not applicable; **Bold** indicates exceeds MCL or SMCL)

Parameter	Well (units mg/L unless otherwise noted)	Treated Water[1] (units mg/L unless otherwise noted)	MCL (units mg/L unless otherwise noted)
Alkalinity as $CaCO_3$	316	--	--
Arsenic, dissolved	0.002	--	0.05[2]
Barium, dissolved	--	0.119	2
Calcium, dissolved	131	--	--
Chloride, dissolved	22	--	250 (SMCL)
Fluoride, dissolved	0.6	0.76	4.0
Total Hardness as $CaCO_3$	448	--	--
Iron , dissolved	**1.2**	**--**	**0.3 (SMCL)**
Magnesium, dissolved	29	--	--
Manganese, dissolved	**0.17**	**--**	**0.05 (SMCL)**
Total Mercury	Nondetect	--	0.002
Nitrate Nitrogen	--	0.07	10
Potassium , dissolved	9.5	--	--
Selenium, dissolved	Nondetect	--	0.051
Sodium, dissolved	38	--	--
Sulfate, dissolved	174	--	250 (SMCL)
Total Coliforms	Nondetect	Nondetect	No more than one sample may be coliform positive
Total Dissolved Solids	**649**	**--**	**500 (SMCL)**
Gross Alpha	14 pCi/L	--	15 pCi/L
pH	7.2	--	--

[1] Values from August 1999, annual drinking water quality report for the Omaha tribal public water supply system.
[2] Effective at time of reporting.

Table 6-5. Qualitative Classification of Water According to Level of Hardness

Description	Hardness (mg/L as $CaCO_3$)
Soft	Less than 50
Moderately hard	50 - 150
Hard	150 - 300
Very hard	Greater than 300

Source: George Tchobanoglous, Edwad D. Schroeder University of California at Davis, *Water Quality*, 1985.

Although secondary contaminant constituents are not considered harmful to human health, they may impart undesirable cosmetic and aesthetic properties to water. High concentrations of hardness, for instance, will consume excess soap. Iron will give water a medicinal or metallic taste and cause staining problems in laundry and plumbing fixtures. Manganese can cause black stains on clothing and clog pipes if it precipitates. TDS greater than 500 mg/L may cause taste, odor, and color problems and deteriorate or cause mineral precipitation in plumbing and appliances.

Production Capacity

Information received from the Omaha Tribe reveal that three groundwater wells with individual pumping design capacities of 150, 400, and 500 gpm can provide the Macy tribal system with a total combined pumping capacity of 896 gpm. Pump tests, performed by the Tribal Environmental Protection Department and the IHS in June - July 2001, revealed the following flow rates after well rehabilitation efforts:

Well #1 (near Water Treatment Plant) -	106 gpm
Well #2 (S. well near Walthill) -	302 gpm
Well #3 (N. well near Walthill) -	488 gpm
Total	896 gpm

Tables 6-6 and 6-7 contrast current and future water demands to the production criteria listed on Page 6-7.

Table 6-6. Tribal Water System: Assessment of Average Day Demand Production Rate with the Largest Well (500 gpm) Out of Service
(Units in gallons per day)

Year	Average Day Demand	Available from 150 & 400 gpm Wells	Additional Capacity Required
2000	472,500	587,520	none
2020	855,600	587,520	268,080
2040	1,549,050	587,520	961,530

Table 6-7. Tribal Water System: Assessment of Maximum Day Demand Production Rate with All Wells Operational
(Units in gallons per day)

Year	Maximum Day Demand	Available from Three Wells	Additional Capacity Required
2000	945,000	1,290,200	none
2020	1,711,200	1,290,200	421,000
2040	3,098,100	1,290,200	1,807,900

As indicated, the existing system has sufficient capacity to meet the current demand, however, additional raw water capacity is required prior to Year 2020 and through Year 2040. Additional capacity needed to meet maximum day demand, indicated in Table 6-7, would also satisfy average day demands indicated in Table 6-6. For Years 2020 and 2040, therefore, 421,200 and 1,807,900 gallons per day are required, respectively. Table 6-8 shows the number of wells that would be needed to meet the additional capacity required in Years 2020 and 2040. The average design capacity of the system's three supply wells, 350 gpm, was used for this calculation.

Table 6-8. Well Design

Year	Additional Capacity Required[1] (Gallons/day)	Additional Capacity Required[2] (Gallons/minute)	Gallons per minute per well required[3]	Total Number of additional Wells Required[4]
2020	421,200	292	292	1
2040	1,807,900	1,256	350	4

1. From Table 6-7.
2. Gallons per day (column 1) divided by 1,440 minutes per day.
3. 350 gpm (the average of three existing system wells) or actual gpm (column 2) if less than 350 gpm.
4. Column 3 divided by column 4 and rounded up. Should one well be added before Year 2020, only three wells would be required before 2040.

Storage Systems

The tribal system has a total storage capacity of 450,000 gallons provided by a 150,000 gallon elevated steel tank (treatment plant standpipe) and a 300,000 gallon at-grade steel tank (Macy storage tank) each built in 1976.

As previously explained on Page 6-7, storage requirements are the sum of the equalization storage and the greater of either fire flow storage or emergency storage for the entire system. The amount of storage required for Years 2000, 2020 and 2040 is shown in Table 6-9.

Equalization and emergency storage requirements for Macy proper and pressure Zones 1, 2, and 3 service areas will each be supplied by storage tanks in each of these areas. Pressure zones are described in the "Distribution System" section on Page 6-13 and depicted on Figure 1 of Appendix A. Equalization storage was determined for each pressure zone based on the type of land use currently found within the Reservation as if the zonal boundaries were in place today. That is, for each gallon per minute of maximum day demand, the previously defined criteria requires 183 gallons of equalization storage. The total equalization storage is then apportioned among the four pressure zones in proportion to the current land uses found on the Reservation. Similarly, the emergency storage shown in Table 6-9 for each future development year is the total emergency storage apportioned among each of the four service pressure zones.

Table 6-9. Tribal Water System: Assessment of Storage Capacity
(Units are in gallons)

Year	Tank	Equalization Storage	Fire Flow[1] Storage	Emergency Storage	Total Required	Additional Required[2]
2000	Treatment Plant and Macy Tank	120,000	540,000	1,417,500	1,537,500	1,087,500
2020	Treatment Plant (Zone 1)	46,600	540,000	550,600	597,200	447,200
2020	Zone 2 Tank	129,600	0	1,533,000	1,662,600	1,662,600
2020	Zone 3 Tank	23,300	0	275,300	298,600	298,600
2020	Macy Tank	17,600	330,000	208,300	347,600	46,600
2040	Treatment Plant (Zone 1)	84,300	540,000	997,000	1,081,300	931,300
2040	Zone 2 Tank	235,000	0	2,775,000	3,010,000	3,010,000
2040	Zone 3 Tank	42,200	0	498,000	540,200	540,200
2040	Macy Tank	31,900	330,000	377,000	408,900	108,900

[1] Fire flow is determined from the Uniform Fire Code. The Year 2000 requirement is the maximum fire flow required for the whole system, since the treatment plant supplies the entire water supply. In Years 2020 and 2040, the treatment plant will provide the fire flow requirements for Zone 2 and Zone 3 tanks. The Macy tank will provide fire flow for the Carl T. Curtis Health Center.

[2] The additional required volume is determined as the total required minus the existing capacity of 150,000 gallons for the Treatment Plant tank or 300,000 gallons for the Macy Storage Tank or the combined sum of 450,000 for the Year 2000. Since the Zone 2 and Zone 3 tanks are new tanks, the existing capacity for those tanks is 0 and the additional required volume is equal to the total required volume for those tanks. Additional storage requirements do not include prior year capacity.

Distribution System

Very hilly topography, and elevations ranging from less than 1,100 feet in the east to 1,450 feet in the west, make it very difficult to provide consistent water pressure in the Macy Service Area. Currently, pressure zones are created with two pressure reducing valves in Macy proper and twelve in the outlying system area. The existing distribution system consists of an 8-inch diameter main loop with branches to serve Macy and the rural area.

The water distribution system was analyzed using an uncalibrated hydraulic software model developed by Haestad Methods, Inc., of Waterbury, Connecticut (*Cybernet Version 3.0).* Results from several analyses verified that, at present, there are service pressure deficiencies in the existing system for estimated peak instantaneous and peak hour demands. Additionally, the capability of the system to provide adequate fire flow was shown to be limited. Numerous areas have deficient pressure, especially where 2- and 3-inch diameter distribution pipe exist. With regard to Year 2040 demands, the analytical model showed that the tribal water distribution system will need extensive modification. Results of the Year 2040 analysis are detailed in Appendix A, "Hydraulics for Water Distribution System - The Omaha Tribe of Nebraska". The model analysis indicated that the tribal distribution system is amenable to four pressure zones as described in general terms below and illustrated in Figure 6-4.

Pressure Zone 1, for areas situated at elevations over 1,350 feet, would be served by the elevated treatment plant tank. Pressure Zone 2, for areas positioned between 1,250 and 1,350 feet, would be served by a new elevated tank. Pressure Zone 3, for areas between elevations 1,150 and 1,250 feet, would be served by a new elevated tank. The Macy pressure zone is split. The Carl T. Curtis Health Education Center and a small area of nearby residences are served by the Macy tank. The rest of the Macy pressure zone is served by the pressure Zone 2 tank.

Fire flow storage would be supplied by the treatment plant and the Macy storage tank. The storage tank in pressure Zone 1 will downfeed to storage tanks in pressure Zones 2 and 3 for fire protection. The Macy storage tank will have sufficient fire flow capacity for the Carl T. Curtis Health Education Center since it is the largest structure in the service area.

Current Water System Performance
The water distribution and storage system meets the needs of the residents only minimally. Storage is short by approximately 1,087,500 gallons and significant portions of the system have deficient pressure. The northwest part of the Macy Service Area, where distribution pipes are only two to three inches in diameter, is the largest area of deficient pressure. The southeast corner of the system experiences deficient pressures due to its elevation and its distance from the storage tank.

Village of Pender

Overview
The Village of Pender, located in the western half of the Reservation, is home to approximately 1,148 people. Potable water is supplied by three wells with a total combined pumping capacity of 780 gpm. In addition to providing water to Pender, the Village provides water to the Thurston County Rural Water District under a contractual agreement. Pender's water storage capacity of 555,000 gallons is provided by three structures. The initial water system was installed in 1932 with an elevated steel water tower and some distribution lines. Since 1955, the pumped groundwater has been disinfected with sodium hypochlorite at each well house before distribution to storage. Fire protection is provided by fire hydrants on the Village's water distribution system. An assessment of the age and condition of the entire Pender water system was beyond the scope of this study as was identifying any impacts to the water system associated with changes in the demands of the Thurston County Rural Water District.

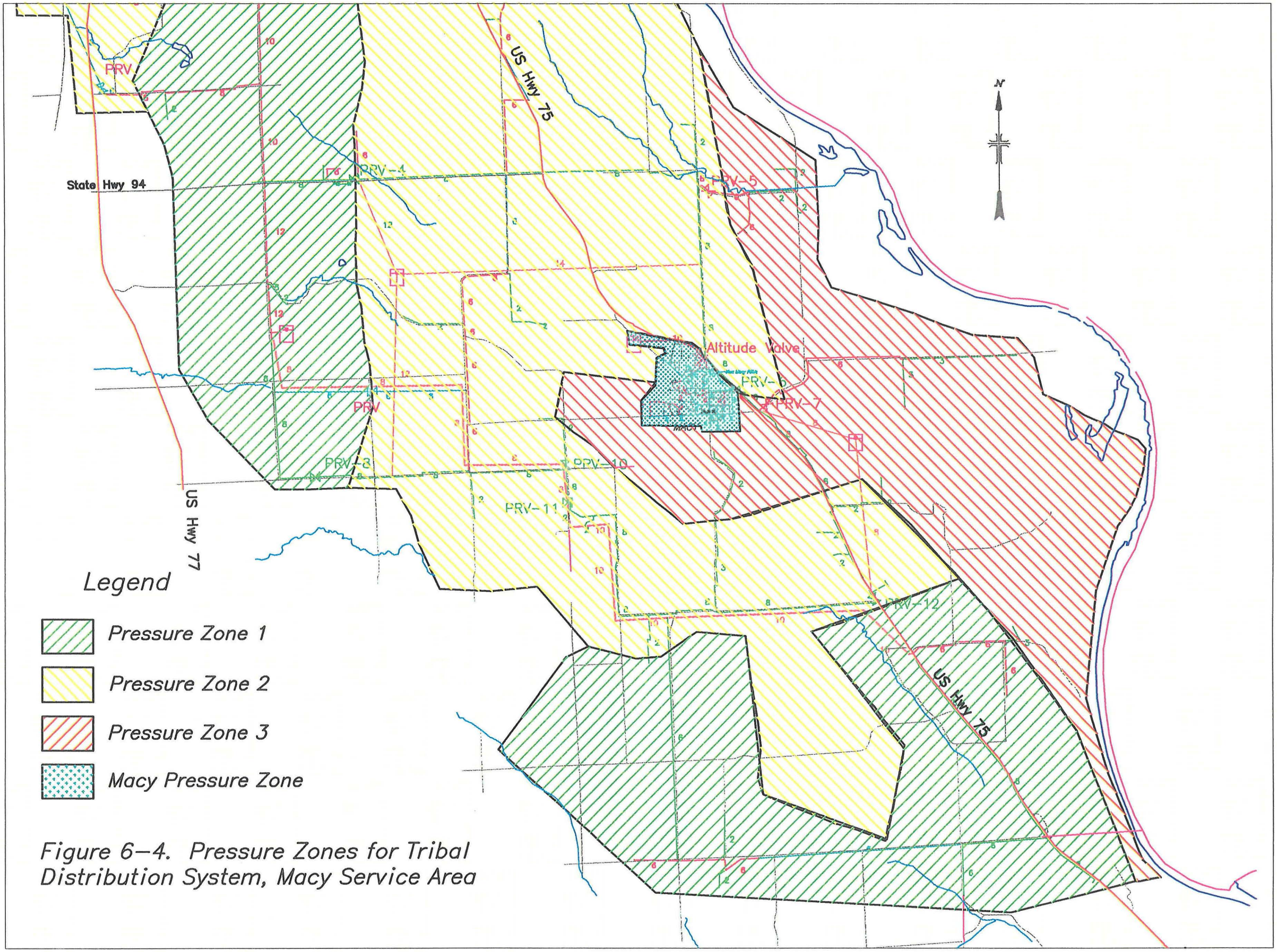


Figure 6–4. Pressure Zones for Tribal Distribution System, Macy Service Area

The Village of Pender's potable water services are provided through the Utility Department, which reports to City Council. This department also is responsible for the Village's electric power, solid waste, police, and water services. The Utility Department Superintendent, Mr. Robert Fendrick, has seven full time staff and two to three part time employees. Engineering services are provided by the firm of Johnson, Erickson, and O'Brien Engineering (JEO) of Wahoo, Nebraska. A water conservation program has not been established in Pender.

Water Quality and Treatment

Raw and treated water quality of the Pender system are shown in Table 6-10. As indicated, all water quality values meet both primary and secondary MCLs established by the U.S. EPA. Current water treatment consists of disinfection using liquid sodium hypochlorite at each well house.

Table 6-10. Village of Pender Raw and Treated Water Quality
(-- , no data or not applicable)

Parameter	Well[1] (units mg/L unless otherwise noted)	Treated Water[2] (units mg/L unless otherwise noted)	MCL (units mg/L unless otherwise noted)
Total Arsenic	0.002 - 0.032	0.03[3]	0.05[4]
Total Barium	0.185 - 1.24	0.195	2
Total Cadmium	Nondetect	Nondetect	0.005
Total Chromium	0.001 - 0.003	0.002	0.1
Fluoride	--	0.26 - 0.34	4.0
Total Mercury	Nondetect	--	0.002
Nitrate Nitrogen	--	8.2 - 9.4	10
Total Selenium	Nondetect - 0.016	0.016	0.051
Sulfate	24 - 60	24 - 60	250 (SMCL)
Total Coliform	Nondetect	Nondetect	No more than one sample may be coliform positive
Total Dissolved Solids	490	--	500 (SMCL)
Gross Alpha	7.4 - 9.4 pCi/L	7.4 - 9.4 pCi/L	15 pCi/L
Volatile and Semi-Volatile Organics, Pesticides and Herbicides	--	Nondetect	--

1. Values from 1996 and 1997 water chemistry data for Pender, Nebraska, except as noted.
2. Values from Pender treated water chemical results provided by the Nebraska Division of Public Health, 1997.
3. In May 1995 and April 1997, the State of Nebraska Department of Health Laboratory reported arsenic levels of 33 and 32 µg/L, respectively.
4. Effective at time of reporting.

Subsequent to data reported in Table 6-10, total coliform samples tested positive in July, August, and November of 1998; July of 1999; and March and July of 2000 (State of Nebraska, Environmental Quality Group, C. Mitchell). Additionally, the upper range of nitrate values reported in Table 6-10 (9.4 mg/L) approached the nitrate MCL of 10 mg/L.

In May 1995 and April 1997, the State of Nebraska Department of Health Laboratory reported arsenic levels of 33 and 32 µg/L, respectively, in the village potable water. The FinalRule to 40 CFR Part 9, 141 and 142, National Primary Drinking Water Regulations regarding arsenic, dated January 22, 2001, lowered the arsenic standard from 50 µg/L to 10 µg/L for community water systems (public water systems serving at least 15 locations or 25 residents regularly, year round). The rule became effective on February 22, 2002. Community water systems serving 25 to 10,000 persons, such as Pender's, must meet this standard by January 2006.

Based on these findings, the existing water treatment system provides safe drinking water and no additional treatment is needed at this time. However, monitoring for all Safe Drinking Water Act contaminants is recommended. Special attention is urged for total coliform, nitrate, and arsenic, in light of past violations of these Primary Drinking Water Act constituents. By Year 2006, the arsenic standard of 10 part per billion (ppb) may warrant a water treatment process such as chemical precipitation with ferric sulfate to conform village water to the new standard. Should nitrate in the groundwater continue to rise, Pender may need to consider blending with better quality water if available, or implementing a nitrate removal process, such as ion exchange or reverse osmosis, to meet required standards. Chapter 7 describes treatment options for Pender.

Production Capacity

Three groundwater wells with capacities of 210, 225, and 345 gpm supply Pender with a combined pumping capacity of 780 gpm. Well water is drawn from the alluvial aquifer adjacent to Logan Creek (Reclamation, M. Phillips). To determine if additional raw water wells are required, Tables 6-11 and 6-12 compare current and future Pender water system demands to the production criteria listed on Page 6-7.

Table 6-11. Village of Pender: Assessment of Average Day Demand Production Rate with the Largest Well (345 gpm) Out of Service

(Units in gallons per day)

Year	Average Day Demand	Available from 210 & 225 gpm Wells	Additional Capacity Required
2000	172,200	626,400	none
2020	172,200	626,400	none
2040	172,200	626,400	none

Table 6-12. Village of Pender: Assessment of Maximum Day Demand Production Rate with All Wells Operational
(Units in gallons per day)

Year	Maximum Day Demand	Available from Three Wells	Additional Capacity Required
2000	344,400	1,123,200	none
2020	344,400	1,123,200	none
2040	344,400	1,123,200	none

As shown, no additional raw water pumping capacity is needed in the Pender system through Year 2040 for either average day or peak day demands.

Storage Capacity
The Village of Pender has 555,000 gallons of storage capacity distributed as follows:
- A 100,000 gallon above ground, concrete reservoir built in 1900 - referred to as North Reservoir,
- A 400,000 gallon above ground, concrete reservoir built in 1977 - referred to as South Reservoir, and
- A 55,000 gallon elevated steel water tower built in 1932.

Table 6-13 summarizes existing and future (Years 2000, 2020, and 2040) storage capacity required for equalization, fire flow, and emergency storage capacity.

Table 6-13. Village of Pender: Assessment of Storage Capacity
(Units in gallons)

Year	Equalization Storage	Fire flow Storage	Emergency Storage	Total Required[1]	Additional Required[2]
2000	43,768	180,000	516,600	560,368	5,368
2020	43,768	180,000	516,600	560,368	5,368
2040	43,768	180,000	516,600	560,368	5,368

[1] Sum of equalization and larger of fire flow or emergency storage.
[2] Total required minus the 555,000 gallons of existing storage capacity.

As indicated above, additional storage capacity of 5,368 gallons is required to meet Year 2000, 2020, and 2040 demands. Since this value is less than 1 percent of the total current storage, no change is needed unless replacement of the current tank is required.

Current Water System Performance

Pender is not experiencing any critical problems with either the water treatment or water storage systems. Water storage tanks are drained and inspected at five year intervals under a regular inspection program. From a Bureau of Reclamation site inspection in August 2000, installation of new controls and a chlorinator was planned for the water distribution and treatment system.

Village of Walthill

Overview

Located near the center of the Reservation, the Village of Walthill is home to approximately 1,018 people. Water pumped from the Dakota aquifer is supplied to approximately 350 water service connections by two wells. The Village has one water storage standpipe with a capacity of 250,000 gallons. Water is treated at a 400 gpm filtration plant. Fire protection is provided by fire hydrants on the Village's water distribution system.

Walthill's water supply services are administered by the Village's Utility Department with Mr. Terry Tipton, Utility Superintendent. The firm of Johnson, Erickson, and O'Brien Engineering has been retained for engineering services.

Water Quality and Treatment

A complete water quality analysis was not available to assess the efficacy of the Walthill water treatment system. However, similar to the tribal system, Walthill utilizes groundwater from the Dakota aquifer. It is reasonable to assume that raw water quality of the Walthill system is akin to the USGS groundwater quality data shown in Table 6-4. As such, raw water meets all primary drinking water standards. With regard to secondary standards, the water is very hard (448 mg/L as $CaCO_3$, reference Table 6-5); iron and manganese concentrations of 1.2 and 0.17 mg/L exceed their respective SMCLs of 0.3 and 0.05 mg/L; and the TDS of 649 mg/L exceeds the SMCL of 500 mg/L. Water treated at the 400 gpm filtration plant is followed by chlorination for disinfection.

Although secondary contaminant constituents are not considered deleterious to human health, high concentrations of hardness consume more soap; iron gives water a medicinal or metallic taste and causes staining problems in laundry and plumbing fixtures; manganese causes black stains on clothing and can clog pipes if it precipitates; and TDS greater than 500 mg/L may cause taste and odor problems and deteriorate or cause mineral precipitation in plumbing and appliances. It is recommended, therefore, that raw water be treated to meet SMCL criteria. Treatment options are offered in Chapter 7.

Production Capacity

Walthill has a total production capacity of 550 gpm delivered by two metered groundwater wells rated at 200 and 350 gpm. To determine if additional supply wells are required, Tables 6-14 and 6-15 apply production criteria listed on Page 6-7 to current and future water system demands for Years 2000, 2020, and 2040.

Table 6-14. Village of Walthill: Assessment of Average Day Demand Production Rate with the Largest (350 gpm) Well Out of Service

(Units in gallons per day)

Year	Average Day Demand	Available from 200 gpm Well	Additional Capacity Required
2000	152,700	288,000	none
2020	223,500	288,000	none
2040	327,300	288,000	39,300

Table 6-15. Village of Walthill: Assessment of Maximum Day Demand Production Rate with Both 200 and 350 gpm Wells Operational

(units in gallons per day)

Year	Maximum Day Demand	Available from Both Wells	Additional Capacity Required
2000	305,400	792,000	none
2020	447,000	792,000	none
2040	654,600	792,000	none

As indicated, the existing raw water pumping system has sufficient capacity to meet current and Year 2020 demands. However, an additional raw water pumping capacity of 39,300 gallons per day (gpd) is required in Year 2040 to satisfy average day demand production criteria with the largest well out of service.

Storage Capacity

Walthill has 250,000 gallons of existing storage capacity in a welded, steel standpipe constructed in 1977. A maintenance program is in place to drain and inspect the water storage tank every three years. Table 6-16 summarizes current and future storage capacity required for equalization, fire flow, and emergency storage for the Years 2000, 2020, and 2040.

Table 6-16. Village of Walthill: Assessment of Storage Capacity
(Units in gallons)

Year	Equalization Storage	Fire flow Storage	Emergency Storage	Total Required[1]	Additional Required[2]
2000	38,811	180,000	458,100	496,911	246,911
2020	56,806	180,000	670,500	727,306	477,306
2040	83,189	180,000	981,900	1,065,089	815,089

[1] Sum of equalization and larger of fire flow or emergency storage.
[2] Total required minus the 250,000 gallons of existing storage capacity. Additional storage requirements do not include prior year capacity.

As indicated in Table 6-16, additional capacity of approximately 246,900, 477,300, and 815,100 gallons is required to meet Year 2000, 2020, and 2040 storage capacity requirements, respectively.

Current Water System Performance
There are currently 350 metered water service connections to the system. The water distribution system contains one booster pump station and one pressure reducing valve. According to Mr. Terry Tipton, the water system operator, current water use ranges from an average of 120,000 gallons per day in the winter to 200,000 gallons per day in the summer when some ball fields are irrigated. At present, there are no perceived problems with the water quality, although, Mr. Tipton indicates that iron in the water caused one of the filter tanks to corrode after 13 years of use and residents have indicated that water pressure and water quality problems have adversely affected their home water heaters.

Village of Rosalie

Overview
The Village of Rosalie is located in the south central part of the Reservation. Potable water is supplied to approximately 60 homes (about 194 people) from two wells drawing water from the Dakota aquifer. Water storage is provided by a 50,000 gallon elevated steel tank installed in 1912. Most residents have in-home water softeners. There is no centralized water treatment. Residents are charged a flat fee for water usage. Homes are not individually metered. Fire protection is provided by fire hydrants on the Village's water distribution system. According to Mayor Christine Baker (August 2000), Rosalie has two part time operators certified in water and wastewater operation.

Water Quality and Treatment
Like Macy and Walthill, Rosalie draws its source water from the Dakota aquifer. As such, the raw water quality of the Rosalie system is most likely similar to the water quality shown in

Table 6-4. Excessive hardness and high levels of iron, manganese and TDS, impart undesirable use and aesthetic characteristics to the water. As learned during an on-site visit in September 1999, most residents provide in-home treatment as the Village has no centralized water treatment system. As indicated by U.S. EPA, total coliform exceeded the MCL in December 1992, October 1994, November 1995, and October 2000 in delivered water. Options for providing better water quality to Rosalie are provided in Chapter 7.

Production Capacity

Wells of 154 and 170 gpm provide Rosalie with a combined pumping capacity of 324 gpm. To determine if additional raw water wells are required, production criteria listed on Page 6-7 were applied to Year 2000, 2020, and 2040 water system demands. Findings are shown in Tables 6-17 and 6-18.

Table 6-17. Village of Roslie: Assessment of Average Day Demand Production Rate with the Largest (170 gpm) Well Out of Service

(Units in gallons per day)

Year	Average Day Demand	Available from 154 gpm Well	Additional Capacity Required
2000	29,100	221,760	none
2020	35,400	221,760	none
2040	42,900	221,760	none

Table 6-18. Village of Rosalie: Assessment of Maximum Day Demand Production Rate with Both 154 and 170 gpm Wells Operational

(Units in gallons per day)

Year	Maximum Day Demand	Available from Both Wells	Additional Capacity Required
2000	58,200	466,560	none
2020	70,800	466,560	none
2040	85,800	466,560	none

As indicated in these tables, no additional production capacity is needed to meet average day or peak day demands through Year 2040.

Storage Capacity

Rosalie has 50,000 gallons of storage capacity in one elevated steel tank. Table 6-19 summarizes current and future storage capacity required for equalization, fire flow, and emergency storage for Years 2000, 2020, and 2040.

Table 6-19. Village of Rosalie: Assessment of Storage Capacity

(Units in gallons)

Year	Equalization Storage	Fire flow Storage	Emergency Storage	Total Required[1]	Additional Required[2]
2000	7,396	180,000	87,300	187,396	137,396
2020	8,998	180,000	106,200	188,998	138,998
2040	10,904	180,000	128,700	190,904	140,904

[1] Sum of equalization and larger of fire flow or emergency storage.

[2] Total required minus the 50,000 gallons of existing storage capacity. Additional storage requirements do not include prior year capacity.

As indicated in Table 6-19, additional storage of approximately 137,400, 139,000, and 141,000 gallons is required to meet Year 2000, 2020, and 2040 demands, respectively. Since the additional storage requirement is primarily due to fire flow, regardless of the year viewed, any new, additional storage should be sized to the Year 2040 requirement.

Current Water System Performance

Rosalie has had some difficulty meeting the coliform bacteria standard. As indicated, treated water quality data provided by the U.S. EPA revealed that total coliform was found to exceed the MCL in December 1992, October 1994, November 1995, and October 2000. Most homes have water softeners installed to reduce hardness. Whether or not individual homeowners are providing the required maintenance for these small treatment units was not investigated for this study. The existing water storage tank was relined with epoxy paint in 1999. The valves of the water storage tank are leaking and need to be replaced. Exterior painting is also needed for protection. The water distribution system is experiencing leakage from aging galvanized pipe installed in 1912 (Superintendent, Village of Rosalie, H. Sawyer).

Summary Assessment

A summary assessment of community water systems operating within the Reservation is shown in Table 6-20 below.

Table 6-20. Summary Assessment of Existing Community Potable Water Systems

System	Water Quality	Production	Storage[1]
Tribal, Village of Macy Service Area	Raw water exceeds SMCL for Fe, Mn, and TDS and is also very hard. Will require oxidation treatment to remove Fe and Mn, and lime softening for hardness removal. Blending is recommended over reverse osmosis system to lower TDS to meet Secondary Maximum Contaminant Levels.	Current raw water production satisfies demand criteria. Additional capacity is required by Year 2020 (292 gpm) and by Year 2040 (1,256 gpm), assumed to be satisfied with four 350 gpm well pumps.	Current storage is 450,000 gallons. Current storage deficit is 1.1 million gallons. For Year 2020, additional storage capacity of 2.5 million gallons will be needed as follows: 447,200 gallons for Zone 1(treatment plant site); 46,600 gallons for the Village of Macy; 1,662,600 gallons for Zone 2; and 298,600 gallons for Zone 3. For Year 2040, additional storage capacity of 4.6 million gallons will be needed as follows: 931,300 gallons for Zone 1(treatment plant site); 108,900 gallons for the Village of Macy; 3,010,000 gallons for Zone 2; and 540,200 gallons for Zone 3.
Pender	Treated water has good quality; borderline TDS. Arsenic levels in excess of 30 µg/L have occurred in the groundwater. Arsenic Rule imposes 10 µg/L limit in 2006. Total coliform tested positive several times in the past.	The 210, 225, and 345 gpm wells provide sufficient capacity to meet current and Year 2040 demands	Additional storage capacity of about 5,400 will be required in Years 2000, 2020, and 2040. This value is less than 1% of current total storage; no changes recommended unless replacement of current tanks required.
Walthill	Raw water exceeds SMCL for Fe, Mn, and TDS and is also very hard. Will require oxidation treatment to remove Fe and Mn, and lime softening for hardness removal. Blending is recommended over reverse osmosis system to lower TDS to meet Secondary Maximum Contaminant Levels.	Some residents complain about low pressure. The 200 and 350 gpm wells meet the current demand. In Year 2040, additional production capacity of 30 gpm will be required to meet average day demand production rate with the largest well out of service.	Additional storage capacity of about 247,000, 477,300, and 815,100 gallons is required in Years 2000, 2020, and 2040, respectively.
Rosalie	Raw water exceeds SMCL for Fe, Mn, and TDS and is also very hard. Will require oxidation treatment to remove Fe and Mn, and lime softening for hardness removal. Blending is recommended over reverse osmosis system to lower TDS to meet Secondary Maximum Contaminant Levels.	The 154 and 170 gpm wells provide sufficient capacity to meet current and Year 2040 demands	Additional storage capacity of about 137,400, 139,000, and 141,000 gallons is required in Years 2000, 2020, and 2040, respectively.

[1] Additional storage requirements do not include prior year capacity.

Distribution lines throughout each community will need to be replaced or extended to accommodate future growth. Cost estimates presented in Chapter 7 for wells and storage are based on the deficiencies noted in Table 6-20. Costs for expanded water distribution lines are based on estimates for additional piping to accommodate population growth.

Chapter Seven - Conceptual Design Plans for Villages to Meet Long Term Water Supply and Treatment System Needs

This chapter provides water supply and treatment system conceptual design plans that illustrate the type of facility enhancements each Reservation community would need to meet Year 2040 projected service demands. Appraisal or sub-appraisal level cost estimates are provided for major system components. At the onset of the chapter, background information is provided on water treatment technologies particularly applicable to source water constituents on the Reservation.

Water Treatment Technologies

Several water treatment technologies are available to address water quality problems associated with hardness, iron, manganese, TDS, nitrate, arsenic and total coliform bacteria as they occur in village systems. The choice of a treatment technology will depend to large degree on the raw water quality and the desired level of finished water quality. Removal of the primary drinking water contaminants -nitrate, arsenic, and coliform bacteria- from these systems is necessary to protect public health and welfare.

Options to meet primary drinking water constituent standards include:

- Blending system water with water of better quality,
- Utilizing a new, improved water source,
- Treatment to reduce contaminant concentrations such as ion exchange for nitrate; co-precipitation for arsenic; and disinfection for total coliform.

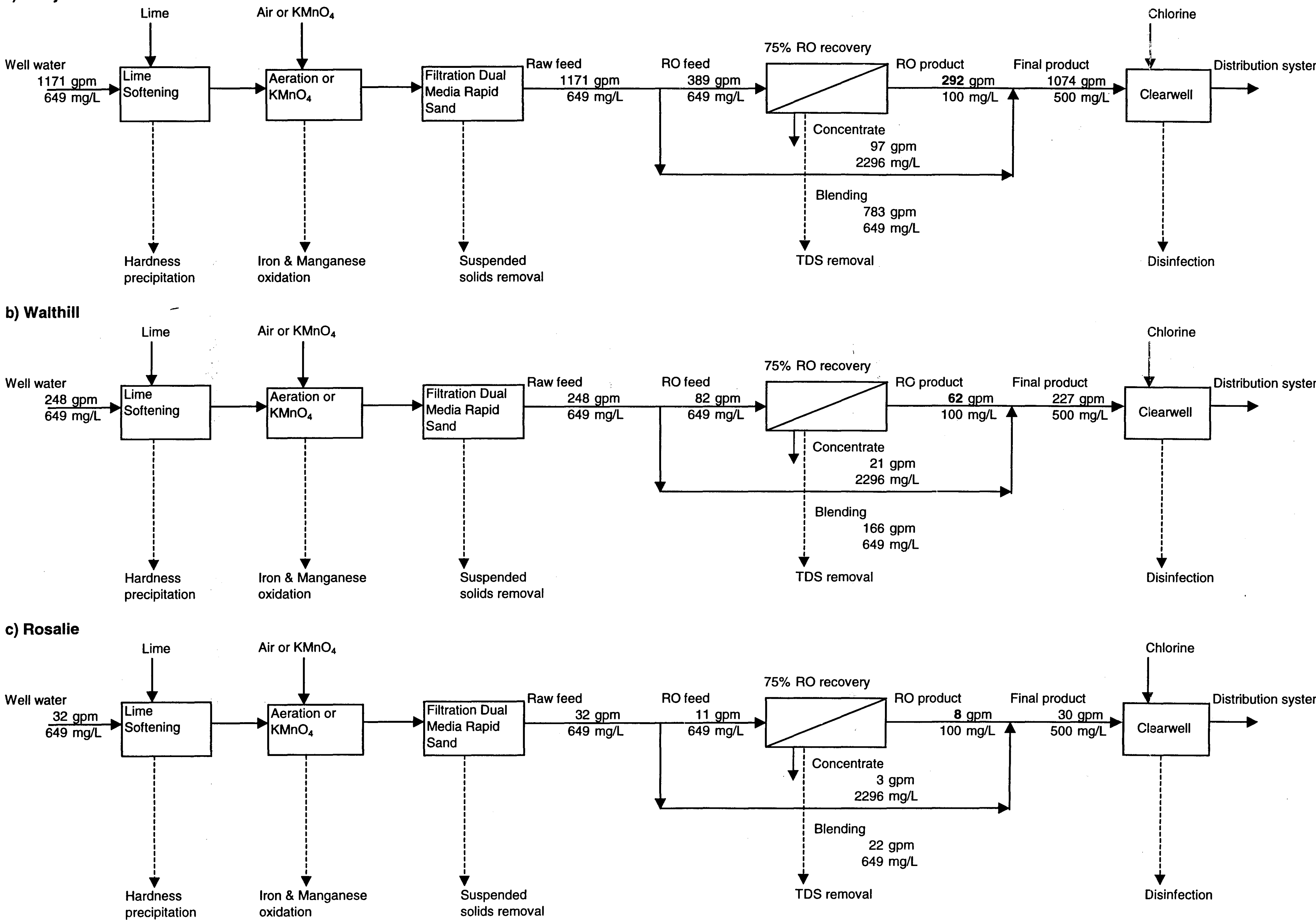
Water blending would be the cheapest and least complex option. It would involve, however, finding an alternate water source of better water quality, either surface or groundwater. Short of this, the required level of treatment would have to be defined and treatment processes selected to attain the desired level of treatment.

A possible process train to reduce all secondary contaminants to below SMCLs would involve hardness removal by lime softening, and iron and manganese removal by aeration and/or chemical precipitation followed by filtration. This pre-treated water would then be blended with water treated by reverse osmosis (RO) to achieve a final TDS of no greater than 500 mg/L. Disinfection and pH neutralization could be done to further polish the water. Figure 7-1 presents a schematic of this treatment scenario for average day flows. Water treatment fact sheets for the removal of all contaminants of concern associated with Reservation communities are provided in Appendix B. Discussion of additional treatment options for Year 2040 is found on Page 7-3.

Membrane processes such as reverse osmosis or nanofiltration may also be used to remove most contaminants. However, these processes are expensive, require skilled operators, and have a high level of maintenance. Cost estimates are based on maximum day flows (two times average day flow) but do not include these more advanced treatment processes.

Figure 7-1. Year 2040 Average Day Flow Treatment Schematics, Tribal System-Macy Service Area, Villages of Walthill and Rosalie

a) Macy



Note:
gpm - gallons per minute
mg/L - milligrams per liter
$KMnO_4$ - Potasium permanganate
RO - Reverse Osmosis
Flow based on average day demands

Bureau of Reclamation February 2002

Because of their widespread use and overall applicability to the village systems, a brief discussion of the ion exchange and chemical precipitation processes is presented below. A general discussion of alternative technologies is presented in the fact sheets appearing in Appendix B.

Ion Exchange - Ion exchange is a reversible chemical process in which ions form an insoluble, permanent, solid resin bed are exchanged for different ions in the feed water. The process relies on the fact that water solutions must be electrically neutral, therefore ions in the resin bed are exchanged with ions of similar charge in the water. In the case of NO_3^-, operation begins with a fully recharged resin bed, having enough Cl^- or OH^- ions to carry out the anion exchange. Typically, polymer resin bed is composed of millions of medium sand grain size, spherical beads. As water passes through the resin bed, the Cl^- or OH^- anions are released into the water, being substituted or replaced with NO_3^- anions (ion exchange). When the resin becomes exhausted of Cl^- or OH^- ions, the bed must be regenerated by passing a strong, usually NaCl (or KCl), solution over the resin bed, displacing the NO_3^- ions with Cl^- ions. Current resins are not completely NO_3^- selective and may remove other anions, such as SO_4^{-2}, before removing the nitrate compounds. Therefore, NO_3^- ion exchange requires careful consideration of the complete raw water characteristics. Typically, NO_3^- ion exchange utilizes a Cl^- or OH^- strongly basic anion resin bed.

Co-precipitation - Co-precipitation provides for the removal of soluble metal ions, such as arsenic, during ferric sulfate coagulation, alum coagulation, or lime softening. There are four types of co-precipitation:

1) *Inclusion* - involves mechanical entrapment of a portion of the solution surrounding the growing particle. Inclusion co-precipitation is significant only for large particles.
2) *Adsorption* - involves the attachment of an impurity to the surface of a particle of precipitate. This process is significant for the removal of small particles.
3) *Occlusion* - involves a contaminant entrapped in the interior of a particle of precipitate. The particles grow larger to enclose the adsorbed contaminant.
4) *Solid-solution formation* - involves a particle of precipitate becoming contaminated with a different type of particle that precipitates under similar conditions and is formed from ions whose size is about equal to those of the ions of the original precipitate.

The Village of Pender could utilize ion exchange to keep nitrate under the 10 mg/L MCL. Co-precipitation with ferric sulfate could be used to conform arsenic to the proposed arsenic rule if compliance was required. If high levels of both arsenic and nitrate were a problem in the Pender system, reverse osmosis could be used to reduce these contaminants.

Another option available to small communities, such as Rosalie, are in-home treatment units. Home filters which remove hardness, iron, and manganese are readily available. Home filters for the removal of TDS are not as readily available, are more costly, and maintenance rests with the homeowner.

Year 2040 Production Requirements

The Tribal system serving the Village of Macy area will require approximately 1,256 gpm of additional pumping capacity to meet the Year 2040 maximum day demand production rate with all the wells operational. The Village of Walthill will require 30 gpm of additional capacity to meet the Year 2040 average day demand production rate with the largest well out of service. The Villages of Pender and Rosalie both have sufficient production capacity to meet water supply demands through Year 2040. Since well flows for Pender and Rosalie exceed maximum day flow for water treatment purposes, adjustment of well flows will be necessary to match treatment capacity requirements.

Likely alternatives to increase system production are to add additional well(s) or increase production from existing wells. For purposes of this report, cost estimates are based on installation of new wells. For the Macy area system, four 300-feet deep wells with 8-inch casings would be needed. It is assumed they would be equipped with 350 gpm, 350-foot total dynamic head well pumps. Walthill would need one 100-foot deep well with 4-inch casing most likely equipped with a 30 gpm pump. Construction cost estimates include well houses for flow metering, well installation, pump controls, and protection for electrical components associated with well pumps. Although not addressed in this report, installation of a properly conceived water conservation program could effectively offset some of the forecast water demand. It is an item that would need to be evaluated in any future water planning effort.

Year 2040 Storage and Distribution Needs

All municipal storage and water distribution systems on the Reservation will need to be expanded to meet Year 2040 demands. Storage volumes required by Year 2040 for the Villages were developed in Chapter 6. Buried concrete and elevated steel storage tanks were used for cost estimating purposes.

The future size of water distribution systems was estimated by extrapolating system size to anticipated population growth. As such, each Village's existing land area, housing and population density, and extent of current water distribution service were increased proportionately by a population growth factor. For example, if Rosalie's projected population growth to Year 2040 was 1.5, the Year 2000 water distribution system capacities would be increased by this same factor.

Construction Costs to Meet Year 2040 Demands

This section provides water supply and treatment system conceptual design plans that illustrate the type of facility enhancements each Reservation community would need to implement to meet Year 2040 projected service demands. Cost estimates (at appraisal or sub-appraisal level, depending on the amount of information available) are provided for major system components needed to accomplish these changes. At this level of study, these estimates are accurate to ±40% and are useful for only general planning purposes. Therefore, they were not and should not be applied on a per capita or individual household basis. Underlying assumptions used to formulate the estimates would have to be further refined to obtain greater accuracy.

Specific quantity estimate worksheets are detailed in Appendix C. The unit prices were obtained from the Means Cost Estimating Handbooks, historical data obtained from projects previously bid, vendor quotes, and estimator judgement. In some instances, crew and production rates needed to be established to develop unit prices.

A line item for unlisted items of 15% was added to each feature to account for small, unidentified items. The line item listed as "Contract Cost" is the amount that this feature is anticipated to cost at time of bid and award.

A line item for contingencies of 25% was added to each feature to account for unanticipated changes that might occur after award. Contingencies are defined as those items that may increase costs of the project after award. Examples of changes after award are differing site conditions or delays due to weather. The line item listed as "Field Cost" is the amount that this feature is anticipated to cost after all construction has been completed on this feature including changes.

A 30% non-contract cost allowance has been added for project costs associated with design data collection, design, contract administration, and construction management. The cost estimate does not include operation and maintenance costs.

Tribal System, Village of Macy Service Area

The Macy Service Area distribution system was analyzed and modified using the Haestad hydraulic software referenced in Chapter 6. The model design splits the system into four pressure zones as discussed in Chapter 6 and illustrated in Figure 6-4. The system would be served by four new tanks as shown in Table 7-1. Figure 7-2 shows pipeline layout for Year 2040. Pipe lengths needed for the Year 2040 system array are shown in Table 7-2. The system is detailed in the Reclamation report presented in Appendix A.

Table 7-1. Tank Construction for the Year 2040 Distribution System

Tank	Additional Volume Provided[1] (Gallons)	Maximum Water Surface Elevation (ft)	Height of Tank (ft)	Diameter (ft)	Height Above the Ground (ft)
Treatment Plant (Zone 1)	939,000	1,549	30	73	55
Zone 2 Tank	3,000,000	1,450	30	131	20
Zone 3 Tank	553,000	1,339	30	56	59
Macy Tank	110,000	1,336	30	25	56

1. This volume is the volume to be provided in addition to any existing tanks.

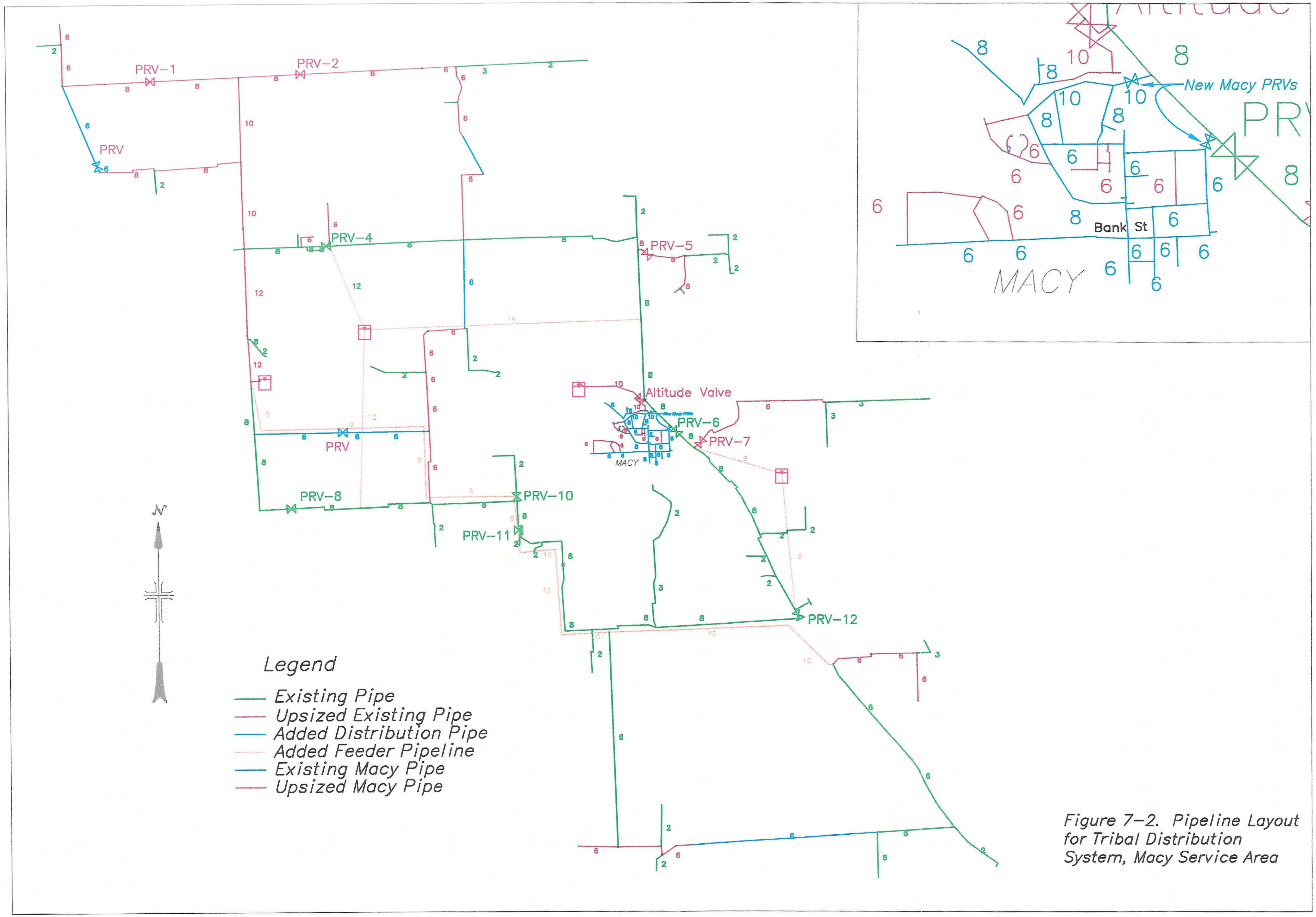


Figure 7–2. Pipeline Layout for Tribal Distribution System, Macy Service Area

Table 7-2. Pipe Lengths Needed for Year 2040 Distribution System

Pipe Size (inches)	Length (feet)
6	119,000
8	70,000
10	79,000
12	8,000
14	17,000
Total	309,000

Modifications to the existing tribal system used for cost estimating purposes are as follows:

- Adding a 1,171 gpm (nominal, average day rate) water treatment plant for iron, manganese, and hardness removal,
- Adding two new tanks to serve pressure Zones 2 and 3,
- Adding additional tanks at the water treatment plant and for the Carl T. Curtis Health EducationCenter,
- Upsizing pipes as necessary for adequate pressure,
- Adding parallel piping to isolated high points from the treatment plant,
- Upsizing any pipe in the Village of Macy that is less than 6-inches to 6-inches,
- Adding connecting loops along roads where reasonable (all added pipe 6-inches or greater),
- Adding pressure reducing valves to the new looping pipelines where they cross pressure zone boundaries,
- Up-sizing many of the 6-inch and smaller branch pipelines to at least 6-inches, and
- Adding fire hydrants to any new or upsized 6-inch or greater pipe.

The large projected increase in Year 2040 demand could be met by increasing pipe sizes and adding four storage tanks. Adequate system performance for all conditions of flow and demand (including fire demand), however, could not be obtained. Further model development would be warranted at a more detailed level of study.

A construction cost estimate for configuring the entire Macy area system to meet Year 2040 water needs is presented in Table 7-3 on the following page.

Table 7-3. Cost Estimate to Conform the Macy Area System to Year 2040 Needs

Item	Cost
Wells	$120,000
Water treatment	$1,084,500
Distribution system	$10,615,740
Storage	$5,550,000
Mobilization	$870,000
Unlisted items	$2,759,760
***CONTRACT COST** (Subtotal of items above)*	***$21,000,000***
Contingencies	$5,000,000
***FIELD COST** (Subtotal of Contract Cost plus Contingencies)*	***$26,000,000***
Non Contract Cost	$8,000,000
CONSTRUCTION COST	***$34,000,000***

The total construction cost to upgrade the water system is 34 million dollars. Water treatment is based on the maximum day flow rate of 2,150 gallons per minute for aeration, chemical feed systems, filtration, and disinfection using chlorine.

Village of Pender

Assuming water quality trends persist, a new water treatment system will be required for arsenic and nitrate removal. The following facilities factored into estimating construction costs to conform the Pender system to meet Year 2040 water needs:

- An arsenic removal system incorporating ferric sulfate addition, filtration, pumping, chlorine disinfection, and sludge disposal lagoons sized for a maximum day rate of 118 gpm (nominal, average day rate),
- A 118 gpm (nominal, average day rate) ion exchange system for nitrate removal.

Cost estimates are shown in Table 7-4 on the following page.

Table 7-4. Cost Estimate to Conform the Pender System to Year 2040 Needs

Item	Cost
Water treatment	$479,000
Distribution system	$0
Storage	$0
Mobilization	$24,000
Unlisted items	$77,000
CONTRACT COST *(Subtotal of items above)*	***$580,000***
Contingencies	$140,000
FIELD COST *(Subtotal of Contract Cost plus Contingencies)*	***$720,000***
Non Contract Cost	$220,000
CONSTRUCTION COST	***$940,000***

The total construction cost to upgrade the water system is 940,000 thousand dollars. Water treatment is based on the maximum day flow rate of 239 gpm for aeration, chemical feed systems (coagulant and chlorine), filtration, and nitrate removal by ion exchange.

Village of Walthill

The following facilities factored into estimating construction costs to conform the Walthill system to meet Year 2040 water needs:

- A 250 gpm (nominal, average day rate) water treatment plant for iron and manganese removal,
- One 815,000 gallon ground concrete tank for additional storage capacity,
- About 15,180 feet of 12-inch water main and 47,000 feet of 6-inch water main for renovation of the water distribution system, and
- A 30 gpm well.

Cost estimates are shown in Table 7-5 on the following page.

Table 7-5. Cost Estimate to Conform the Walthill System to Year 2040 Needs

Item	Cost
Wells	$34,800
Water treatment	$303,800
Distribution system	$1,419,480
Storage	$500,000
Mobilization	$115,000
Unlisted items	$326,920
CONTRACT COST *(Subtotal of items above)*	***$2,700,000***
Contingencies	$700,000
FIELD COST *(Subtotal of Contract Cost plus Contingencies)*	***$3,400,000***
Non Contract Cost	$1,000,000
CONSTRUCTION COST	***$4,400,000***

The total construction cost to upgrade the water system is 4.4 million dollars. Water treatment is based on a maximum day flow rate of 460 gpm for aeration, chemical feed systems, filtration, and disinfection using chlorine.

Village of Rosalie

The following facilities factored into estimating construction costs to conform the Rosalie system to meet Year 2040 water needs:

- A 32 gpm (nominal, average day rate) water treatment plant for iron, manganese, and hardness removal,
- One 141,000 gallon elevated steel tank for additional storage capacity, and
- About 3,000 feet of 12-inch water main and 22,000 feet of 6-inch water main for renovation of the water distribution system.

Cost estimates are shown in Table 7-6 on the following page.

Table 7-6. Cost Estimate to Conform the Rosalie System to Year 2040 Needs

Item	Cost
Water treatment	$113,000
Distribution system	$323,845
Storage	$250,000
Mobilization	$34,000
Unlisted items	$109,155
***CONTRACT COST** (Subtotal of items above)*	***$830,000***
Contingencies	$220,000
***FIELD COST** (Subtotal of Contract Cost plus Contingencies)*	***$1,050,000***
Non Contract Cost	$300,000
CONSTRUCTION COST	***$1,350,000***

The total construction cost to upgrade the Rosalie water system to Year 2040 is 1.35 million dollars. Water treatment is based on a maximum day flow rate of 60 gpm for aeration, chemical feed systems, filtration, and disinfection using chlorine.

Summary of Costs to Upgrade Municipal Systems

A summary of construction cost estimates to meet the projected Year 2040 water system improvements for the Macy Service Area and the Villages of Pender, Walthill, and Rosalie are shown in Table 7-7 below.

Table 7-7. Cost Summary to Upgrade Water Supply Systems

System	Construction Cost
Tribal System, Village of Macy Service Area	$34,000,000
Village of Pender	$ 940,000
Village of Walthill	$ 4,400,000
Village of Rosalie	$ 1,350,000

Chapter Eight - Wastewater Systems on the Reservation

This chapter offers a technical review of the physical infrastructure of municipal wastewater collection and treatment systems on the Reservation. By way of introduction, regulations pertinent to wastewater disposal and key aspects of wastewater collection and treatment are briefly described.

Background

Regulatory Climate and Operator Certification

The Clean Water Act, 40 CFR 110-140, was passed by Congress to restore and protect the integrity of surface waters of the United States by preventing or controlling pollution with the ultimate goal of making all surface waters useable for fishing and swimming. Wastewater treatment plants are allowed to discharge to rivers, streams, and other natural watercourses if a discharge permit is obtained from a state or federal regulatory agency.

In Nebraska, there is pending litigation between the State Department of Environmental Quality (DEQ) and the U.S Environmental Protection Agency over the jurisdiction of wastewater compliance for tribal villages. The jurisdictional indecision between these agencies has resulted in delayed discharge permit issuance [U.S. EPA Region VII, Tribal NPDES (National Pollution Discharge Elimination System) Manager, C. Taylor] and diminished assistance and enforcement actions for Reservation wastewater systems. At present, the Village of Macy is the only tribal community on the Omaha Indian Reservation receiving assistance from the Indian Health Service (IHS, M. Clifford).

According to the State of Nebraska and the U.S. EPA, the level of certification for wastewater operators depends on the size of the system and the level of treatment provided by the wastewater treatment facility. Levels of operator certification are defined in NE Title 197. For towns with lagoon systems, such as Macy and Rosalie, a "Class Lagoon" operator certificate is required. For towns with activated sludge mechanical aeration plants with lift stations, such as Pender and Walthill, a Class 2 operator certification is required. All four villages currently meet the operator certificate levels required.

Remote Residential and Cluster Housing Wastewater Systems

Many single family dwellings and cluster housing developments on the Omaha Indian Reservation use individual wastewater treatment systems such as septic tanks followed by absorption fields or small lagoon systems. Quantifying the number of these small systems was beyond the scope of this study. It is likely that these systems will remain in operation well into the future due to their remoteness from a central community wastewater collection and treatment system and the limited growth projected for these areas. It could not be determined which entity was responsible for regulation of on-site wastewater disposal systems.

General Description of Wastewater Collection

Collecting wastewater from homes or commercial establishments requires a service line from the building to the street, a collection sewer, and, for greater distances, a large interceptor sewer. Velocity in the sewer pipeline is a critical design parameter and is determined by the smoothness of the pipe wall, the amount of flow, and the slope of the installed pipe. Velocities less than 2 feet per second may cause solids to settle in the pipe. Velocities greater than 12 to 15 feet per second may cause the inside pipe wall to scour and require frequent pipe replacement. Interceptors having a larger pipe diameter than collector sewers provide a large carrying capacity at low slopes. Wherever a sewer line crosses a stream, protecting the pipeline from the scouring action of the stream typically requires that the pipe be encased in concrete. The length of the concrete encasement must include both the surface and the subsurface width of the stream for adequate protection.

Lift stations are a common feature of collection systems. They are pumping chambers constructed of precast or cast-in-place concrete and are used to lift untreated wastewater. Each lift station typically contains two submersible effluent or grinder pumps and a wet well sized to store a minimum of 30 minutes of wastewater at the average day flow. Each pump is sized to pump the peak day flow or the stored wastewater at a design total dynamic head. The pumps alternate in operation to provide uniform wear. Pump controls are float operated. An outlet for a portable engine generator is typically provided in case of power outage. Lift stations are costly to install and require continual maintenance. Their use should be avoided, if possible, by locating treatment facilities at a lower elevation than the collection lines.

When estimating wastewater flows for collection and treatment, it is customary practice to add in an amount for infiltration and inflow (I/I). Infiltration is the groundwater that leaks into the sewer system generally through deteriorated and or defective pipes. This flow fluctuates seasonally with the movement of groundwater. Inflow is stormwater that enters directly into the sewer system from sources such as flooded manhole covers, yard and roof drains, and cross-connections with storm sewers (Corbitt, 1999). A typical design rate to account for infiltration and inflow into a sanitary sewer is 250 gallons per day per inch diameter of pipe per mile of pipe length.

General Description of Wastewater Treatment

Treatment systems for domestic, non-industrial wastewater, presume that most of the waste is water and biodegradable organic solids. Treated wastewater, also known as effluent, will contain minimal amounts of solids and impart a low oxygen demand to the receiving water. As defined by U.S. EPA, "Primary" treatment consists of screening, grinding, and removal of large suspended material. Secondary treatment defines a level of treatment which follows primary treatment. It includes aeration (which promotes the microbiological destruction of organics in the waste); clarification to settle, collect, and remove solids from the water; and disinfection for virus and bacterial protection.

U.S. EPA's national standards for secondary wastewater treatment plant effluent water quality are 30 mg/L for a 30 day average and 45 mg/L for a maximum day value for both total suspended solids (TSS) and biochemical oxygen demand (BOD). In addition, most plants are required to discharge water that is not too acidic or alkaline, i.e., in a pH range from 6 to 9. There are other parameters of concern when effluent is discharged to a receiving water that has been classified for aquatic, agricultural, aesthetic, or recreational uses. These may include ammonia, coliform bacteria, dissolved oxygen, or constituents capable of causing acute and chronic toxicity.

Streams can receive or assimilate various levels of pollutants in wastewater treatment plant effluent and can tolerate them up to a certain level before stream degradation occurs. This level, when a stream is adversely affected by a pollutant, is defined by the U.S. EPA as the total maximum daily load (TMDL). TMDL is a limit on the daily amount of a pollutant received by a stream and is predicated on the stream's flow and water chemistry. States must first monitor a stream by collecting samples and performing chemical analyses to evaluate the sensitivity of the stream to receive pollutants. In Nebraska, TMDLs on the Missouri river have not been finalized by the U.S. EPA. Therefore, all tributaries to the Missouri river also have yet to have their TMDLs set. For this reason, some villages on the reservation have wastewater effluent parameters noted in their discharge permits as merely a value to report each month in lieu of a required numerical discharge limit.

A summary of the last issued NPDES permit for each village is shown in Table 8-1 below. Pender, Walthill, and Rosalie have permits issued by the Nebraska Department of Environmental Quality whereas Macy has a federal permit written by the U.S. EPA in Kansas City.

Table 8-1.
Summary of Wastewater Discharge Permitting - Omaha Indian Reservation Communities
(All units mg/L unless otherwise noted; -- , no data or not applicable)

	Macy	Pender	Walthill	Rosalie
NPDES Permit Number	NE61263	NE40908	NE21211	NE46302
Date Issued	12/9/98	10/6/97	12/10/89	3/9/92
Date Expired	12/9/03	10/5/02	12/9/94	3/8/97
Issuing Agency	U.S. EPA-VII	NE DEQ	NE DEQ	NE DEQ
Receiving Water	Blackbird Cr.	Logan Cr.	Omaha Cr.	Big Slough Cr.
Effluent Discharge Limits	--	--	--	--
Flow Capacity, MGD[9]	0.21	--	0.07	--
BOD[1]				
Weekly Average	45	40 of CBOD[2]	45	45
Monthly Average	30	25 of CBOD[2]	30	30
TSS[3]				
Weekly Average	45	45	45	--
Monthly Average	30	30	30	80
Max. Semi-annual	--	--	--	120
pH, in std. Units	6 to 9	6.5 to 9	6 to 9	6 to 9
Nitrate as N, max.	--	--	--	100
Ammonia-Nitrogen[4]				
Daily Maximum	--	17.9[5] and 47.2[6]	--	--
Monthly Average	--	12.3[5] and 32.3[6]	--	16.3
Maximum Semi-annual	--	--	--	32.8
Pimephales promelas[5]	--	7.1 TUc[8] day max.	--	--
Pimephales promelas[6]	--	1.07 TUa[8] day max.	--	--
Ceriodaphnia[5]	--	7.1 TUc[8] day max.	--	--
Ceriodaphnia[6]	--	1.07 TUa[8] day max.	--	--
DO[7] 1 day minimum	--	3.1	--	--
Other Requirements	influent	influent, sludge and metals	influent	influent

1 Biochemical Oxygen Demand
2 Carbonaceous Biological Oxygen Demand
3 Total Suspended Solids
4 Report requirement only. No limit specified. Rationale cities model results as <2 mg/L.
5 Summer season defined as April 1 - Oct. 31
6 Winter season defined as Nov.1 - Mar. 31
7 Dissolved Oxygen
8 TU = Toxic Unit; a = acute, c = chronic
9 MGD = million gallons per day

Reviewing the number of times a wastewater facility produces effluent which exceeds discharge standards provides an indication of facility performance. For purposes of this assessment, U.S. EPA-Kansas City was contacted and a search of their Permit Compliance System (PCS) was made for Macy, Pender, Walthill and Rosalie. No data was available for the Villages of Macy and Rosalie after December 1998. As shown in Table 8-2 below, prior to December 1998, permit infractions for Walthill, Pender and Rosalie are relatively minor. Walthill, however, has had repeated problems removing BOD which is indicative of poor operation and maintenance, insufficient aeration, or overloading of the treatment works.

Table 8-2. Status of NPDES Wastewater Discharge Permit Violations for Omaha Indian Reservation Communities

(-- , no data, or not applicable)

	Macy	Pender	Walthill	Rosalie
NPDES Permit Number	NE61263	NE40908	NE21211	NE46302
BOD[1]	--	Jan-00	Jan-97 May-97 Feb-97 Jun-98 Mar-97 Jul-98 Apr-97 Jan-00	Jun-98; No data after 12/98
TSS[2]	--	Apr-00	May-96	No data after 12/98
pH	--	Feb-99	--	No data after 12/98
Flow	--	--	--	No data after 12/98
Ammonia	--	--	--	No data after 12/98

1 Biochemical Oxygen Demand
2 Total Suspended Solids

In the narrative that follows, each village wastewater treatment system is described and evaluated in terms of its ability to meet current and future flows.

Municipal Systems

Population estimates for Years 2000, 2020, and 2040, introduced in Chapter 2 and utilized in this chapter to estimate wastewater flows, are presented in Table 8-3 as follows.

Table 8-3. Population Projections Used to Estimate Wastewater Flows

Year	Macy Service Area	Village of Pender	Village of Walthill	Village of Rosalie	Omaha Reservation
2000	3,150	1,148	1,018	194	5,667
2020	5,704	1,148	1,490	236	8,666
2040	10,327	1,148	2,182	286	14,102

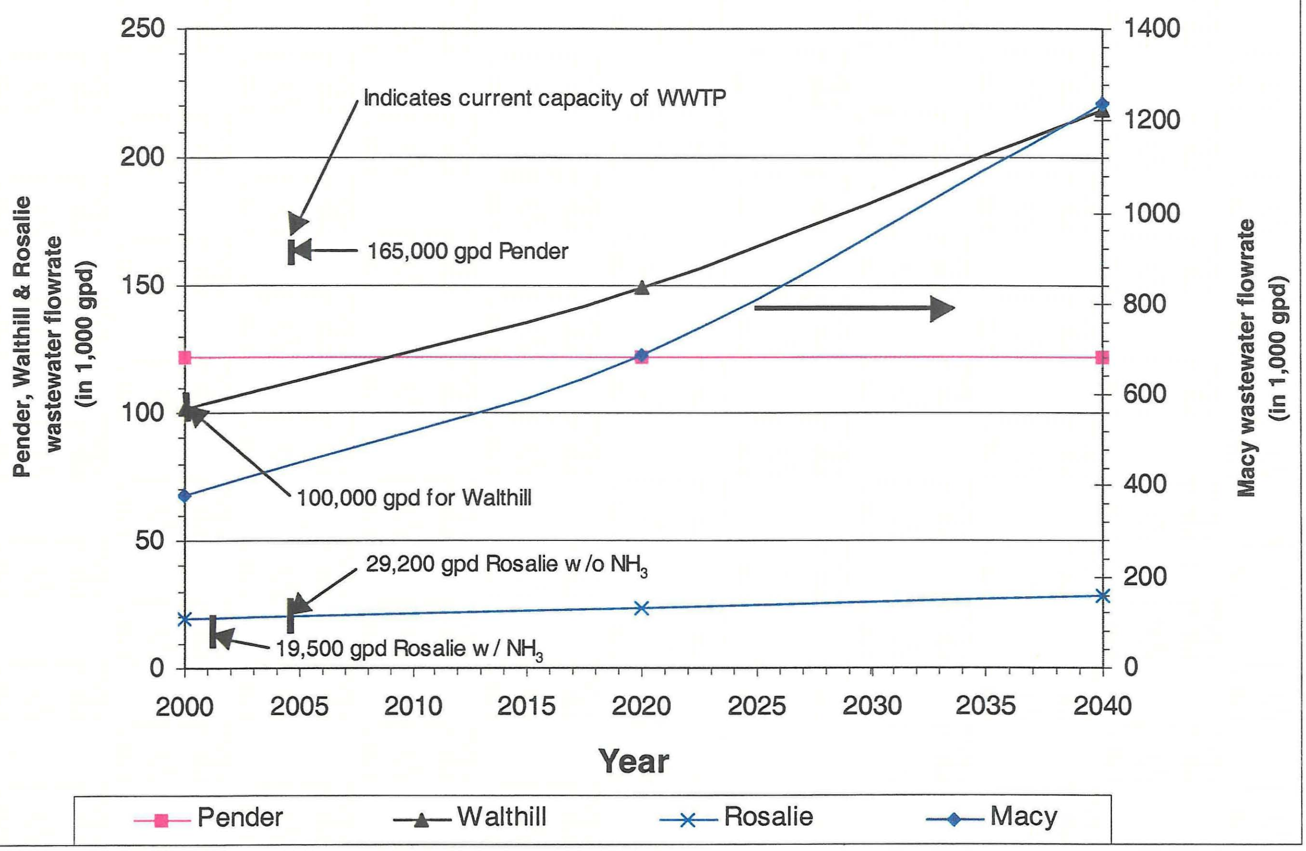
Per capita average day flows applied in this section were selected as follows. For Macy, the State of Nebraska's 120 gpcd standard wastewater flow estimate was adopted. For Pender, the unit loading was determined from EPA flow data and current population. For the Villages of Walthill and Rosalie, a unit loading value of 100 gpcd was used. This figure was about mid-range between the state standard and calculated flows for Walthill. Unit loading values, in gallons per capita per day, were then applied to the projected population estimates to determine future wastewater flows. The unit loading and average day wastewater flow estimates are presented below in Table 8-4 and are shown graphically in Figure 8-1. Rated capacity of each village wastewater treatment facility is also shown in Figure 8-1.

Table 8-4. Wastewater Unit Flows and Current and Projected Wastewater Flows

(Units in gallons per day)

Year	Macy	Pender	Walthill	Rosalie
	Unit Flows			
	120 gpcd	117 gpcd	100 gpcd	100 gpcd
2000	378,000	134,316	101,800	19,400
2020	684,480	134,316	149,000	23,600
2040	1,239,240	134,316	218,200	28,600

Figure 8-1. Omaha Reservation Communities Current and Projected Wastewater Flowrates and Rated Treatment Facility Capacities



<u>Tribal System, Village of Macy</u>

<u>Description</u>

The Village of Macy's wastewater system is administered by the Omaha Tribal Utility Commission, Mr. Mert Christiansen, Superintendent and certified operator. Mr. Christiansen is assisted in the operation and maintenance of this system by one certified and one non-certified operator. On occasion, the Indian Health Service is enlisted to provide engineering services. The State of Nebraska had no information on this system since the U.S. EPA has been operative in Macy.

The Village wastewater system consists of a collection network with one lift station and a 3-celled wastewater lagoon discharging treated effluent to Blackbird Creek in accordance with U.S. EPA discharge permit No. NE61263. Permit data and limitations are detailed in Table 8-1, and permit violations are noted in Table 8-2. The collection system utilizes both

Table 8-1, and permit violations are noted in Table 8-2. The collection system utilizes both 6- and 8-inch PVC pipe. Installed in 1975, the collection system may be allowing some inflow from storm water and roof drains. According to IHS, the lift station contains two pumps each rated at 450 gpm (IHS, M. Clifford).

There are quite a few homes and farms around Macy served by the water system that are not connected to the wastewater system. In fact, it has been estimated by IHS that only about 1,900 of the approximate 3,150 people residing in the Macy area are connected to the lagoon system. Since the wastewater collection system has not been extended to many outlying housing developments or residences, these dwellings utilize individual forms of treatment such as lagoons or septic tanks followed by leach fields.

The 3-celled "discharging" lagoon system was originally constructed as a 4-celled full retention system designed by B & E Engineering of Yankton, South Dakota. In 1996, IHS implemented design improvements which removed the berm between cells 1 and 2 and modified the discharge piping so the lagoons would discharge continuously. According to IHS (IHS, K. Esplin), flow is currently routed first into cell 1 and alternately to either cell 3 or 4. Cells 3 and 4 are designed for periodic discharge into Blackbird Creek. The lagoons have yet to reach the level needed to produce discharge.

Ability to Meet Current Flows

Average day wastewater flow data from IHS dated back to February 1995 and covered only one month of recorded lift station flows (133,000 gallons per day). Information about the current average day wastewater flow was not available from the U.S. EPA or the State of Nebraska's Department of Environmental Quality. No violations for Macy appear in the U.S. EPA PCS database of past violations summarized in Table 8-2.

From the September 1999 on-site visit conducted by Reclamation, it was evident that numerous problems exist with the wastewater system. The collection system is old and the operating staff is small. Experienced staff has left in recent years. Dealing with infiltration and inflow, broken lines, and lift station problems resulting from flooding appears to place the operating staff in a reactive mode. The current wastewater lagoons appear to be losing wastewater through percolation which is preventing proper operation as discharging lagoons; this, however, needs to be verified.

The capacity of the lagoon system depends on the level of treatment desired, specifically, for ammonia removal. The current discharge permit notes the capacity of 213,468 gpd for a population of 2,100. The U.S. EPA fact sheet associated with the permit is based on removing ammonia and fecal coliform and conforming the discharge to Blackbird Creek to the 2-mg/L ammonia limit applicable to warm water streams. It should be noted, however, that the current permit only requires ammonia nitrogen reporting and not an ammonia discharge limit. The U.S. EPA is currently working on establishing the total daily maximum load on the Missouri River and its tributary Blackbird Creek and, until this is done, an ammonia standard may not be issued for this tributary. This would allow an increase in the lagoon capacity due to a shorter lagoon detention period.

If the capacity of the system were 213,468, as noted in U.S. EPA documents, then, as shown in Figure 8-1, Macy's wastewater treatment facility would be overloaded if the estimated 1,900 people were producing 120 gpcd (the State of Nebraska's typical wastewater flow estimate) rather than the approximate 70 gpcd based on data from the IHS. In view of this, and the anticipated population growth in and around the Village, immediate planning would be needed to expand the treatment system.

Ability to Meet Year 2040 Flows

Average day wastewater flow increases proportionally with population growth. The estimates for projected wastewater flows for Macy assume that all households will be connected to the wastewater and treatment system. As shown graphically in Figure 8-1, by Year 2040 the average day flow in the Macy Service Area may reach nearly 1.24 million gallons per day (MGD). Collection system and treatment plant or lagoon expansions will be required.

Village of Pender

Description

The Village of Pender's wastewater services are provided through the Utility Department, which reports to City Council. This department also is responsible for the Village's electric power, solid waste, police, and water services. The Utility Department Superintendent, Mr. Robert Fendrick, has seven full time staff and two to three part time employees. Engineering services are provided by the firm of Johnson, Erickson, and O'Brien Engineering of Wahoo, Nebraska.

The Village's wastewater system consists of a collection system, two lift stations, and an activated sludge wastewater treatment plant that discharges treated effluent to Logan Creek. Wastewater treatment is accomplished by the 165,000 gallon per day, contact stabilization, activated sludge treatment plant. This capacity has been determined from the design report prepared by JEO and is consistent with State and U.S. EPA records. In addition, there are two lagoon cells available for treatment if needed or when flows exceed the plant capacity of 0.165 MGD. According to Mr. Fendrick, these lagoons are non-discharging; provide an additional treatment capacity of 135,000 gpd; are 9.5 acres in area and 5-foot deep; and used from Spring to Fall. During a September 1999 field tour, the wastewater facilities appeared to be in good working order.

Parts of the collection system may have been installed in the late 1890s. It is unknown whether the wastewater collection system was designed as a combined sewer both for wastewater and stormwater. The sizes of all pipes in the collection system are shown in Table 8-5 (Fendrick).

Table 8-5. Village of Pender Wastewater Collection Line Summary

Diameter of Sewer (Inches)	Length of Pipe (Feet)
4	1,360
6	3,959
8	36,435
10	2,208
12	2,691
15	1,739
18	346
24	2,450

A lift station located at the primary treatment section of the wastewater plant contains three pumps each rated at 240 gpm at 28 feet of total dynamic head. These pumps can pump raw wastewater to either the mechanical wastewater treatment plant (WWTP) or to the lagoons. Both the lift station and treatment plant were inspected by Reclamation in September 1999 and found to be in good working order. A second lift station, located along Industrial Road, lifts a small amount of wastewater with two 5-horsepower pumps approximately three blocks to the intersection of Lloyd and Graham Streets. The U.S. EPA PCS database for treatment plant effluent violations, summarized in Table 8-2, indicates that Pender had three violations since February 1999.

Ability to Meet Current Flows

According to the U.S. EPA PCS database, for the twelve month period ending June 2000, the average day and maximum day flows in the Pender system were 134,100 and 285,500 gpd, respectively. Using Pender's current population of 1,148, and the U.S. EPA average daily flow record, Pender generates an average wastewater flow of 117 gpcd. Since the capacity of the WWTP is 165,000 gpd, and maximum day flows of nearly two times this rate have been recorded, it may be concluded that there are many days throughout the year that the lagoons are needed to avoid overloading the plant. It is advised that Pender collect operational and water quality data to ensure efficient operation of all wastewater facilities.

Ability to Meet Year 2040 Flows

A new 90,000 gpd wastewater treatment plant has been added so that Pender's treatment capacity (now at 0.165 MGD) can be expanded to 0.25 MGD, twice the average day flow.

Village of Walthill

Description

The Village of Walthill's wastewater services are administered by the Village's Utility Department with Mr. Terry Tipton, Utility Superintendent. The firm of Johnson, Erickson, and O'Brien Engineering has been retained for engineering services.

The wastewater system consists of a collection system with one lift station and an activated sludge wastewater treatment plant which discharges treated effluent to Omaha Creek (permit requirements are shown in Table 8-1). There are approximately 22,800 linear feet of sewer pipe in the collection system. A breakdown of pipe size, however, was not available. The lift station, located in the center of town, pumps raw sewage approximately 200 feet horizontally to the wastewater treatment plant. In 1987, JEO performed pump tests on the lift station and found the capacities of its two pumps to be 130 and 110 gpm. The age of the lift station and estimated capacities were not verified during this study. The wastewater treatment plant is about 30 years old (T. Tipton, August 2000 facsimile of wastewater system data).

Wastewater treatment is accomplished by the 100,000 gpd activated sludge wastewater treatment plant. This design capacity was noted in a 1987 engineering assessment of the Village's wastewater facilities prepared by JEO (August 2000 facsimile from R. Bottorff, JEO Engineering). The same capacity appears on both State and U.S. EPA records where this plant is listed as able to serve a population equivalent to 1,000 people.

Ability to Meet Current Flows

No information was available regarding the condition of the collection system or lift station. The Village of Walthill's current population of 1,018 produces an average day flow of 68,000 gallons or 67 gpcd (R. Irwin, Nebraska Department of Environmental Control, August 2000 personal communication with R. Jurenka, Reclamation). According to the U.S. EPA PCS database, for the 12 month period ending June 2000, the average day and maximum day flows were 72,600 gpd and 116,500 gpd, respectively. One may conclude that when comparing maximum day flows reported in this database with plant capacity, at present, the treatment plant on occasion is hydraulically overloaded. This is consistent with findings by JEO in 1987 (Bottorff, 1987). Given the age of the treatment plant and the reported incidents of hydraulic overloading, it may be assumed that severe infiltration and inflow problems exist in the collection system.

With regard to treatment plant effluent performance, the U.S. EPA database showed that the Walthill facility had trouble meeting the BOD limitation for several months in 1997 and 1998. The lack of recent and complete operational and water quality data makes assessing current plant performance difficult. As shown in Table 8-2, eight BOD violations and one solids violation since May of 1996 indicate that this facility is having problems treating current flows.

Ability to Meet Year 2040 Flows
Housing development linked to population growth will place additional demand on the existing lift station and treatment facilities in the future. It is recommended that the Village monitor flows and treatment plant performance so that an expanded wastewater treatment plant can be designed and constructed to keep pace with future demand.

Village of Rosalie

Description
The Village of Rosalie's wastewater service is administered by the Village's Utility Department which reports directly to the Mayor, Christine Baker. The utility staff consists of two people both with water and wastewater operator certifications (C. Baker).

The Village of Rosalie's wastewater system consists of a collection system with one lift station, and a facultative 2-celled wastewater lagoon discharging to Big Slough Creek (South Omaha Creek). The lagoon is operated under discharge permit number NE46302. Permit details are displayed in Table 8-1. According to dimensions noted on Consolidated Engineering Co. drawings (April 1968), the two non-aerated lagoon cells have 1.0 and 2.5 million gallon capacities, respectively, for a total volume of 3.5 million gallons.

According to these same drawings, there are approximately 11,500 feet of either 6- or 8-inch diameter pipe and an unknown length of 4-inch force main serving the Village. Installed as early as the 1930s (C. Baker), the collection system may be allowing higher than normal infiltration and inflow. Installed in 1968, the lift station is rated at 50 gpm at 55 feet of total dynamic head (Smith and Lovelace, 1968[1]). During a Reclamation field visit of September 1999, it was observed to be in good working condition.

Ability to Meet Current Flows
Information about the current average day flow was not available from the U.S. EPA, the State of Nebraska, the Nebraska Rural Water Association, or from village authorities. The U.S. EPA PCS database of past violations is summarized in Table 8-2. It has no data entered since December 1998. Based on the limited amount of operational flow and water quality data available, no assessment of wastewater collection system performance could be rendered for this study.

Given that the volume of the lagoons is 3.5 million gallons, the capacity of the system can be determined based on hydraulic load and detention time. Applying the State of Nebraska's recommended design criteria of a 120-day lagoon detention time, the Rosalie lagoons would be rated for a daily inflow of 29,200 gallons. However, if an ammonia standard is imposed on Big Slough Creek, which would require a longer 180-day detention time to promote denitrification, then the allowable rated capacity is reduced to 19,500 gpd.

[1]As provided by J. Martinsen of Falcon Supply Company by facsimile copy of August 2000.

Dividing the 29,200 and 19,500 gpd inflow figures by Rosalie's current population of 194 yields average flows of 150 and 100 gpcd, respectively. Since 150 gpcd exceeds the average unit loading of 100 gpcd, the lagoon system appears adequately sized to serve the current population if the ammonia standard is not imposed. If the ammonia standard is imposed by the new permit, the lagoon system is at capacity.

Ability to Meet Year 2040 Flows

Assuming the ammonia standard is imposed, the Year 2040 flow of 28,600 gpd would exceed the existing lagoon capacity of 19,500 gpd and a 9,100 gpd lagoon would be needed. Wastewater collection system piping will need to be added in proportion to the existing collection system and the ratio of the projected Year 2040 population to the current population.

Chapter Nine - Conceptual Design Plans for Villages to Meet Current and Long Term Wastewater Disposal Needs

The initial part of this chapter outlines current and long term (Year 2040) needs of municipal wastewater treatment and collection systems on the Reservation. As the chapter progresses, conceptual design plans are presented that illustrate the type of program each Reservation community would need to implement to meet projected Year 2040 wastewater service demands. Appraisal or sub-appraisal level cost estimates (depending on the amount of information available) are provided for each system. For cost estimating purposes, it is assumed that current housing density will be maintained as population increases.

Immediate Needs for Village Wastewater Treatment and Collection Systems

The wastewater collection and treatment needs for the Villages of Macy, Pender, Walthill, and Rosalie were discussed in Chapter 8 and are summarized as follows:

Tribal System, Village of Macy

Macy's collection system should be tested for sources of leakage and I/I. Additionally, an operations plan for the lagoons should be prepared and provided to the Tribal Utility Department. Tribal wastewater personnel should receive updated training on lagoon operations. The sewage flow and strength should be measured and recorded monthly to assess lagoon operating parameters.

Village of Pender

Whereas the wastewater collection system dates back to 1890, an inspection should be made and a survey performed to locate leaks and possible high I/I in the system.

Village of Walthill

In 1987, the engineering firm of JEO had identified problems with overloaded treatment units, high collection system I/I, and a WWTP effluent not meeting NPDES permit criteria as associated with the Walthill system. Peak day flow and water quality effluent violations identified in this assessment indicate that the Walthill treatment plant has operational or sizing problems, or both, and substantiate the JEO findings. It is recommended that the wastewater collection and treatment system be examined, in depth, in an independent study.

Village of Rosalie

An on-site investigation to assess the condition of the wastewater collection and treatment systems is recommended since very little data is available. Based on a September 1999 field visit, the lift station and treatment lagoons appeared to be working satisfactorily. However, data collection to ensure adequate and efficient operation was not being performed. The wastewater lagoon system is at capacity if the ammonia nitrogen standard is enforced.

Year 2040 Wastewater Needs

Comparing projected average day flows with wastewater collection and treatment information compiled for this assessment, Year 2040 planning needs for the Villages of Macy, Pender, Walthill, and Rosalie appear as follows:

Tribal System, Village of Macy

If the current housing density is maintained, by the Year 2040, the Macy system will require about 165,500 feet of 6-inch sewer main and about 22,700 feet of 8-inch sewer main. Assuming 10% of the average day flow will require a lift pump, one lift station will be required. An estimated 104 million gallons of additional capacity will be required in the discharging lagoons by Year 2040. As detailed in the appended worksheets (Appendix C), total cost for these upgrades could run approximately $17,500,000.

Village of Pender

Assuming wastewater treatment in the Year 2040 is accomplished by the current activated sludge treatment method, a 90,000 gpd wastewater treatment plant will be needed. As detailed in Appendix C, total cost for these improvements could be approximately $980,000.

Village of Walthill

If the current residential housing density is maintained, Walthill will require about 25,000 feet of 6-inch sewer main and about 4,000 feet of 8-inch sewer main. It is also likely that an additional lift station will need to be added bringing the total pumping capacity to 180 gpm at an assumed pressure of 30 feet. Assuming that the Village will continue using an activated sludge plant to treat domestic wastewater, approximately 0.15 MGD of additional capacity will be needed (Year 2040 demand of 0.264 minus current plant capacity of 0.1 MGD). As detailed in the appended worksheets (Appendix C), the total cost for these upgrades could run approximately $2,900,000.

Village of Rosalie

If the current housing density is maintained, by Year 2040, the wastewater collection system for the Village will require about 5,500 feet of 6-inch sewer main, 2,900 feet of 4-inch force main, and one lift station. An estimated 9,200 gpd of new, discharging lagoon volume will be needed for a 180-day detention time. As detailed in Appendix C, total cost for these upgrades could run approximately $910,000.

Construction Costs to Meet Year 2040 Demands

This section provides water supply and treatment system conceptual design plans that illustrate the type of facility upgrades each Reservation community would need to implement to meet Year 2040 projected service demands. Cost estimates (at appraisal or sub-appraisal level, depending on the amount of information available) are provided for major system components. At this level of study, these estimates are accurate to ±40% and are useful for only general planning purposes. Therefore, they were not and should not be applied on a per capita or individual household basis. The design is only adequate to determine that a workable system could be developed.

Underlying assumptions used to formulate the estimates would have to be further refined to obtain greater accuracy.

An allowance of about 15% of the estimated costs was included for unlisted items, a 25% contingency was added, and a 30% non-contract cost added. The non-contract cost includes design data collection, design, contract administration, or construction management costs.

Wastewater collection system quantities assume proportional growth from the Villages' existing land area, housing and population density, and level of current wastewater collection service. The cost estimate does not include operation and maintenance costs. For additional detailed unit costs, the estimate worksheets are included in this report in Appendix C.

Tribal System, Village of Macy

If the current housing density is maintained, by the Year 2040, the Macy system will require about four times the current level of sanitary sewers. Also, assuming 10% of the average day flow requires a lift pump, one lift station will be required by Year 2040. As indicated in Table 9-1 on the following page and detailed in Appendix C, total cost for these upgrades could run approximately $17,500,000. Major system improvements include:

- 165,500 feet of 6-inch sewer main,
- 2,700 feet of 8-inch sewer main,
- One lift station, and
- 104 million gallons of additional capacity in the discharging lagoons.

Table 9-1. Cost Estimate to Conform the Macy Wastewater System to Year 2040 Needs

Item	Cost
Wastewater treatment	$4,988,222
Collection system	$4,006,700
Mobilization	$450,000
Unlisted items	$1,555,078
CONTRACT COST *(Subtotal of items above)*	***$11,000,000***
Contingencies	$2,500,000
FIELD COST *(Subtotal of Contract Cost plus Contingencies)*	***$13,500,000***
Non Contract Cost	$4,000,000
CONSTRUCTION COST	***$17,500,000***

Village of Pender

The following facilities form the basis of estimating construction costs required for Year 2040 development:

- A 90,000 gpd activated sludge wastewater treatment plant.

As indicated in Table 9-2 on the following page and detailed in Appendix C, total cost for these improvements could run approximately $980,000.

Table 9-2. Cost Estimate to Conform the Pender Wastewater Sytem to Year 2040 Needs

Item	Cost
Wastewater treatment	$500,000
Collection system	$0
Mobilization	$25,000
Unlisted items	$75,000
***CONTRACT COST** (Subtotal of items above)*	***$600,000***
Contingencies	$150,000
***FIELD COST** (Subtotal of Contract Cost plus Contingencies)*	***$750,000***
Non Contract Cost	$230,000
CONSTRUCTION COST	***$980,000***

Village of Walthill

The following facilities form the basis of estimating construction costs required for Year 2040 development:

- 25,000 feet of 6-inch sewer main,
- 4,000 feet of 8-inch sewer main,
- One lift station, 180 gpm at 30 feet, and
- A 0.15 MGD activated sludge wastewater treatment plant.

As indicated in Table 9-3 on the following page and detailed in Appendix C, total cost for these improvements could run approximately $2,900,000.

Table 9-3. Cost Estimate to Conform the Walthill Wastewater System to Year 2040 Needs

Item	Cost
Wastewater treatment	$765,000
Collection system	$704,860
Mobilization	$73,000
Unlisted items	$207,140
CONTRACT COST *(Subtotal of items above)*	***$1,750,000***
Contingencies	$450,000
FIELD COST *(Subtotal of Contract Cost plus Contingencies)*	***$2,200,000***
Non Contract Cost	$700,000
CONSTRUCTION COST	***$2,900,000***

Village of Rosalie

The following facilities form the basis of estimating construction costs required for Year 2040 development:

- 5,500 feet of 6-inch sewer main,
- 2,900 feet of 4-inch force main,
- One lift station, and
- 9,100 gpd of new, discharging lagoon volume for a 180-day detention time.

As indicated in Table 9-4 on the following page and detailed in Appendix C, total cost for these improvements could run approximately $910,000.

Table 9-4. Cost Estimate to Conform the Rosalie Wastewater System to Year 2040 Needs

Item	Cost
Wastewater treatment	$219,100
Collection system	$241,976
Mobilization	$23,000
Unlisted items	$75,924
CONTRACT COST *(Subtotal of items above)*	***$560,000***
Contingencies	$140,000
FIELD COST *(Subtotal of Contract Cost plus Contingencies)*	***$700,000***
Non Contract Cost	$210,000
CONSTRUCTION COST	***$910,000***

<u>Summary of Costs to Upgrade Municipal Systems</u>

Construction cost estimates to meet the projected Year 2040 water system improvements for the Villages of Macy, Pender, Walthill, and Rosalie are summarized in Table 9-5 below.

Table 9-5. Cost Summary to Upgrade Wastewater Systems

Service Areas	Construction Cost
Macy	$17,500,000
Pender	$980,000
Walthill	$2,900,000
Rosalie	$910,000
Total Wastewater Cost	**$22,290,000**

Chapter Ten - Recommendations for Further Study

This water needs assessment was performed for the purpose of examining the water supply and wastewater treatment capability on the Reservation in the context of current and future water demands. In line with the level of detail normally utilized in a needs assessment investigation, only existing data, personal communications, and a brief field tour were utilized to arrive at study conclusions. Based on study findings, and keeping in mind inaccuracies inherent in study assumptions and occurrences of limited data availability, various short and long term actions and data acquisition initiatives are recommended to assure that optimal water supply and wastewater disposal services are provided in all Reservation communities. A listing of these items is offered below.

Village of Macy Service Area

- Source water and treated water quality need to be accurately characterized and evaluated against regulatory criteria.
- Current average day potable water and wastewater flows need to be firmly established.
- The wastewater collection system should be tested for sources of leakage and infiltration and inflow.
- Sewage flow and strength should be measured and recorded monthly to assess lagoon operating parameters even if there is no discharge.
- An operations plan for the lagoons should be prepared.
- Piping and Pressure Reducing Valve changes from the hydraulic network model analysis (Appendix A) of the existing system need to be considered.
- Water system performance for all conditions of flow and demand for the Year 2040 needs to be modeled.

Village of Pender

- Monitoring for total coliform, nitrate, and arsenic in treated water is recommended.
- Should the arsenic standard be reduced to 10 part per billion for Year 2006, water treatment may be needed to conform village water to the new standard.
- Should nitrate in the groundwater continue to rise, blending with better quality water or implementing a nitrate removal process may be required.
- Current average day wastewater flow needs to be firmly established.
- Operational and water quality data need to be ascertained to ensure efficient operation of all wastewater facilities.
- The wastewater collection system should be checked for leakage and possible infiltration and inflow.

Village of Walthill

- Both raw and treated water quality for the potable water system need to be established.
- Updated and comprehensive operational and water quality data are needed to properly assess wastewater treatment plant performance.
- Operational studies are needed to re-examine 1987 findings of overloaded treatment units, high

collection system infiltration, and wastewater treatment plant effluent not meeting NPDES permit criteria.
- Overall condition of the wastewater collection system and pipe sizing need to be determined.
- The age of the lift station and its estimated capacity need to be established.
- Additional monitoring of flows and treatment plant performance is needed to properly design and construct future wastewater expansion.

Village of Rosalie
- Water system raw and potable water quality needs to be established.
- Current average day potable water and wastewater flows need to be established.
- On-site investigation needs to be performed to assess the condition of the wastewater collection and treatment systems.
- Operational data should be collected to ensure adequate and efficient operation of the lift station and treatment lagoons even if there is no discharge.
- Past NPDES permit violations should be evaluated.
- Wastewater capacity studies linked to ammonia removal should be initiated.

Two additional observations were noted. First, none of the Reservation communities have a formalized water conservation plan. It has been demonstrated that 10 to 20 percent water savings can accrue from a properly conceived water conservation program. Second, many single family dwellings and cluster housing developments on the Omaha Indian Reservation use individual wastewater treatment systems, for example, septic tanks followed by absorption fields or small lagoon systems. Assessment of the integrity of these systems was beyond the scope of this study, but should be included in any future water planning initiatives.

Bibliography

American Water Works Association, 1989. Distribution Network Analysis for Water Utilities, AWWA M32.

B & E Engineering, Inc., 1978. Technical Aspects of Phase 1, Water Resource Inventory, Omaha Indian Reservation; Portions Prepared for Nebraska Inter-Tribal Development Corporation. Yankton, South Dakota.

B & E Engineering, Inc., 1981. Phase II Water Resources Inventory , Omaha Indian Reservation; Portions Prepared for Nebraska Inter-Tribal Development Corporation. Yankton, South Dakota.

Corbitt, Robert A., 1999. Standard Handbook of Environmental Engineering, Second Edition.

Davis et al., 1995. Baseline Assessment of Water Quality on the Reservation of the Omaha Tribe, The Final Water Quality 106 Report prepared in fulfillment of EPA Assistance Agreement I 007797-01-2; Omaha Tribe Environmental Protection Department.

Davis, Ralph K. and Darryll T. Pederson, October 1992. Water Resources Data and Suggestions for Water Code Development, Omaha Indian Reservation, Omaha Tribe of Nebraska; submitted to Omaha Tribal Council, October 1992.

Ellis, M. J., 1984. Overview of the Dakota Aquifer System in Nebraska; Proceedings of Symposium on Geohydrology of the Dakota Aquifer; National Water Well Association.

Gosselin, D. C. and others, 1996. Missouri River Lowlands Hydrogeologic Summary from Domestic Well-water Quality in Rural Nebraska; URL http://nesen.unl.edu/csd/illustrations/gwregion/missouri.html.

Gosselin, D. C. and others, 1996. Northeast Glacial Drift Area Hydrogeologic Summary from Domestic Well-water Quality in Rural Nebraska; URL http://nesen.unl.edu/csd/illustrations/gwregion/ne-glacial.html.

Johnson, O'Brien, and Erickson, 1987. Village of Walthill, Nebraska, Preliminary Study, Wastewater Treatment Facilities.

Lawton, D. R. , Owen Goodenkauf, B. V. Hanson, and F. A. Smith, March 1984. Dakota Aquifers in Eastern Nebraska, Aspects of Water Quality and Use; Proceedings of Symposium on Geohydrology of the Dakota Aquifer; National Water Well Association.

Nebraska Natural Resources Commission, 1997. Agricultural Crops Database; Nebraska Natural Resources Commission homepage, URL http://www.nrc.state.ne./us/.

Omaha Tribe of Nebraska, February 1997. Interim Draft: Integrated Resource Management Plan; Assembled and submitted by Mark Versch, Environmental Protection Department, Omaha Tribe of Nebraska.

Smith and Lovelace, Inc. 1968. Outline Drawing and Engineering Order, September 24, 1968.

U.S. Department of Agriculture, 1997. National Agricultural Statistical Service, 1997 Census of Agriculture, Report AC97- A -27, Vol. A, Part 27; Nebraska State and County Data, March 1999.

U.S. Department of Commerce, 1984. 1982 Census of Agriculture. Part 27, Nebraska. Bureau of the Census. U.S. GPO, Washington, D.C. 1984.

_____, 1989. 1987 Census of Agriculture. Part 27, Nebraska. Bureau of the Census. U.S. GPO, Washington, D.C. 1989.

_____, 1994. 1992 Census of Agriculture. Part 27, Nebraska. Bureau of the Census. U.S. GPO, Washington, D.C. 1994.

_____, 1990. Census of Housing, Detailed Housing Characteristics, American Indian and Alaskan Native Areas. 1990-CH-2-1A U.S. Bureau of the Census.

_____, 1990. Census of Population, General Population Characteristics: American Indian and Alaskan Native Areas. 1990 CP-1-1A, Bureau of the Census.

_____, 1990. Census of Population, General Population Characteristics, Nebraska. 1990 CP-1-4, Bureau of the Census.

_____, 1990. Census of Population and Housing, Characteristics of American Indians by Tribe and Language, sections 1 and 2, Bureau of the Census.

_____, 1990. Census of Population and Housing, Population and Housing Unit Counts, Nebraska. 1990 CPH-2-4, Bureau of the Census.

_____, 1990. Census of Population and Housing - STF 1A and 3A, profile 01 for Nebraska and Social and Economic Characteristics of American Indian and Alaskan Native Areas, sections 1 and 2, CP-2-1A, Bureau of the Census.

_____, 1990. Census of Population and Housing, Summary Population and Housing Characteristics, Nebraska. 1990 CPH-1-4, Bureau of the Census.

_____, 1990. Census of Population and Housing, Summary Population and Housing Characteristics, U.S. 1990-CPH-1-1, Bureau of the Census.

_____, 1990. Census of Population, Social and Economic Characteristics, Nebraska. 1990 CP-2-4, Bureau of the Census.

_____, 1990. Census of Population and Housing, Summary Social, Economic, and Housing Characteristics, Nebraska. 1990 CPH-5-4 Bureau of the Census.

_____, 1979. County Business Patterns, Nebraska 1977. U.S. Bureau of the Census. Washington, D.C.

_____, 1983. County Business Patterns, Nebraska 1981. U.S. Bureau of the Census. Washington, D.C.

_____, 1992. County Business Patterns, Nebraska 1990. U.S. Bureau of the Census. Washington, D.C.

_____, 1997. County Business Patterns, Nebraska 1994. U.S. Bureau of the Census. Washington, D.C.

U.S. Geological Survey, 1996. Physical Characteristics and Water-Resources Appraisal of the Omaha and Winnebago Indian Reservations in Northeastern Nebraska and Northwestern Iowa; Administrative Report prepared for the Bureau of Indian Affairs.

_____, Verstraeten, I. M. and others, 1996. Physical Characteristics and Water-Resources Appraisal of the Omaha and Winnebago Indian Reservations in Northeastern Nebraska and Northwestern Iowa; U.S.G.S. Administrative Report.

Wright Water Engineers, Inc., 1999. Second Bioassessment of Selected Creeks on the Reservation of the Omaha Tribe of Nebraska and Iowa; Prepared for : Omaha Tribe of Nebraska and Iowa, Macy, Nebraska.

APPENDICES

Appendix A: *Hydraulics for Water Distribution System - The Omaha Tribe of Nebraska*

Appendix B: *Fact Sheets:*
- *Arsenic*
- *Iron and Manganese*
- *Nitrate/Nitrite*
- *Total Dissolved Solids*
- *Total Coliform and E-Coli*

Appendix C: *Estimate Worksheets*

Appendix D: *Photo Gallery*

Appendix A
Hydraulics for Water Distribution System
The Omaha Tribe of Nebraska

I. Background and General Discussion

In 1993, the Bureau of Reclamation performed a review of the solid waste disposal system, the water treatment system, and the water supply and distribution system for the Omaha Tribe of Nebraska. This review resulted in a formal examination report that summarized the required activities and facilities renovations for use as a comprehensive plan for the utility system. This review also resulted in funding from the Farmers Home Administration for repair and improvements to the systems.

A Review and Evaluation of Needs, Water and Wastewater Systems was completed in 1997. This appraisal level report documents conditions found during a May 1997 re-inspection by the Bureau of Reclamation. Although improvements had been made in the solid waste system, the water system was still in need of immediate repair and improvement to ensure reliable and safe drinking water. This review revealed that a continuing problem with the operation of the water distribution system is the existence of improper pressures at individual residences. At some houses pressures are normally too high. This situation may cause problems with in-house plumbing, e.g., leakage. At other locations, pressures occur that are often too low. A recommendation was made in this report to improve operational pressure zones by modifying the settings and locations of PRVs (Pressure Reducing Valves). A hydraulic analysis was not done at that time to confirm the details of that recommendation. Therefore a recommendation was also made that a hydraulic review and system modification design be done.

When the Needs Analysis was initiated, the decision was made to develop a hydraulic model that could be used to refine the PRV settings and locations recommendation and also to suggest a layout to meet the future needs of the Omaha Tribe water distribution system.

II. Data

Design Data used for assessment of the pipeline water distribution system was obtained from the following:

- The Tribal Water System Maps provided by: Olsson Associates December of 1995, Typical Details of valves provided by Olsson Associates December 1995, and "Omaha Tribal Water Control System Improvements 1996" provided by Olsson Associates.

- The report: "Review and Evaluation of Needs, Water and Wastewater Systems The Omaha Tribe of Nebraska", U.S. Department of the Interior, Bureau of Reclamation, October 1997.

- The structural details of the pumping plant and elevated tanks were obtained from drawings entitled: "Omaha Tribal Water System for the Omaha Tribe of Nebraska Macy, Nebraska May 24, 1978." provided by Dana Larson Roubal and Associates Architects and Engineers.

- Maps and data were obtained from the Indian Health Service. Information was also obtained from telephone conversations with the Indian Health Service in Nebraska.

- Aerial photographs were obtained from the USGS.

- Topographic maps covering the Omaha Tribe of Nebraska reservation.

III. Criteria

A number of documents were used to establish design criteria used for this study. These documents are:

- *Water Systems Planning Handbook April* 1997, Washington State Department of Health Environment Health Programs Division of Drinking Water, Table 1 - Tabulated Maximum Instantaneous Flows.,

- *AWWA Manual of Water Supply Practices - Distribution Network Analysis for Water Utilities AWWA M32*,

- *AWWA Manual of Water Supply Practices - Distribution System Requirements for Fire Protection AWWA M31*, and

- *The Uniform Fire Code* -1997.

Production Capacity

The required total well (production) capacity is the maximum day demand per person (300 gallons) multiplied by a factor to account for the possibility that pumping does not occur 24 hours per day. Using a pumping time of 20 hours per day, the factor is (24/20)=1.2 and the required pumping capacity is 360 gallons per person per day.

Storage Capacity

The tank volume consists of the following: Operational Storage, Standby storage, and Fire Flow Storage.

Operational Storage

Operational Storage was determined by a hydraulic analysis of the system.

Standby Storage

The standby storage is equal to 3 times the average daily flow.

Fire Flow Storage

Duration to compute fire flow storage was determined according to table 1:

Table 1
Duration of Fire Flow

Required Fire Flow (gal/min)	Duration (hr)
2,750 or less	2
3,000 to 3,750	3
greater than 3,750	4

System Pressure -

Normal working pressure at service connections -
30 lbs/in^2 minimum, 90 lbs/in^2 maximum.

System pressure at any point at peak demand with fire flow -
20 lbs/in^2 minimum

System Demand -

Average daily demand - 150 gal/min/person
Maximum daily demand - 300 gal/min/person (Average daily demand times 2)
Peak hour demand - 435 gal/min/person (Maximum daily demand times 1.45)

System Sizing -

The minimum diameter of water main providing fire protection and serving a fire hydrant is 6 inches.

IV. Procedure

The program *Cybernet Version 3.0* (Haestad Methods, Inc.) was used to analyze the system hydraulics. The Hazen-Williams formula was used in the program to calculate hydraulic losses. The type of pipe used was PVC and the Hazen-Williams "C" value that was used was 130. The "C" used is considered conservative but since no minor losses were estimated, total losses and therefore hydraulic capacity of the system are reasonable.

Initial runs were for the model of the existing system. After that, runs were made to determine what could be done with the PRV locations and settings to reduce undesirable conditions. All problems cannot be eliminated by only modifying the PRVs.

For the future system configuration, system demands for the design year, year 2040, were used and the system was modified until required conditions could be met. The first runs for year 2040 were for normal demands. After that, fire flow was added and the system adjusted until fire flow conditions could be met.

Flows

The population of the Macy area is 3,150. The peak average demand per person per day is 300 gallons. This is the figure that was used for the Winnebago study. Using these numbers the total peak demand is 945,000 gallons per day, or 656.25 gallons per minute. The total number of connections for the Macy area is 462 thus the average peak-day demand per connection is 1.42 gallons per minute. The number of connections were assigned to the nodes in the model and using the above numbers the flow was determined for each node.

The next figures to determine were the peak hour demand flows. The figure 1.45 was used as the ratio between the peak-hour demand and the maximum-day demand. This number was obtained from p. 37 of AWWA Manual of Water Supply Practices - Distribution Network Analysis for Water Utilities AWWA M32, since no diurnal curve was provided. Therefore, the peak hour demands were obtained by multiplying the average-peak day demands by 1.45.

It was also necessary to determine the flows for the year 2040. The population of the Macy area is expected to increase to 10,327 by year 2040. Therefore the ratio between the population in the year 2040 to the year 2000 is 10,327/3,150 = 3.28. The average-peak day and peak hourly flows for the year 2040 were determined by multiplying the year 2000 figures by 3.28.

Fire Flow

Houses

The fire flow for nodes with houses was 750 U.S. gallons per minute for the area outside of the town of Macy. For houses in the town of Macy, 1000 U.S. gallons per minute was used for nodes with houses. The figure for houses outside the town of Macy was determined from AWWA Manual of Water Supply Practices - Distribution System Requirements for Fire Protection. AWWA M31 -1998 Table 1-5. 750 U.S. gallons per minute may be used for houses that are between 31 and 100 feet apart. It was reasoned that the houses in the outskirts of Macy would be sufficiently far apart to use this figure. The figure of 1000 U.S. Gallons per minute for houses within the town of Macy was determined from the Uniform Fire Code -1997 Division III Fire Protection Appendix III-A Fire-Flow Requirements for Buildings - Section 5.1 for One- and Two-Family Dwellings. The higher fire flow was used for houses in the town of Macy because they are closer to each other than the houses in the outskirts.

Other Buildings

The fire flow for other buildings was based on the area of the buildings. Appendix III-A of the 1997 Uniform Fire Code was used to determine the flows. It was assumed that type II-N and III-N structures are present. The area of the buildings was determined either from the DOQQ quad aerial photographs from the USGS or from the tribe.

Sizing of the Tanks

The tank volume consists of the following: the sum of operational storage, and the greater of Emergency or Standby Storage.

Operational Storage

Operational Storage was determined by using the diurnal curve from AWWA Distribution Network Analysis for Water Utilities - AWWA M32 - 1989 figure 2-4. It was determined that the storage came to 183 Gallons per Gallon per minute of average daily demand (assuming 24 hours of pumping). Using the Maximum Day Average Demand for the year 2040, (2150 GPM). The operational storage comes to 393,000gallons.

The operational storage was proportioned according to housing units served directly by the various tanks. Thus, the operational storage was allocated as follows: 21 % pressure zone 1 tank, 60% pressure zone 2 tank (including the Macy pressure zone without the Carl T. Curtis Health Center area), 11 % pressure zone 3 tank, and 8% Macy tank (Carl T. Curtis Health Center area only).

Emergency Storage

The standby storage is equal to 3 times the average daily flow. Using 150 gallons per person per day, and a present population of 3,150 with a growth rate of 3.28 for the year 2040 the average daily flow storage comes to:1,549,000 gallons. Three times this amount yields a value of 4.647,000 gallons of emergency storage required for the whole Macy area.

The emergency storage was also proportioned according to housing units the same as it was for operational storage.

Fire Flow Storage

The treatment plant tank supplies the fire flow for zones 1, 2, 3, and the Macy zone, excluding the Carl T. Curtis Health Center area, since they are all connected. This comes to 540,000 gal. for the largest building in all these zones, the Omaha Tribal Administration Building. The Macy storage tank will supply fire flow to the Carl T. Curtis Health Center. This volume is 330,000 gal.

Total Storage Required (Year 2040)

The Storage requirements for the system will be satisfied with the new tank arrangement as described in Table 6-9, with the fire flow requirements for the Carl T. Curtis Health center being provided entirely by the Macy storage tank.

V. Results

The hydraulic model studies were done for two different situations. The first was to determine what could be done for immediate improvements to the existing system. The second was to provide a possible layout to be used in the Needs Assessment for the year 2040.

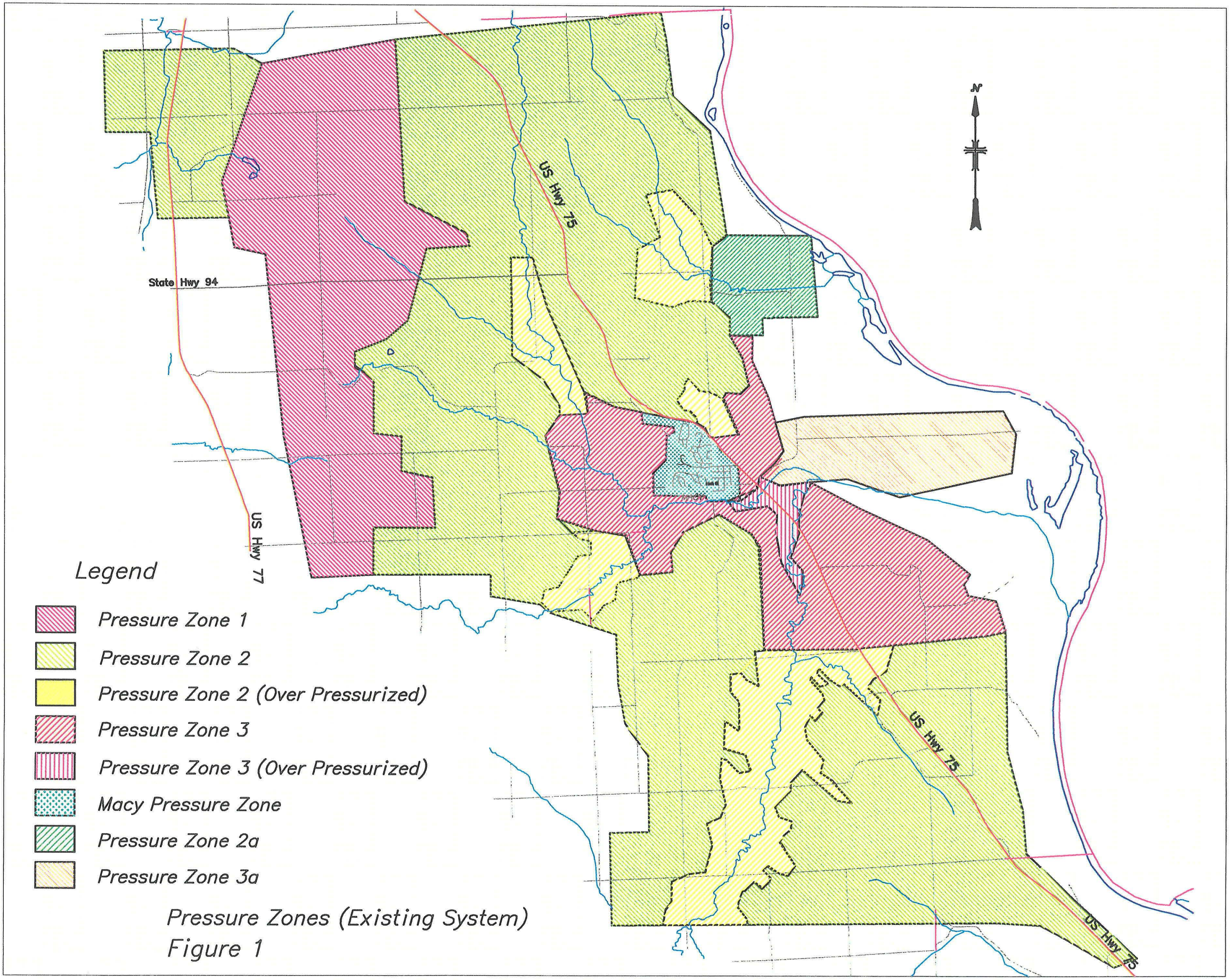
1. Improved Operational Pressure Zones, Modifying Settings and Locations of PRV's

Appendix C of the 1997 Review and Evaluation of Needs is a memorandum from Bob Jurenka (P.E. BOR-Denver) to Area Manager, Nebraska-Kansas Area Office dated January 8, 1997. The subject was "Water System Pressure Reducing Valve Network". This memorandum preliminarily reviewed locations and settings of the existing PRV's on the distribution system. This review showed that by modifying pressure zones, service pressures to both service connections experiencing too high pressures and too low pressures could be improved. The results of the model study confirmed this and further refined the suggested modifications.

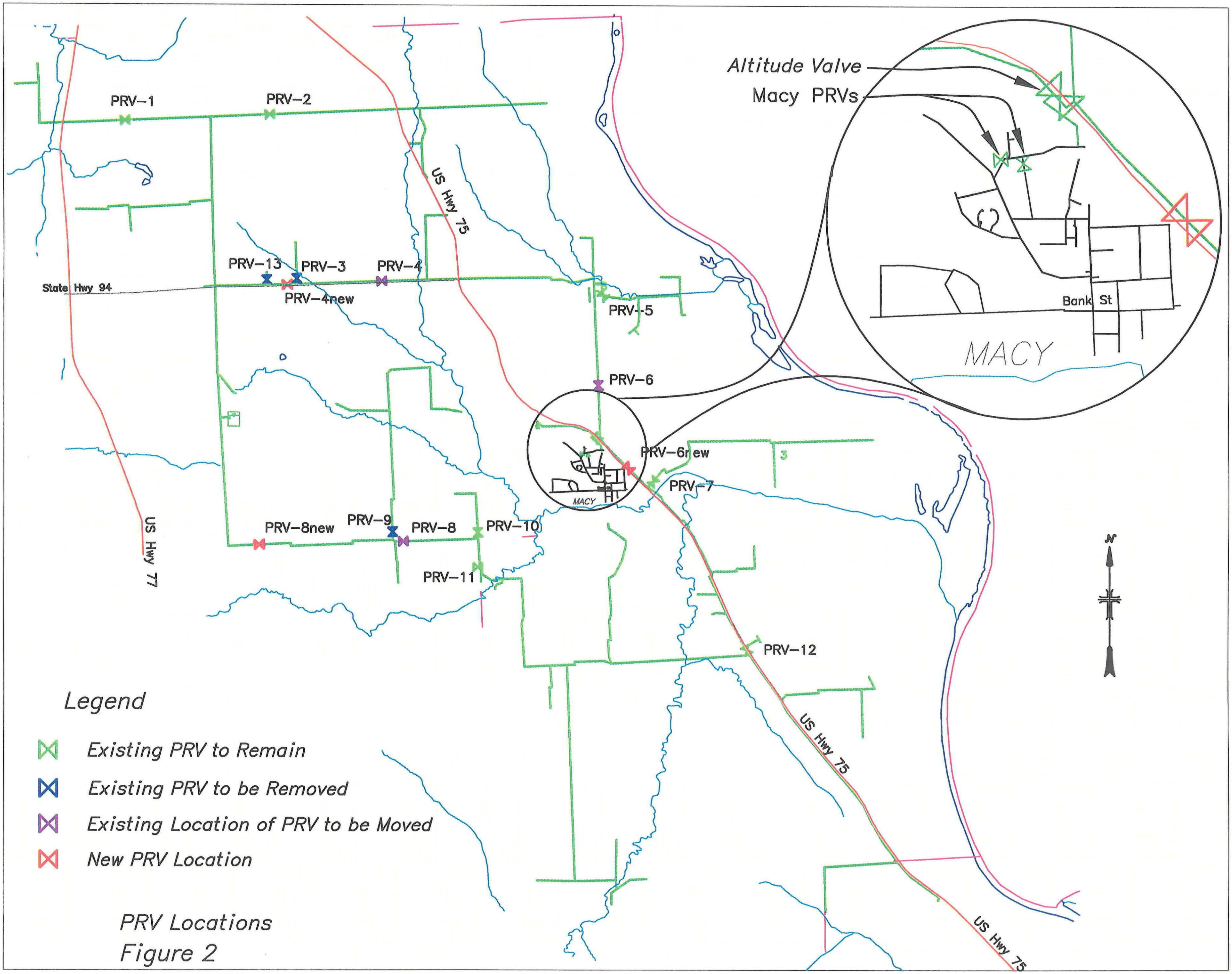
The aforementioned memorandum recommends modifications in the PRV locations and settings to improve the existing system's water delivery capability. The present system was analyzed to determine if PRV settings and locations could alleviate pressure deficit problems. Changing the size of pipe was not considered. Significant improvements to water delivery pressures can be made by relocating the PRV's and changing the PRV settings. However, completely acceptable conditions cannot be achieved.

In order to come up with recommendations for PRV locations and setting, pressure zones were identified based on the existing tank water levels and service connection elevations. Figure 1 shows the existing pressure zone areas. Some of the areas served by pressure zone 2 are lower in elevation than the established lower zone 2 boundary. These areas will be over pressured during low demand conditions and individual service connection PRVs may be required. Lower elevation areas to the east are shown as subzones of zones2 and 3. These areas are served by pipelines with PRVs to avoid over pressurizing the service connections.

Figure 2 shows suggested PRV locations. Moving PRV 4, 6, and 8 are recommended. Also, PRV 3, 9, and 13 are recommended to be removed. These recommendations are slightly different that the previous recommendations.



Pressure Zones (Existing System)
Figure 1



PRV Locations
Figure 2

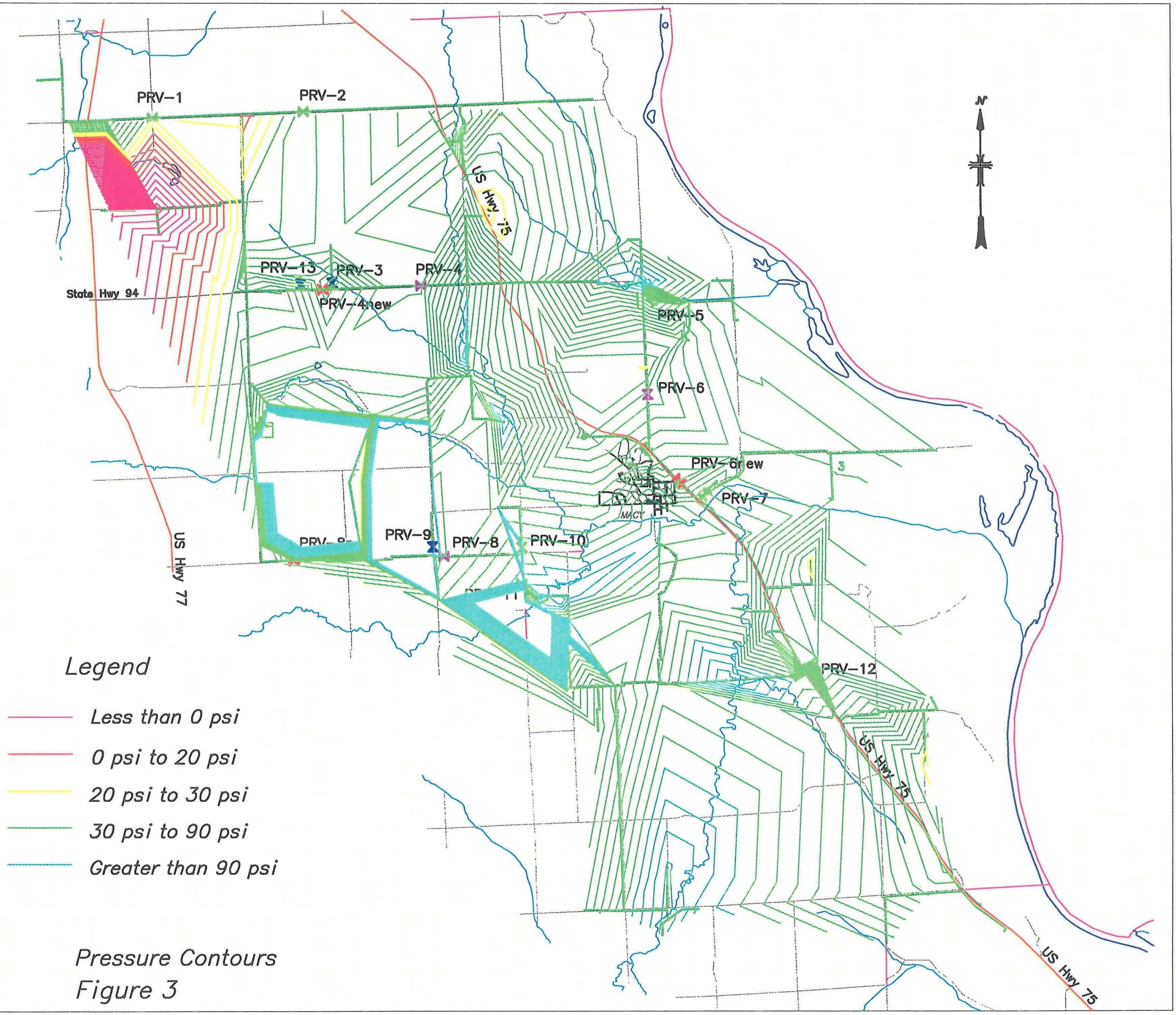
The recommended pressure settings are given in Table 2. Values are given for the HGL (hydraulic grade line) elevations that should be used. The pressure settings are the corresponding pressure values if the valve elevations shown are correct. The valve elevations need to be field verified before the recommended pressure setting are implemented.

Table 2
PRV Settings

PRV	Action	Elevation (ft)	HGL* Setting (ft)	Pressure ** Setting (psi)
PRV-1	Adjust Pressure	1340	1409	30
PRV-2	Adjust Pressure	1360	1440	35
PRV-3	Remove	—	—	---
PRV-4	Move	1250	1440	82
PRV-5	Adjust Pressure	1147	1257	48
PRV-6	Move	1165	1292	55
PRV-7	None	1107	1250	62
PRV-8	Move	1350	1440	39
PRV-9	Remove	---	—	---
PRV-10	None	1183	1375	83
PRV-11	None	1200	1335	59
PRV-12	Adjust Pressure	1200	1292	40
PRV-13	Remove	—	—	—

Note: If the valve is to be moved, the data is for the new location.
* HGL = Hydraulic Grade Line
** This is the pressure setting if the valve elevation is correct.

The hydraulic model run with all the recommendations included shows that all the problems with the system will not be solved. We believe that these recommendations are the best situation that can be achieved with a small amount of system modification. Figure 3 shows the results of the hydraulic analysis with these modifications. This figure shows contours of pressure in psi. The yellow and magenta contours show where pressures will still be low.



Pressure Contours
Figure 3

Two areas that experience deficient pressures for the present peak-hour flows are: the 2-inch line in the North-West part of the system, near Walthill and the 4" pipeline that tees off of the main 6" pipeline in the south-east part of the system (South of the town of Macy).

The pressure deficit for the 2-inch pipeline in the northwest part of the system cannot be alleviated by changing PRV settings or relocating them since there are excessive friction losses in the 2-inch line and therefore it is not adequate to deliver the flows.

The pressure deficit for the 4" line that tees off of the main 6" pipeline in the southeast part of the system was alleviated by relocating PRV 6 from a position just North of Macy to a position just to the east of Macy on the 8" pipeline. Since PRVs 6 (new position) and 12 both serve the same pressure zone they should be set to the same hydraulic gradeline. The pressure setting for PRV 12 was reduced from an HGL elevation of 1400 (according to "Review and Evaluation of Needs, Water and Wastewater Systems The Omaha Tribe of Nebraska" October 1997) to 1292. This reduction in pressure setting alleviated the pressure deficit by decreasing the flow in east-west line just south of PRV 12.

Many areas will not support fire flow.

2. System Design to Meet Year 2040 Needs.

Distribution System

To meet year 2040 needs the water supply system will need extensive reconfiguration. Several system configurations might be possible to meet year 2040 demands. To determine the configuration that would best meet the needs at the least cost will require comparative designs and cost estimates. The designs must be at a greater level of detail than the current design but do not need to be at a construction design level. This level of design required is usually called feasibility level.

Three potential system configurations were identified in this study. The first was basically keeping the existing layout and upsizing the components until the hydraulic criteria were satisfied. This configuration also included some additional pipelines to create some additional loops within pressure zones. The second configuration identified was to slightly upsize the existing loop and make it a high pressure supply line by taking out the PRVs. This would provide high enough pressure throughout the service area and lower elevation areas would be supplied the proper pressure with the use of PRVs on the branch pipelines. The third configuration was to keep the existing main loop concept, slightly upsized, with PRVs. The system storage would be distributed by pressure zone. Direct connections would be provided from the upper pressure zone to the distribution areas requiring higher elevation service connections. This third configuration also included some additional looping in pressure zones. An appraisal level design was done for the first and third configuration. The third configuration was the one selected for the cost estimate for the needs assessment study.

Figure 4 shows the system layout used for the year 2040 cost estimate.

The characteristics of this system layout start with the criteria that any pipeline supplying fire flow must be 6-inches or larger. In a few outlying areas smaller pipelines were retained. No fire hydrants were planned in these locations. The main 8-inch loop of the existing system was mostly retained. This loop keeps the PRV locations as recommended for the immediate improvements discussed earlier. A small portion of the west area of the main loop was upsized to supply water to the northern areas. The pipe main extending to the north of the loop was upsized and in the extreme northwest area a loop was created. This loop required an additional PRV, (PRV-A1) to control pressures in that area. PRV-A1 and PRV-1 must be set to the same HGL elevation. A new loop was created north of the main loop by adding a short pipeline and the pipe diameter in that area was increased.

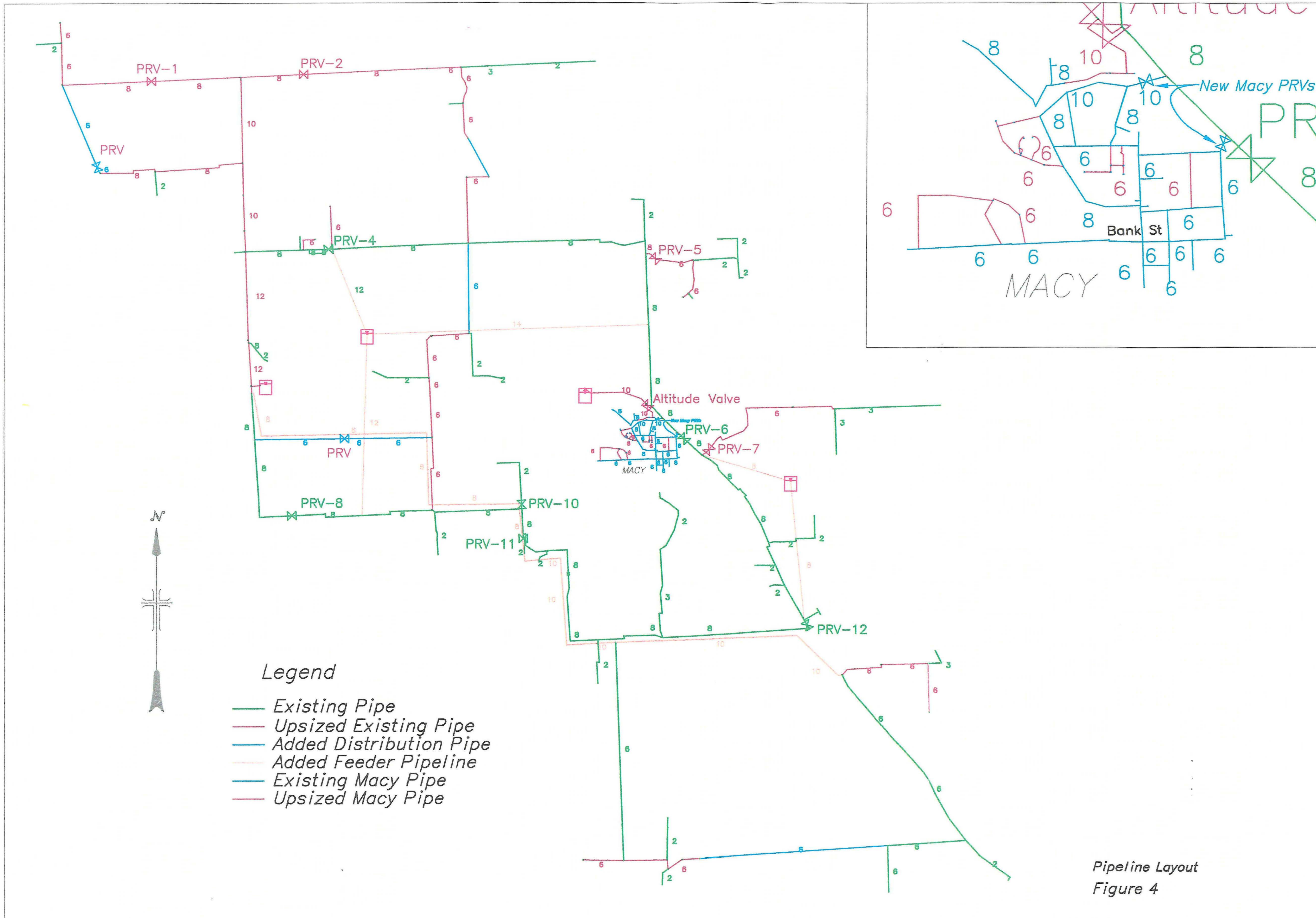
A new tank was added to pressure zone 2. This allowed meeting pressure needs in that area and required additional feeder pipelines for connecting the tank and looping. A new PRV, (PRV-A2) was added upstream of the tank. PRVs 2, 4, 8, and A2 must have the same HGL setting. The far southeast portion of the system is at approximately the same elevation as pressure zone 1. The pipe in this area was increased in size and additional pipe added to create a loop. In addition, existing system connections were removed for this loop and a separate zone 1 feeder pipeline was added. Storage and related connecting feeder pipelines were added in zone 3.

The town of Macy presented additional problems. The existing ground tank is fed from pressure zone 2 and the tank level is controlled by a altitude valve. This tank was installed initially to provide a reliable source of water for the health center. The proposed layout disconnects the majority of the town from the tank and allows the tank to serve only the health center and a very small portion of the northwest portion of the town which is at a higher elevation. The remainder of the town of Macy is also served from pressure zone 2. However, with a direct connection to the main loop, the town of Macy will be over pressurized. To solve this, PRVs were added to the two Macy connections to the main loop. The entire town of Macy including that portion served by the Macy tank are considered in the Macy pressure zone, the fourth zone. All of the pipe in the town of Macy was sized to a minimum diameter of 6-inches. A simplified pressure zone layout is shown in figure 5.

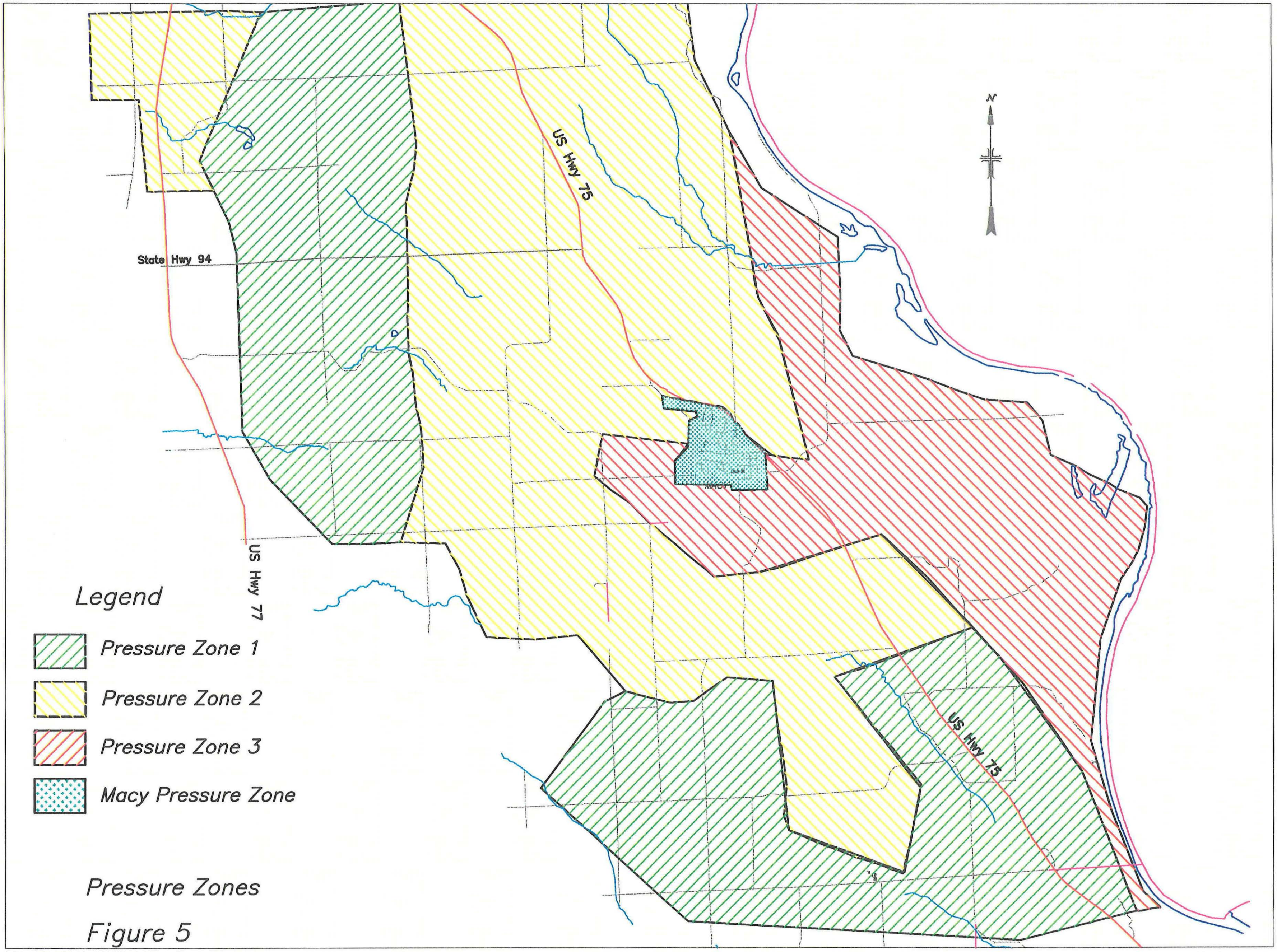
Table 3 shows the proposed tank elevations, PRV settings, and pressure zones.

Table 3
Year 2040 Elevations and Settings

	Tank Water Surface Elevations (ft)	PRV HGL Settings (ft)
Pressure Zone 1 **Ground Surface Elev. 1350 and greater**		
Water Treatment Plant Tank	1539 to 1559	
PRV-1		1479
PRV-A1		1479
PRV-2		1440
PRV-4		1440
PRV-A2		1440
PRV-8		1440
Pressure Zone 2 **Ground Surface Elev. 1250 to 1350**		
Pressure Zone 2 Tank	1420 to 1440	
PRV-5		1257
PRV-6		1340
PRV-10		1375
PRV-11		1335
PRV-12		1340
PRV-Macy 1		1270
PRV-Macy 2		1270
Altitude Valve		1352
Macy Tank	1322 to 1352	
Pressure Zone 3 **Ground Surface Elev. 1250 to 1350**		
Pressure Zone 3 Tank	1320 to 1340	
PRV-7		1250



Pipeline Layout
Figure 4



Pressure Zones

Figure 5

ARSENIC

FACT SHEET

See related Fact Sheets: Acronyms & Abbreviations; Glossary of Terms; Cost Assumptions; Raw Water Composition; and WaTER Program.

1. CONTAMINANT DATA

A. Chemical Data: Arsenic (As), inorganic element, semi-metal, stable and sparingly soluble, atomic number 33, atomic weight 74.92. Inorganic oxidation states (in water): +3 (Arsenite-most toxic) and +5 (Arsenate). As has no taste, smell, or color in water.

B. Source in Nature: As is a naturally occurring element found in soils, surface water, and groundwater, with the highest natural concentrations of As usually found in areas of geothermal activity. However, very little is known about the geologic, hydrologic, and biogeochemical conditions which favor dissolution of arsenic into groundwaters. As is found in varying levels in most food groups with the major sources being marine plants and shellfish. In industry, As is used in the production of pesticides and herbicides, from cotton and wool processing, as a wood preservative, a feed additive, in various metal alloys, and in mining. As can result from pesticide runoff; from seepages from hazardous waste sites; and from areas near cemetaries where burials were conducted from about 1880 to 1910 when As was used as an embalming fluid. As is ingested by either drinking contaminated water, eating food that has been washed in the water, or ingestion in small doses by way of the human food chain.

C. SDWA Limits (currently under review): MCL is 0.05 mg/L. USEPA is scheduled to propose revised standard by 1/1/2000 and promulgate final rule by 1/1/2001.

D. Health Effects of Contamination: As is a known carcinogen and poisoning can be either acute or chronic. As is a teratogen, meaning it can enter the metabolic system of unborn babies. Acute poisoning results from ingestion of large quantities of As at one time resulting in stomach pain, nausea, vomiting, or diarrhea which may lead to shock, coma, and even death. Chronic poisoning occurs over long periods of time often resulting in skin lesions, thickening or discoloration of the skin, and numbness in the feet and hands (neuritis). As poisoning has been linked to higher rates of cancer of the lungs, bladder, kidney, liver, and skin. Young children, the elderly, unborn babies, and people with long-term illnesses are at greater risk of As poisoning.

2. REMOVAL TECHNIQUES

Optimal As removal is dependent on many individual water characterisitics, including source water pH, TDS, sulfides, other salts, quantity of water to treat, and amount of As present. As^{+5} is most effectively removed, therefore As^{+3} may be converted through preoxidation with Cl_2, $FeCl_3$, or $KMnO_4$ to As^{+5}. Preoxidation with Cl_2 may create undesireable concentrations of disinfection by-products.

A. USEPA BAT (currently under review): Not yet specified in regulation; however, technologies with the highest removal efficiencies are coagulation and filtration; lime softening; reverse osmosis; or activated alumina.

- Coagulation and filtration uses the conventional treatment processes of chemical addition, coagulation, and dual media filtration. Benefits: low capital costs for proven, reliable process. Limitations: operator care required with chemical usage; sludge disposal.
- Lime softening for As treatment uses two types of chemical additions. First, $Ca(OH)_2$ is added in sufficient quantity to raise the pH to about 10 to precipitate carbonate hardness. Next, Na_2CO_3 is added to precipitate noncarbonate hardness. Benefits: proven and reliable. Limitations: operator care required with chemical usage; sludge disposal.
- RO uses a semipermeable membrane, and the application of pressure to a concentrated solution which causes water, but not suspended or dissolved solids, to pass through the membrane. Benefits: produces highest As removal, along with high quality water. Limitations: cost; pretreatment/feed pump requirements; concentrate disposal.
- AA uses extremely porous and highly adsorptive aluminum ore media to adsorb As^{+5}. Benefits: containment of As^{+5} in adsorption bed. Limitations: highly selective to As^{+5} resulting in frequent regeneration; results in creation of hazardous waste requiring disposal. AA cost curves will be included in a future revision.

B. Alternative Methods of Treatment: Ion exchange can remove As however efficieny is affected by SO_4^{-2}, TDS, Se, F^-, and NO_3^-. Electrodialysis reversal can achieve removal of As at about 80%. Nanofiltration can achieve removal of As at about 90%. In the presence of dissolved Fe and Mg, As will co-precipitate and can be removed with Greensand or other specialized Fe and Mg filtration media.

C. Safety and Health Requirements for Treatment Processes: Personnel involved with demineralization treatment processes should be aware of the chemicals being used (MSDS information), the electrical shock hazards, and the hydraulic pressures required to operate the equipment. General industry safety, health, and self protection practices should be followed, including proper use of tools.

3. BAT PROCESS DESCRIPTION AND COST DATA

General Assumptions: Refer to: Raw Water Composition Fact Sheet for ionic concentrations; and Cost Assumptions Fact Sheet for cost index data and process assumptions. All costs are based on *ENR*, PPI, and BLS cost indices for February 1999. General sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal are not included.

3A. Coagulation and Filtration:

Process - Coagulation and filtration uses the conventional chemical and physical treatment processes of chemical addition, rapid mix, coagulation, flocculation, and dual media filtration. Chemical coagulation and flocculation consists of adding a chemical coagulant combined with mechanical flocculation to allow fine suspended and some dissolved solids to clump together (floc). $Fe_2(SO_4)_3$ has been proven to be the most effective coagulant for As^{+5} removal. Filtration provides final removal by dual media filtering of all floc and suspended solids.

Pretreatment - Preoxidation to convert As^{+3} to As^{+5}. Jar tests to determine optimum pH for coagulation, and resulting pH adjustment, may be required.

Maintenance - A routine check of chemical feed equipment is necessary several times during each work period to prevent clogging and equipment wear, and to ensure adequate chemical supply. All pumps, valves, and piping must be regularly checked and cleaned to prevent buildup of carbonate scale, which can cause plugging and malfunction. Routine checks of contaminant buildup in the filter is required, as well as filter backwash. Recharging or clean installation of media is periodically required.

Waste Disposal - Filter backwash and spent material require approved disposal.

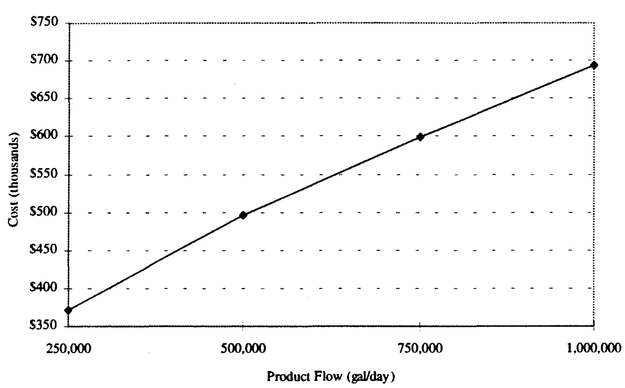
Advantages -

- Lowest capital costs for larger systems.
- Lowest overall operating costs for larger systems.
- Proven and reliable.
- Most effective for As^{+5}.

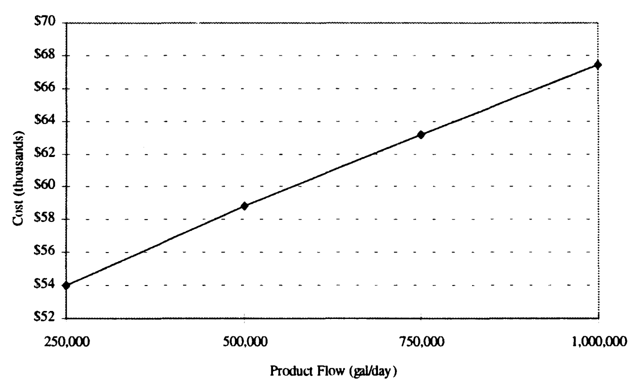
Disadvantages -

- Not appropriate for smaller systems.
- Operator care required with chemical handling.
- Produces high As-contaminated sludge volume.
- High or low pH reduces treatment efficiency; secondary treatment may be required.

BAT Equipment Cost*



BAT Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal. Costs are presented for direct filtration (coagulation and flocculation plus filtration). Costs for coagulation and filtration would be less since flocculation is omitted.

3B. Lime Softening:
Process - Lime softening uses chemical additions followed by an upflow SCC to accomplish coagulation, flocculation, and clarification. Chemical additions include $Ca(OH)_2$ to precipitate carbonate and Na_2CO_3 to precipitate noncarbonate hardness. In the upflow SCC, coagulation and flocculation (agglomeration of the suspended material, including As, into larger particles), and final clarification occur. In the upflow SCC, the clarified water flows up and over the weirs, while the settled particles are removed by pumping or other collection mechanisms (i.e. filtration).

Pretreatment - Jar tests to determine optimum pH for coagulation, and resulting pH adjustment, may be required. Optimum pH is about 10.5 or higher.

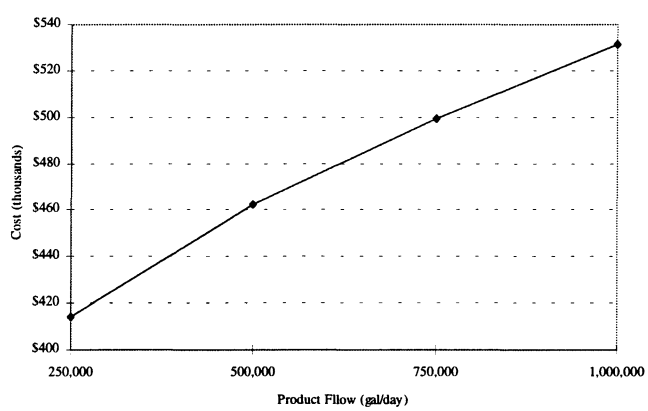
Maintenance - A routine check of chemical feed equipment is necessary several times during each work period to prevent clogging and equipment wear, and to ensure adequate chemical supply. All pumps, valves, and piping must be regularly checked and cleaned to prevent buildup of carbonate scale, which can cause plugging and malfunction. Similar procedures also apply to the sludge disposal return system, which takes the settled sludge from the bottom of the clarifier and conveys it to the dewatering and disposal processes.

Waste Disposal - There are three disposal options for As-contaminated sludges: incineration, landfill, and ocean disposal.

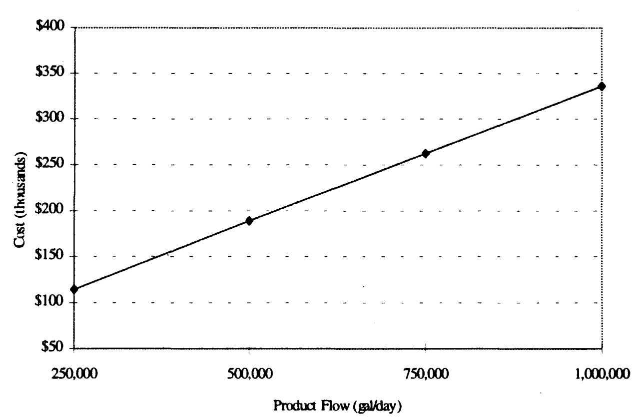
Advantages -
- Other heavy metals are also precipitated; reduces corrosion of pipes.
- Proven and reliable.
- Low pretreatment requirements.

Disadvantages -
- Operator care required with chemical handling.
- Produces high As-contaminated sludge volume.
- Secondary treatment may be required.
- Waters high in sulfate may cause significant interference with removal efficiencies.

BAT Equipment Cost*



BAT Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3C. Reverse Osmosis:

Process - RO is a physical process in which contaminants are removed by applying pressure on the feed water to direct it through a semipermeable membrane. The process is the "reverse" of natural osmosis (water diffusion from dilute to concentrated through a semipermeable membrane to equalize ion concentration) as a result of the applied pressure to the concentrated side of the membrane, which overcomes the natural osmotic pressure. RO membranes reject ions based on size and electrical charge. The raw water is typically called feed; the product water is called permeate; and the concentrated reject is called concentrate. Common RO membrane materials include asymmetric cellulose acetate or polyamide thin film composite. Common membrane construction includes spiral wound or hollow fine fiber. Each material and construction method has specific benefits and limitations depending upon the raw water characteristics and pretreatment. A typical large RO installation includes a high pressure feed pump, parallel 1st and 2nd stage membrane elements (in pressure vessels); valving; and feed, permeate, and concentrate piping. All materials and construction methods require regular maintenance. Factors influencing membrane selection are cost, recovery, rejection, raw water characteristics, and pretreatment. Factors influencing performance are raw water characteristics, pressure, temperature, and regular monitoring and maintenance.

Pretreatment - RO requires a careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling, or other membrane degradation. Removal of suspended solids is necessary to prevent colloidal and bio-fouling, and removal of dissolved solids is necessary to prevent scaling and chemical attack. Large installation pretreatment can include media filters to remove suspended particles; ion exchange softening or antiscalant to remove hardness; temperature and pH adjustment to maintain efficiency; acid to prevent scaling and membrane damage; activated carbon or bisulfite to remove chlorine (postdisinfection may be required); and cartridge (micro) filters to remove some dissolved particles and any remaining suspended particles.

Maintenance - Monitor rejection percentage to ensure As removal below MCL. Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Use of monitoring equations to track membrane performance is recommended. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove fouling and scaling. The system is flushed and returned to service. $NaHSO_3$ is a typical caustic cleaner. RO stages are cleaned sequentially. Frequency of membrane replacement dependent on raw water characteristics, pretreatment, and maintenance.

Waste Disposal - Pretreatment waste streams, concentrate flows, and spent filters and membrane elements all require approved disposal.

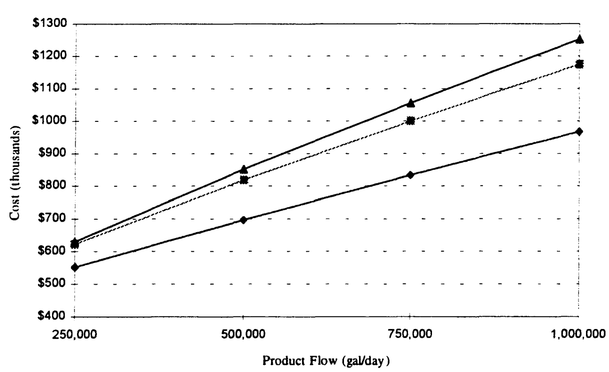
Advantages -

- Produces highest As removal; produces highest quality water.
- Can effectively treat wide range of dissolved salts and minerals, turbidity, health and aesthetic contaminants, and certain organics; some highly-maintained units are capable of treating biological contaminants.
- Low pressure (<100 psi), compact, self-contained, single membrane units are available for small installations.

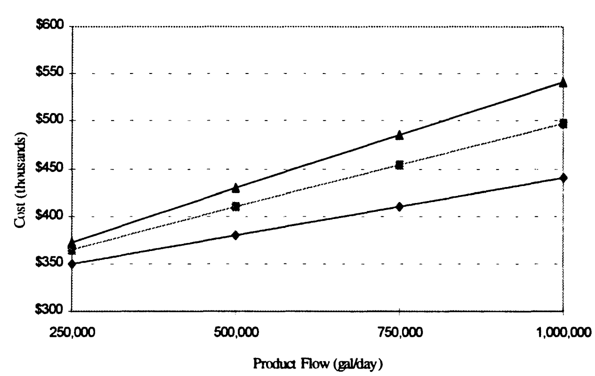
Disadvantages -

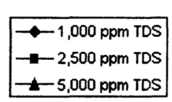
- Relatively expensive to install and operate.
- Frequent membrane monitoring and maintenance; monitoring of rejection percentage for As removal.
- Pressure, temperature, and pH requirements to meet membrane tolerances. May be chemically sensitive.

BAT Construction Cost*



BAT Annual O&M Cost*





*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3D. Activated Alumina:

Process - AA uses an extremely porous media in a physical/chemical separation process known as adsorption, where molecules adhere to a surface with which they come into contact, due to forces of attraction at the surface. AA is a media made by treating aluminum ore so that it becomes porous and highly adsorptive, and is available in powder, pellet, or granule form. The media is activated by passing oxidizing gases through the material at extremely high temperatures. This activation process produces the pores that result in such high adsorption properties.

Contaminated water is passed through a cartridge or canister of AA. The media adsorbs the contaminants. The adsorption process depends on the following factors: 1) physical properties of the AA, such as method of activation, pore size distribution, and surface area; 2) the chemical/electrical nature of the alumina source or method of activation and the amount of oxygen and hydrogen associated with them, such that as the alumina surfaces become filled the more actively adsorbed contaminants will displace the less actively adsorbed ones; 3) chemical composition and concentration of contaminants effect adsorption, such as size, similarity, and concentration; 4) the temperature and pH of the water, in that adsorption usually increases as temperature and pH decreases; and 5) the flowrate and exposure time to the AA, in that low contaminant concentration and flowrate with extended contact times increase the media life. AA devices include: pour-through for treating small volumes; faucet-mounted (with or without by-pass) for POU; in-line (with or without by-pass) for treating large volumes at several faucets; and high-volume commercial units for treating community water supply systems. Careful selection of alumina to be used is based on the contaminants in the water and manufacturer's recommendations.

Pretreatment - With bacterially unstable waters, filtration and disinfection prior to AA treatment may be required. With high TSS waters, prefiltration may be required. If treatment is based on flowrate, a water meter may be required to register and total flowrates.

Maintenance - Careful monitoring and testing to ensure contaminant removal is required. Regular replacement of media may be required and is based on contaminant type, concentration, and rate of water usage. The manufacturer's recommendations for media replacement should be consulted. Recharging by backwashing or flushing with hot water (145°F) may release the adsorbed chemicals, however this claim is inconclusive. Periodic cleaning with an appropriate regenerant such as $Al_2(SO_4)_3$ acid, and/or caustic will extend media life. With bacterially unstable waters, monitoring for bacterial growth is required because the adsorbed organic chemicals are a food source for some bacteria. Flushing is required if the AA filter is not used for several days, and regular backwashing may be required to prevent bacterial growth. Perform system pressure and flowrate checks to verify backwashing capabilities. Perform routine maintenance checks of valves, pipes, and pumps.

Waste Disposal - Backwash/flush water disposal is required if incorporated. Disposal of spent media may be the responsibility of a contractor providing media replacement services.

Advantages -
- Well established.
- Suitable for some organic chemicals, some pesticides, and THMs.
- Suitable for home use, typically inexpensive, with simple filter replacement requirements.
- Improves taste and smell; removes chlorine.

Disadvantages -
- Effectiveness is based on contaminant type, concentration, and rate of water usage.
- Bacteria may grow on alumina surface.
- Adequate water flow and pressure required for backwashing/flushing.
- Requires careful monitoring.

Costs - The BAT costs curves for AA equipment and annual operation and maintenance are being developed and will be included in a future revision.

IRON and MANGANESE

FACT SHEET

See related Fact Sheets: Acronyms & Abbreviations; Glossary of Terms; Cost Assumptions; Raw Water Composition; and WaTER Program.

1. CONTAMINANT DATA

A. Chemical Data: Iron (Fe), atomic number: 26, atomic weight: 55.847; and Manganese (Mn), atomic number: 25, atomic weight: 54.938. Both minerals are soluble in their reduced state (+2), and insoluble in their oxidized state (+3).

B. Source in Nature: Both minerals are naturally occurring and present in varying quantities in most soils and rocks, and in surface and groundwaters. The ferrous and manganous (+2) soluble ions are present in water and when exposed to the oxygen in air (oxidized) turn into the ferric and manganic (+3) insoluble ions which will precipitate. While the soluble forms are usually colorless, the ferric precipitate is usually reddish-brown, and the manganic precipitate is usually brownish-black. Additionally, Fe can be added to a distribution system by corroded water pipes, and Mn can occur as a result of landfills or other waste disposal which acidifies groundwater and reduces its oxygen content.

C. SDWA Limits: SMCL for Fe is 0.3 mg/L, and 0.05 mg/L for Mn.

D. Health Effects of Contamination: As secondary drinking water contaminants, neither Fe or Mn pose any health risks, and in small concentrations are essential to human health. Higher concentrations will give water a medicinal or metallic taste; are a nuisance and will cause staining problems in laundry and plumbing fixtures; may precipitate and clog distribution piping; or may cause the development of Fe or Mn bacteria, a harmless bacteria that may give water an offensive taste or color but still is safe to drink.

2. REMOVAL TECHNIQUES

A. USEPA BAT: As secondary drinking water contaminants, BATs are not assigned.

B. Alternative Methods of Treatment: The most common treatment process for removing Fe and Mn is oxidation with $KMnO_4$ followed by greensand filtration. Oxidation of Fe^{+2} and Mn^{+2} ions with $KMnO_4$ occurs after a brief retention time, when an insoluble solid particle is formed which can be removed by the greensand filter. Benefits: proven; reliable. Limitations: chemical dosages and metering required.

Alternative oxidation processes include aeration with oxygen, chlorine, ozone, and hydrogen peroxide. Simple aeration may be the most economical, but may not be as effective.

In-home water softeners may be used when centralized treatment is not available, when the combined Fe and Mn concentrations are below 1 mg/L, and when the Fe and Mn are still in their soluble reduced states (+2).

C. Related WTTP Publications: WTTP Report #8, "Lake Havasu City Water Treatment Research Study." This report pilot tested two processes, including $KMnO_4$ oxidation followed by greensand filtration and nanofiltration to remove Mn^{+2}.

D. Safety and Health Requirements for Treatment Processes: Personnel involved with demineralization treatment processes should be aware of the chemicals being used (MSDS information), the electrical shock hazards, and the hydraulic pressures required to operate the equipment. General industry safety, health, and self protection practices should be followed, including proper use of tools.

3. BAT PROCESS DESCRIPTION AND COST DATA

General Assumptions: Refer to: Raw Water Composition Fact Sheet for ionic concentrations; and Cost Assumptions Fact Sheet for cost index data and process assumptions. All costs are based on *ENR*, PPI, and BLS cost indices for February 1999. General sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal are not included.

Bureau of Reclamation, Technical Service Center
Water Treatment Engineering and Research Group, D-8230
PO Box 25007, Denver CO 80225 (303) 445-2246

Revision Date: 9/30/99

3A. Oxidation with $KMnO_4$ followed by Greensand Filtration:

Process - Oxidation is a chemical process and filtration is a physical process. $KMnO_4$ is added to the raw water which oxidizes the soluble Fe and Mn into insoluble ferric and manganic oxides which will settle and are filterable. $KMnO_4$ (without prechlorination) is usually used according to the following stoichiometry:

0.94 mg/L $KMnO_4$ per mg/L of Fe^{+2} removed and
1.92 mg/L $KMnO_4$ per mg/L of Mn^{+2} removed.

After the oxidation process is complete, the greensand filter removes the insoluble material. Greensand is a green clay material whose active mineral is glauconite, a natural zeolite with ion exchange properties. Greensand is layered loosely to form the media bed. As water passes through the filter, any remaining soluble Fe and Mn are pulled from the solution by the ion exchange properties of the greensand, and the insoluble Fe and Mn are filtered by the greensand media. Periodically, the greensand media is regenerated by continually feeding $KMnO_4$ just before the filter to recharge the glauconite, regenerating the ion exchange properties. Additionally, periodic backwashing of the filter media to remove the Fe and Mn is required.

Pretreatment - Feeding chlorine ahead of the $KMnO_4$ can make the process more economical. $Ca(OH)_2$ addition may be necessary to achieve the desired pH level or to remove CO_2.

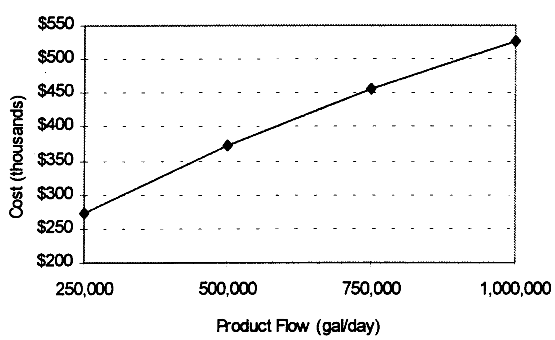
Maintenance - Tests should be conducted at least monthly on samples of the water entering the filter to ensure the Fe and Mn are in their insoluble oxidized states (+3) and to verify $KMnO_4$ dosages. Regeneration and backwashing should be done in accordance with the greensand media manufacturer's recommendations. Perform system pressure and flowrate checks to verify backwashing capabilities. Perform routine maintenance checks of valves, pipes, and pumps.

Waste Disposal - Filter regeneration and backwash waters, and spent media require approved disposal.

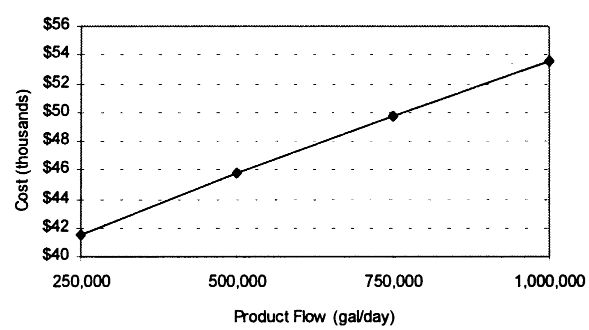
Advantages -
- Low cost.
- Efficient; proven; reliable.

Disadvantages -
- $KMnO_4$ dosage must be exact; bench scale tests are required to determine exact dosage; monitoring of performance to ensure proper dosage.
- Sufficient pressure and flowrate required for backwashing; backwash disposal required.
- Regeneration required; regeneration disposal required.

BAT Equipment Cost*



BAT Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

NITRATE/NITRITE

FACT SHEET

See related Fact Sheets: Acronyms & Abbreviations; Glossary of Terms; Cost Assumptions; Raw Water Composition; and WaTER Program.

1. CONTAMINANT DATA

A. Chemical Data: Nitrate (NO_3^-) and Nitrite (NO_2^-) are inorganic anions. NO_3^- has an oxidation state of elemental nitrogen gas, molecular weight 62.00. NO_3^-/NO_2^- are water-soluble, colorless, odorless, and tasteless. NO_3^- is a macro-nutrient that is an essential part of proteins manufactured by bacteria and algae in water. NO_2^- is a nitrogen-oxygen radical.

B. Source in Nature: Nitrogen is a naturally occurring gas in the earth's atmosphere, at approximately 78% by volume. NO_3^- are naturally occurring nitrogen-oxygen units which combine with various organic and inorganic compounds in both water and plants. Natural sources of NO_3^- in waters include direct fixation of nitrogen gas by algae and bacteria, photochemical fixation, electrical discharge, and oxidation of ammonia and nitrite by nitrifying bacteria. NO_3^- are used by bacteria to form amino acids used in the synthesis of proteins for all plants and animals. Elevated levels of NO_3^- in today's surface and groundwaters are a result of overuse of nutrient-rich chemical fertilizers, municipal and industrial wastewaters, refuse dumps, and improper disposal of human and animal wastes. Both NO_3^- and NO_2^- are added to meat products as preservatives. NO_3^- are reduced to NO_2^- in the saliva of the mouth and upper GI tract.

C. SDWA Limits: The MCL for NO_3^- as nitrogen is 10 mg/L (for NO_3^- as Nitrate, the MCL is 45 mg/L). The MCL/MCLG for NO_2^- is 1 mg/L .

D. Health Effects of Contamination: The health effects of excessive NO_3^-/NO_2^- include Methemoglobinemia (blue baby syndrome - oxygen deprivation in infants under 6 months), and is generally considered a concern for children under age 5. Older children and adults are generally only susceptible if they also experience enzyme or erythrocyte metabolism deficiency, chronic anemia, or gastric diseases.

2. REMOVAL TECHNIQUES

A. USEPA BAT: Ion exchange, reverse osmosis, or electrodialysis.

- IX uses charged anion resin to exchange acceptable ions from the resin for undesirable NO_3^- in the water. Benefits: effective; well developed. Limitations: restocking of salt supply; regular regeneration; competing ions.
- RO uses a semipermeable membrane, and the application of pressure to a concentrated solution which causes water, but not suspended or dissolved solids, to pass through the membrane. Benefits: produces high quality water. Limitations: cost; pretreatment/feed pump requirements; concentrate disposal.
- ED uses semipermeable membranes in which ions migrate through the membrane from a less concentrated to a more concentrated solution as a result of the ions' representative attractions to direct electric current. Benefits: contaminant specific removal. Limitations: electrical requirements; concentrate disposal.

B. Alternative Methods of Treatment: Biological denitrification or chemical reduction; distillation; dilution by blending with higher quality water; or water source relocation. Note: Boiling water concentrates nitrates.

C. Related WTTP Publications:
1) WTTP Report #14, "Brighton ED Testing with Asahi Monovalent Selective Membranes." This report summarizes the pilot testing of an ED water treatment system with special membranes tailored for nitrate removal from water.
2) WTTP Report #15, "Maricopa Groundwater Treatment Study." This report summarizes the field study performed to determine the suitability of several water treatment processes, including RO, ED, and NF, on groundwater containing high levels of nitrate, chloride, and TDS; recommends the use of NF or ED for study area.

D. Safety and Health Requirements for Treatment Processes: Personnel involved with demineralization treatment processes should be aware of the chemicals being used (MSDS information), the electrical shock hazards, and the hydraulic pressures required to operate the equipment. General industry safety, health, and self protection practices should be followed, including proper use of tools.

3. BAT PROCESS DESCRIPTION AND COST DATA

General Assumptions: Refer to: Raw Water Composition Fact Sheet for ionic concentrations; and Cost Assumptions Fact Sheet for cost index data and process assumptions. All costs are based on *ENR*, PPI, and BLS cost indices for February 1999. General sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal are not included.

3A. Ion Exchange:
Process - IX is a reversible chemical process in which ions from an insoluble, permanent, solid resin bed are exchanged for ions in water. The process relies on the fact that water solutions must be electrically neutral, therefore ions in the resin bed are exchanged with ions of similar charge in the water. As a result of the exchange process, no reduction in ions is obtained. In the case of NO_3^-/NO_2^-, operation begins with a fully recharged resin bed, having enough Cl^- or OH^- ions to carry out the anion exchange. Usually polymer resin bed is composed of millions of medium sand grain size, spherical beads. As water passes through the resin bed, the Cl^- or OH^- anions are released into the water, being substituted or replaced with NO_3^- /NO_2^- anions (ion exchange). When the resin becomes exhausted of Cl^- or OH^- ions, the bed must be regenerated by passing a strong, usually NaCl (or KCl), solution over the resin bed, displacing the NO_3^-/NO_2^- ions with Cl^- ions. Current resins are not completely NO_3^-/NO_2^- selective and may remove other anions, such as SO_4^{-2}, before removing the nitrate compounds. Therefore, NO_3^-/NO_2^- ion exchange requires careful consideration of the complete raw water characteristics. Typically, NO_3^- /NO_2^- ion exchange utilizes a Cl^- or OH^-, strongly basic anion resin bed.

Pretreatment - Guidelines are available on accepted limits for pH, organics, turbidity, and other raw water characteristics. Pretreatment may be required to reduce excessive amounts of TSS which could plug the resin bed, and typically includes media or carbon filtration.

Maintenance - Depending on raw water characteristics and NO_3^-/NO_2^- concentration, the resin will require regular regeneration with a NaCl solution. Preparation of the NaCl solution is required. Frequent monitoring is required to ensure nitrate removal. If utilized, filter replacement and backwashing will be required.

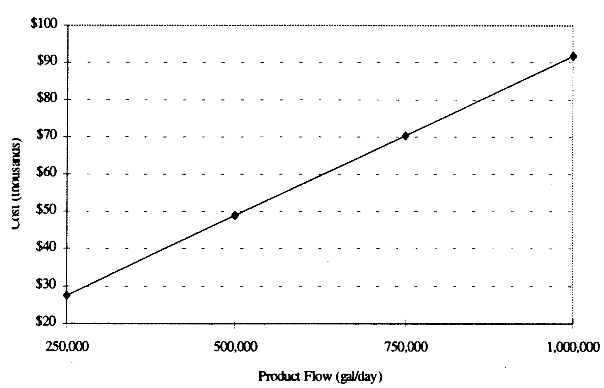
Waste Disposal - Approval from local authorities is usually required for the disposal of concentrate from the regeneration cycle (highly concentrated NO_3^-/NO_2^- solution); occasional solid wastes (in the form of broken resin beads) which are backwashed during regeneration; and if utilized, spent filters and backwash waste water.

Advantages -
- Ease of operation; highly reliable.
- Lower initial cost; resins will not wear out with regular regeneration.
- Effective; widely used.
- Suitable for small and large installations.

Disadvantages -
- Does not completely eliminate all NO_3^-/NO_2^-.
- Requires frequent monitoring for nitrate removal.
- Requires salt storage.
- Strongly basic anion resins are susceptible to organic fouling; reduced life; thermodynamically unstable.

BAT Equipment Cost*

BAT Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3B. Reverse Osmosis:

Process - RO is a physical process in which contaminants are removed by applying pressure on the feed water to direct it through a semipermeable membrane. The process is the "reverse" of natural osmosis (water diffusion from dilute to concentrated through a semipermeable membrane to equalize ion concentration) as a result of the applied pressure to the concentrated side of the membrane, which overcomes the natural osmotic pressure. RO membranes reject ions based on size and electrical charge. The raw water is typically called feed; the product water is called permeate; and the concentrated reject is called concentrate. Common RO membrane materials include asymmetric cellulose acetate or polyamide thin film composite. Common membrane construction includes spiral wound or hollow fine fiber. Each material and construction method has specific benefits and limitations depending upon the raw water characteristics and pretreatment. A typical large RO installation includes a high pressure feed pump, parallel 1st and 2nd stage membrane elements (in pressure vessels); valving; and feed, permeate, and concentrate piping. All materials and construction methods require regular maintenance. Factors influencing membrane selection are cost, recovery, rejection, raw water characteristics, and pretreatment. Factors influencing performance are raw water characteristics, pressure, temperature, and regular monitoring and maintenance.

Pretreatment - RO requires a careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling, or other membrane degradation. Removal of suspended solids is necessary to prevent colloidal and bio-fouling, and removal of dissolved solids is necessary to prevent scaling and chemical attack. Large installation pretreatment can include media filters to remove suspended particles; ion exchange softening or antiscalant to remove hardness; temperature and pH adjustment to maintain efficiency; acid to prevent scaling and membrane damage; activated carbon or bisulfite to remove chlorine (postdisinfection may be required); and cartridge (micro) filters to remove some dissolved particles and any remaining suspended particles.

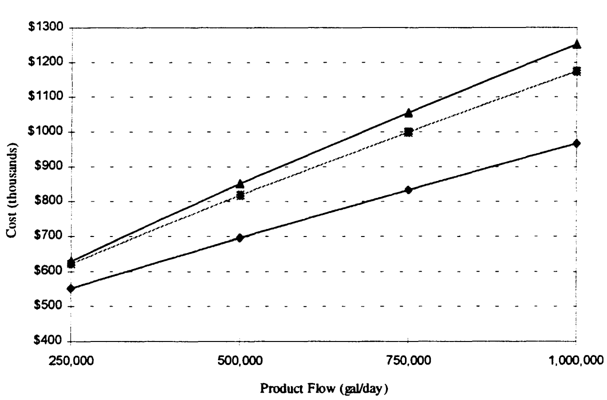
Maintenance - Monitor rejection percentage to ensure NO_3^-/NO_2^- removal below MCL. Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Use of monitoring equations to track membrane performance is recommended. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove fouling and scaling. The system is flushed and returned to service. $NaHSO_3$ is a typical caustic cleaner. RO stages are cleaned sequentially. Frequency of membrane replacement dependent on raw water characteristics, pretreatment, and maintenance.

Waste Disposal - Pretreatment waste streams, concentrate flows, and spent filters and membrane elements all require approved disposal.

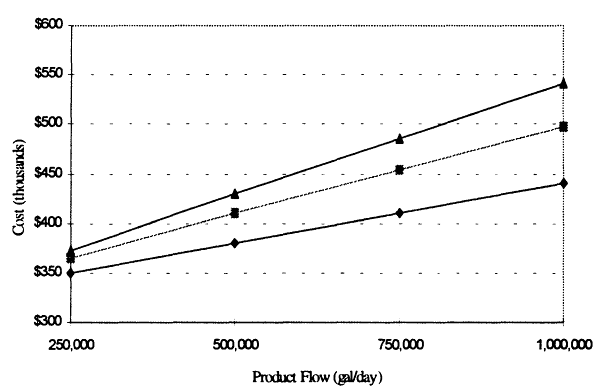
Advantages -
- Produces highest water quality.
- Can effectively treat wide range of dissolved salts and minerals, turbidity, health and aesthetic contaminants, and certain organics; some highly-maintained units are capable of treating biological contaminants.
- Low pressure (<100 psi), compact, self-contained, single membrane units are available for small installations.

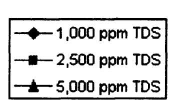
Disadvantages -
- Relatively expensive to install and operate.
- Frequent membrane monitoring and maintenance; monitoring of rejection percentage for NO_3^-/NO_2^- removal.
- Pressure, temperature, and pH requirements to meet membrane tolerances. May be chemically sensitive.

BAT Equipment Cost*



BAT Annual O&M Cost*





*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3C. Electrodialysis:

Process - ED is an electrochemical process in which ions migrate through an ion-selective semipermeable membrane as a result of their attraction to the electrically charged membrane surface. A positive electrode (cathode) and a negative electrode (anode) are used to charge the membrane surfaces and to separate contaminant molecules into ions. The process relies on the fact that electrical charges are attracted to opposite poles. As a result of the removal process, reduction in ions (or TDS) is obtained. A common ED system includes a membrane stack which layers several cell pairs, each consisting of a cation transfer membrane, a demineralized flow spacer, an anion transfer membrane, and a concentrate flow spacer. Electrode compartments are at opposite ends of the stack. The influent feed water (chemically treated to prevent precipitation) and concentrated reject flow in parallel across the membranes and through the demineralized and concentrate flow spacers, respectively. The electrodes are continually flushed to prevent fouling or scaling. Careful consideration of flush feed water is required. Typically, the membranes are cation- or anion-exchange resins cast in sheet form; the spacers are HDPE; and the electrodes are inert metal. ED stacks are tank contained and often staged. Membrane selection is based on careful review of raw water characteristics. A single-stage ED system usually removes 50 percent of the TDS; therefore, for water with more than 1000 mg/L TDS, blending with higher quality water or a second stage is required to meet 500 mg/L TDS.

Electrodialysis Reversal (EDR) uses the technique of regularly reversing the polarity of the electrodes, thereby freeing accumulated ions for cleaning. This process requires additional plumbing and electrical controls, but increases membrane life, does not require added chemicals, and eases cleaning.

Pretreatment - Guidelines are available on accepted limits on pH, organics, turbidity, and other raw water characteristics. Typically requires chemical feed to prevent scaling, acid addition for pH adjustment, and a cartridge filter for prefiltration.

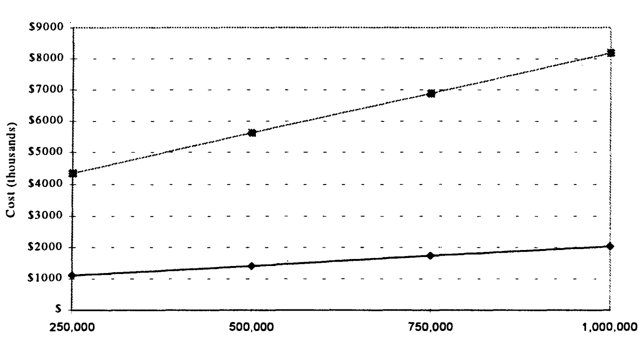
Maintenance - ED membranes are durable, can tolerate pH from 1 - 10, and temperatures to 115°F for cleaning. They can be removed from the unit and scrubbed. Solids can be washed off by turning the power off and letting water circulate through the stack. Electrode washes flush out byproducts of electrode reaction. The byproducts are hydrogen, formed in the cathode spacer, and oxygen and chlorine gas, formed in the anode spacer. If the chlorine is not removed, toxic chlorine gas may form. Depending on raw water characteristics and NO_3^-/NO_2^- concentration, the membranes will require regular maintenance or replacement. ED requires system flushes at high volume/low pressure; EDR backwashing will be required.

Waste Disposal - Highly concentrated reject flows, electrode cleaning flows, and spent membranes require approved disposal. Pretreatment processes and spent materials also require approved disposal.

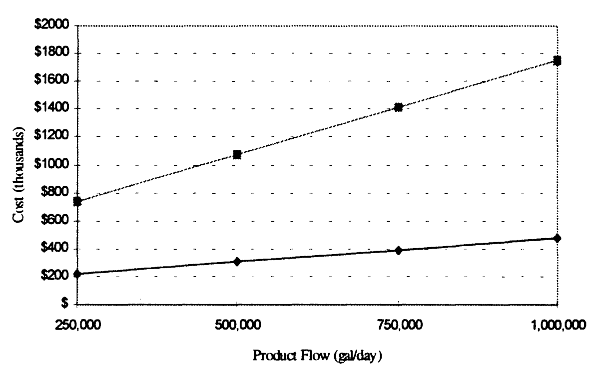
Advantages -
- EDR can operate without fouling or scaling, or chemical addition; suitable for higher TDS sources.
- Low pressure requirements; typically quieter than RO.
- Long membrane life expectancy; EDR extends membrane life and reduces maintenance.

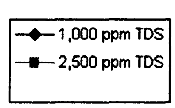
Disadvantages -
- EDR can operate without fouling or scaling, or chemical addition; suitable for higher TDS sources.
- Not suitable for high levels of Fe and Mn, H_2S, chlorine, or hardness.
- Limited current density; current leakage; back diffusion.
- At 50% rejection of TDS per pass, process is limited to water with 3000 mg/L TDS or less.

BAT Equipment Cost*



BAT Annual O&M Cost*





*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

TOTAL DISSOLVED SOLIDS

FACT SHEET

See related Fact Sheets: Acronyms & Abbreviations; Glossary of Terms; Cost Assumptions; Raw Water Composition; and WaTER Program.

1. CONTAMINANT DATA

A. Chemical Data: Total dissolved solids (TDS) or filterable residue are all of the dissolved solids in a water. TDS is measured on a sample of water that has been passed through a very fine filter (usually 0.45 micron) to remove the suspended solids. The water passing through the filter is evaporated (usually 103-105°C) and the residue represents the TDS concentration (in mg/L). TDS is usually comprised of inorganic minerals (salts), small amounts of organic material, and can include small amounts of soluble minerals (Fe and Mn). A conductivity test of water provides only an estimate of TDS, as conductivity is not directly proportional to the weight of an ion, and non-conductive substances cannot be measured by electrical tests.

B. Source in Nature: Inorganic minerals (salts) are commonly found in nature, consisting of positive ions (sodium and calcium) bonded to negative ions (chloride and carbonate). The inorganic mineral compounds, and small amounts of minerals that comprise TDS, are soluble in water, and are deposited by the weathering of the sedimentary rocks and erosion of the earth's surface. Organic material is also naturally occurring in nature, as a result of decaying organisms, plants, and animals. Those organic materials in TDS are also water soluble. Higher concentrations of TDS may occur during and after precipitation events.

C. SDWA Limits: SMCL is 500 mg/L.

D. Health Effects of Contamination: As a secondary drinking water contaminant, TDS does not pose any health risks. Secondary standards refer to those contaminants which cause aesthetic problems. The inorganic minerals and organic material, and small amounts of soluble minerals, in TDS have no notable ill health effects. Na_2SO_4 concentrations above 250 mg/L may produce a laxative effect. Excess sodium may affect those restricted to low sodium diets or pregnant women suffering from toxemia. High levels of TDS may present an objectionable taste, odor, and color to drinking water. Other aesthetic concerns include an indicator of corrosivity, scaling, and limiting the effectiveness of detergents.

2. REMOVAL TECHNIQUES

A. USEPA BAT: As a secondary drinking water contaminant, BATs are not assigned.

B. Alternative Methods of Treatment: The most common treatment processes for removing TDS are reverse osmosis and electrodialysis.

- RO uses a semipermeable membrane, and the application of pressure to a concentrated solution which causes water, but not suspended or most dissolved solids, to pass through the membrane. Benefits: produces high quality water. Limitations: cost; pretreatment/feed pump requirements; concentrate disposal.
- ED uses semipermeable membranes in which ions migrate through the membrane from a less concentrated to a more concentrated solution as a result of the ions' representative attractions to direct electric current. Benefits: contaminant specific removal. Limitations: electrical requirements; concentrate disposal.
- Freezing and distillation can be used for higher concentrations of TDS, as found in sea water or brackish water (<3000 mg/L); and ion exchange can also be used, but has limited effectiveness in concentrations <3000 mg/L.

C. Related WTTP Publications:

1) WTTP Report #6, "Preliminary Research Study of a Water Desalination System for the East Montana Area Subdivisions of El Paso County, El Paso, Texas." This report summarizes the field study performed to determine the economics of several water treatment processes, including RO, ED, and multistage flash distillation, on brackish groundwater; concluded RO with surface water reject disposal was the most economical for the study area.
2) WTTP Report #15, "Maricopa Groundwater Treatment Study." This report summarizes the field study performed to determine the suitability of several water treatment processes, including RO, ED, and NF, on groundwater containing high levels of nitrate, chloride, and TDS; recommends the use of NF or ED for study area.

D. Safety and Health Requirements for Treatment Processes: Personnel involved with demineralization treatment processes should be aware of the chemicals being used (MSDS information), the electrical shock hazards, and the hydraulic pressures required to operate the equipment. General industry safety, health, and self protection practices should be followed, including proper use of tools.

3. BAT PROCESS DESCRIPTION AND COST DATA

General Assumptions: Refer to: Raw Water Composition Fact Sheet for ionic concentrations; and Cost Assumptions Fact Sheet for cost index data and process assumptions. All costs are based on *ENR*, PPI, and BLS cost indices for February 1999. General sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal are not included.

3A. Reverse Osmosis:

Process - RO is a physical process in which contaminants are removed by applying pressure on the feed water to direct it through a semipermeable membrane. The process is the "reverse" of natural osmosis (water diffusion from dilute to concentrated through a semipermeable membrane to equalize ion concentration) as a result of the applied pressure to the concentrated side of the membrane, which overcomes the natural osmotic pressure. RO membranes reject ions based on size and electrical charge. The raw water is typically called feed; the product water is called permeate; and the concentrated reject is called concentrate. Common RO membrane materials include asymmetric cellulose acetate or polyamide thin film composite. Common membrane construction includes spiral wound or hollow fine fiber. Each material and construction method has specific benefits and limitations depending upon the raw water characteristics and pretreatment. A typical large RO installation includes a high pressure feed pump, parallel 1st and 2nd stage membrane elements (in pressure vessels); valving; and feed, permeate, and concentrate piping. Factors influencing membrane selection are cost, recovery, rejection, raw water characteristics, and pretreatment. Recent membrane improvements by manufacturers have produced nanofiltration (NF) membranes that are less costly to purchase and operate.

Pretreatment - RO requires a careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling, or other membrane degradation. Removal of suspended solids is necessary to prevent colloidal and bio-fouling, and removal of dissolved solids is necessary to prevent scaling and chemical attack. Large installation pretreatment can include media filters to remove suspended particles; ion exchange softening or antiscalant to remove hardness; temperature and pH adjustment to maintain efficiency; acid to prevent scaling and membrane damage; activated carbon or bisulfite to remove chlorine (postdisinfection may be required); and cartridge (micro) filters to remove some dissolved particles and any remaining suspended particles.

Maintenance - Monitor rejection percentage to ensure contaminant removal below SMCL. Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Use of monitoring equations to track membrane performance is recommended. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove fouling and scaling. The system is flushed and returned to service. $NaHSO_3$ is a typical caustic cleaner. RO stages are cleaned sequentially. Frequency of membrane replacement dependent on raw water characteristics, pretreatment, and maintenance.

Waste Disposal - Pretreatment waste streams, concentrate flows, and spent filters and membrane elements all require approved disposal.

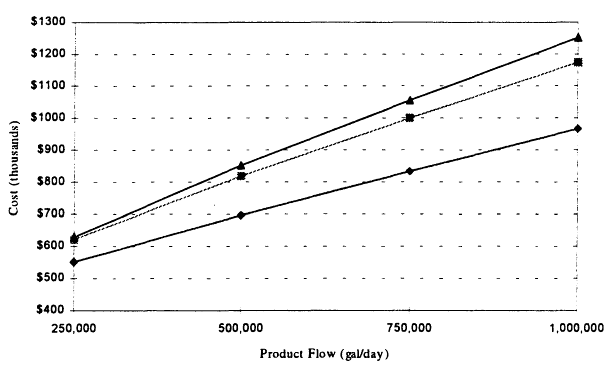
Advantages -

- Produces highest water quality.
- Can effectively treat wide range of dissolved salts and minerals, turbidity, health and aesthetic contaminants, and certain organics; some highly-maintained units are capable of treating biological contaminants.
- Low pressure (<100 psi), compact, self-contained, single membrane units are available for small installations.

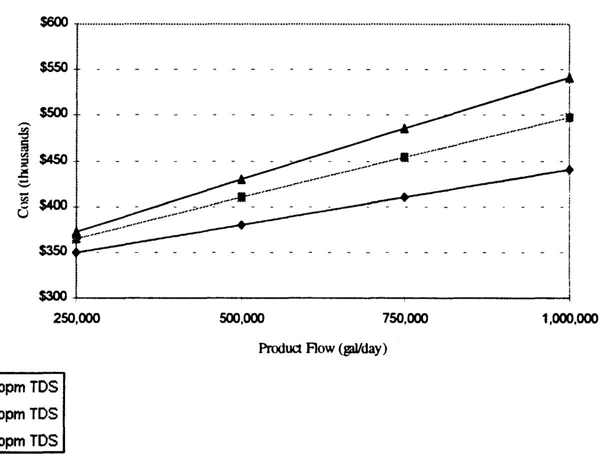
Disadvantages -

- Relatively expensive to install and operate (however NF membranes and operations are less than RO).
- Frequent membrane monitoring and maintenance; monitoring of rejection percentage for contaminant removal.
- Pressure, temperature, and pH requirements to meet membrane tolerances. May be chemically sensitive.

BAT Equipment Cost*



BAT Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3B. Electrodialysis:

Process - ED is an electrochemical process in which ions migrate through ion-selective semipermeable membranes as a result of their attraction to two electrically charged membrane surface. A typical ED system includes a membrane stack with a number of cell pairs, each consisting of a cation transfer membrane, a demineralized flow spacer, an anion transfer membrane, and a concentrate flow spacer. Electrode compartments are at opposite ends of the stack. The influent feed water (chemically treated to prevent precipitation) and concentrated reject flow in parallel across the membranes and through the demineralized and concentrate flow spacers, respectively. The electrodes are continually flushed to reduce fouling or scaling. Careful consideration of flush feed water is required. Typically, the membranes are cation- or anion-exchange resins cast in sheet form; the spacers are HDPE; and the electrodes are inert metal. ED stacks are tank contained and often staged. Membrane selection is based on careful review of raw water characteristics. A single-stage ED system usually removes 50 percent of the TDS; therefore, for water with more than 1000 mg/L TDS, blending with higher quality water or a second stage is required to meet 500 mg/L TDS.

Electrodialysis Reversal (EDR) uses the technique of regularly reversing the polarity of the electrodes, thereby freeing accumulated ions on the membrane surface. This process requires additional plumbing and electrical controls, but increases membrane life, does not require added chemicals, and eases cleaning.

Pretreatment - Guidelines are available on accepted limits on pH, organics, turbidity, and other raw water characteristics. Typically requires chemical feed to prevent scaling, acid addition for pH adjustment, and a cartridge filter for prefiltration.

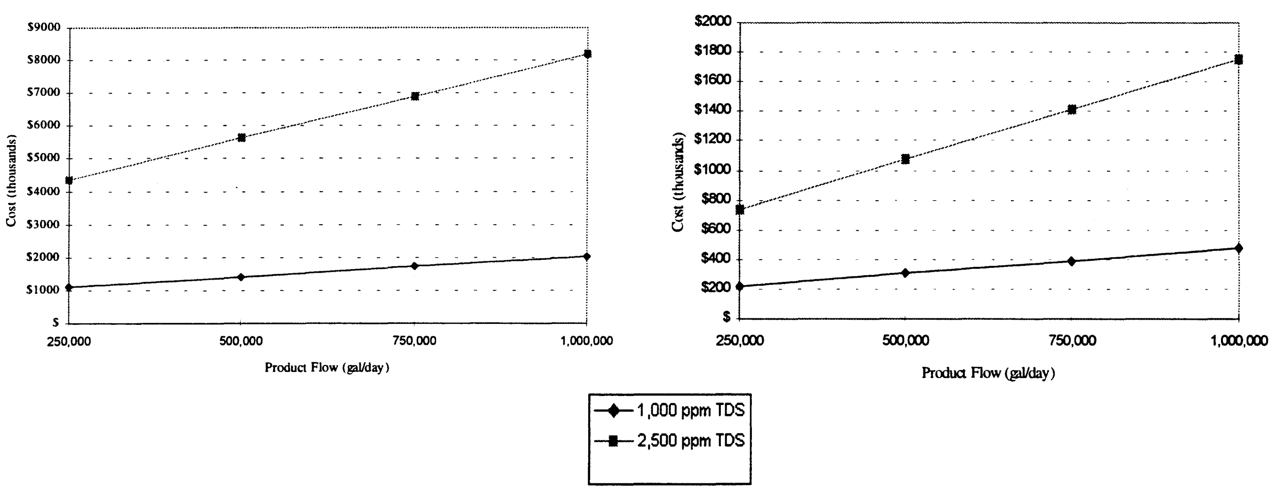
Maintenance - ED membranes are durable, can tolerate pH from 1 - 10, and temperatures to 115°F for cleaning. They can be removed from the unit and scrubbed. Solids can be washed off by turning the power off and letting water circulate through the stack. Electrode washes flush out byproducts of electrode reaction. The byproducts are hydrogen, formed in the cathode space, and oxygen and chlorine gas, formed in the anode spacer. If the chlorine is not removed, toxic chlorine gas may form. Depending on raw water characteristics and TDS concentration, the membranes will require regular maintenance or replacement. ED requires system flushes at high volume/low pressure; EDR requires reversing the polarity. Flushing is continuously required to clean electrodes. If utilized, pretreatment filter replacement and backwashing will be required. The ED stackmust be disassembled, mechanically cleaned, and reassembled at regular intervals.

Waste Disposal - Highly concentrated reject flows, electrode cleaning flows, and spent membranes require approved disposal. Pretreatment processes and spent materials also require approved disposal.

Advantages -
- Low pressure requirements; typically quieter than RO.
- Long membrane life expectancy; EDR extends membrane life and reduces maintenance.

Disadvantages -
- EDR can operate without fouling or scaling, or chemical addition; suitable for higher TDS sources.
- Not suitable for high levels of Fe and Mn, H_2S, chlorine, or hardness.
- Limited current density; current leakage; back diffusion.
- At 50% rejection of TDS per pass, process is limited to water with 3000 mg/L TDS or less.

BAT Equipment Cost* **BAT Annual O&M Cost***



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

TOTAL COLIFORM and E-COLI

FACT SHEET

See related Fact Sheets: Acronyms & Abbreviations; Glossary of Terms; Cost Assumptions; Raw Water Composition; and WaTER Program.

1. CONTAMINANT DATA

A. Chemical Data: Fecal bacteria are single-celled microorganisms, virtually always associated with fecal contamination of water, but not always harmful. Fecal indicator bacteria are used in determining (indicating) the microbial quality of water. Total coliform bacteria and fecal coliform *Escherichia coli* 0157:H7 (E-Coli) are two types of fecal indicator bacteria. Total coliform bacteria, a particular group of waterborne microbiological contaminants regulated by the SDWA, is the most common indicator organism applied to drinking water. E-Coli is one type of pathogenic fecal coliform bacteria, and the most common facultative, disease-causing bacteria in the feces of warm-blooded animals.

B. Source in Nature: By definition, several bacteria can be classified as coliform, and are commonly found in soil, on the surface of leaves, in decaying matter, and can grow in water distribution mains. These types of coliform bacteria aren't fecal contamination related, and do not necessarily indicate unsafe water. The pathogenic fecal coliform bacteria, E-Coli, is naturally occurring in the intestines and feces of most warm-blooded animals, including humans, and when found in water is a direct result of fecal contamination. Almost all surface waters contain some bacteria, while groundwaters are generally free of bacteria unless under the direct influence of surface water. Surface and groundwater contamination can occur as a result of surface runoff through urban areas, woodlands, pastures, or feedlots; on-site septic tank/sewage disposal system leakage/failure; sewage treatment plant/disposal system overload or malfunction; or raw sewage deep well injection. Treatment plant process contamination can occur as a result of filter breakthrough; improper coagulation; use of recycled, concentrated backwash water; process overload; or improper maintenance. Distribution system contamination can occur as a result of cross-connection, broken or leaking waterlines, or back-siphonage.

C. SDWA Limits: The treatment technique maximum contaminant level goal (TT MCLG) for both total coliform and E-Coli is 0 mg/L. For total coliform, >40 samples/month, less than 5% of the samples may be positive; <40 samples/month, less than one sample may be positive. For E-Coli, the Positive Repeat Sample criteria is applied for MCL.

D. Health Effects of Contamination: Self-limiting effects of bacterial ingestion include abdominal cramps and diarrhea. Hemorrhagic colitis (HC) is the acute disease caused by E-Coli. HC results in severe abdominal cramps, watery diarrhea, and lower intestinal bleeding; with occasional vomiting and fever. In some cases, hemolytic uremic syndrome or renal failure can occur. Although not life threatening to healthy adults, these diseases can be fatal to young children, the elderly, and immunocompromised persons. E-Coli is transmitted through fecal-oral ingestion of the bacteria by direct ingestion (i.e. drinking), primary contact recreation (i.e. swimming), or secondary contact (i.e. fishing).

2. REMOVAL TECHNIQUES

A. USEPA BAT: For community surface and groundwater (under the direct influence of surface water) systems, treatment technique is applied. In this case, the accepted TT is use of the conventional treatment processes filtration and disinfection. Benefits: proven; reliable. Limitations: initial investment.

B. Alternative Methods of Treatment: Through proper siting of wells and waste disposal systems, manage, find, or eliminate the source of the contamination. Improving well casing/sealing or drilling deeper wells can improve groundwater quality. Distillation is effective. UV, ozone, and iodine can be effective disinfection methods. Boiling water for 1 minute (5 minutes at higher elevations) is the traditional POU treatment method. Bottled water may be used, although is not regulated for testing for microbial contaminants. Raw water quality can also be improved through complex planning of waste treatment/disposal methods, public watershed, and land management, especially during periods of high precipitation and heavy runoff.

C. Safety and Health Requirements for Treatment Processes: General industry safety, health, and self protection practices for process equipment should be followed, including proper use of chemicals and tools. When dealing with waterborne diseases, take precautions to prevent infection through open cuts/wounds, or illnesses from ingestion. Wear PPE and wash hands thoroughly.

3. BAT PROCESS DESCRIPTION AND COST DATA

General Assumptions: Refer to: Raw Water Composition Fact Sheet for ionic concentrations; and Cost Assumptions Fact Sheet for cost index data and process assumptions. All costs are based on *ENR*, PPI, and BLS cost indices for February 1999. General sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal are not included.

3A. Filtration and Disinfection:
Process - Filtration involves removing contaminant bacteria through screening, settling, or separating. Disinfection refers to inactivation (killing) of the bacteria. Depending on raw water quality and characteristics, filtration of bacteria can be a multi-step process, including screening; coagulation and flocculation; final settling; and final filtering. Screening consists of removing the largest/heaviest suspended solids from the raw water. Chemical coagulation and flocculation consists of adding a chemical coagulant combined with mechanical flocculation to allow fine suspended and some dissolved solids to clump together (floc). Final settling consists of settling of the floc matter. Final filtration consists of removal by filtering (often membrane) of all floc; suspended; and, based on filtration method/size, most dissolved solids, including bacteria. Filtration processes result in lowering overall TSS/TDS and turbidity, which in turn allows greater disinfection contact time on remaining bacteria. Disinfection consists of chemical inactivation of pathogens, bacteria, and viruses. Cl_2 effectively treats bacteria and is the most common disinfection method. Cl_2 demand refers to the amount of chlorine required to inactivate the bacteria and the amount required to allow an effective residual in the distribution system.

For on-site systems with one time groundwater contamination, whether by maintenance, poor construction, single event contamination, etc., concentrated disinfection of the well, casing, and piping is required; and flushing of the system.

The cost curves presented below are for dual media filtration and Cl_2 disinfection.

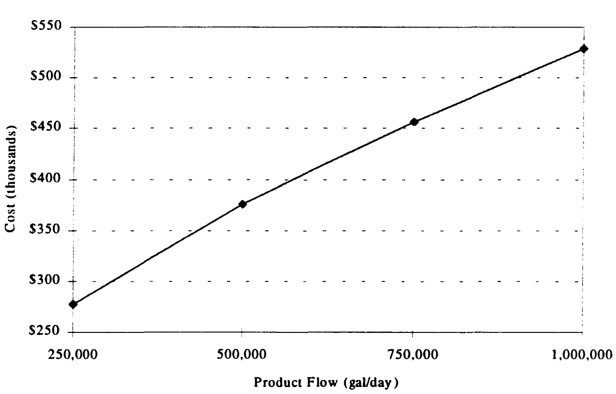
Maintenance - Proper monitoring, operation, and maintenance procedures, especially of the final filter, are essential to ensure the reliability of filtration processes. Recycled filter backwash or membrane cleaning methods may concentrate bacteria and result in a significant source of increased turbidity and bacteria infestation. As a result, a period of filter-to-waste flow may be required after post-backwash/membrane cleaning periods. Because turbidity removal can parallel bacteria removal, finished water turbidity monitoring (<0.5 NTU) may be a useful tool for indicating the degree of pathogen removal.

Waste Disposal - Pretreatment waste streams and spent filters require approved disposal.

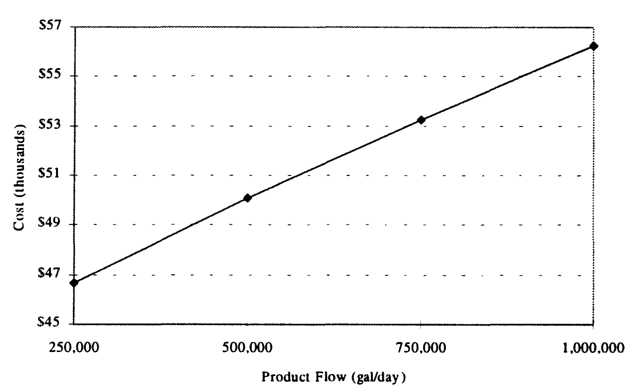
Advantages -
- Well established, conventional treatment processes; readily available.
- Reliable, if properly operated and maintained; provides residual disinfectant.
- Suitable for community or on-site systems.

Disadvantages -
- Requires proper Cl_2 contact times; can give a chlorine after taste and smell.
- Requires careful handling and proper storage of chlorine.
- Cl_2 may combine with organic precursors to form THMs.
- Costly initial investment, and proper operation and maintenance.

BAT Equipment Cost*



BAT Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 01-Jul-2002

Omaha Tribal of Nebraska
Tribal Water System
Pipeline Distribution System

Upgrade for Year 2040 - Macy

PROJECT: BIA

REGION: BIA

FILE: H:\D8170\EST\SPREAD~1\COPELAND\OMAHA\ESTNEW1.WK3

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Furnish and Install the following sizes Line Pipe:					
		6" PVC DR18		108,000	LF	$9.00	$972,000.00
		6" PVC DR18 (Raw Water Line from wells)		12,000	LF	$9.00	$108,000.00
		8" PVC DR18		70,000	LF	$12.00	$840,000.00
		10" PVC DR18		86,500	LF	$17.00	$1,470,500.00
		12" PVC DR18		16,400	LF	$22.00	$360,800.00
		14" PVC DR18		16,700	LF	$28.00	$467,600.00
		Excavation in pipe trench (Vertical Trench)		5,760	CY	$7.00	$40,320.00
		Excavation in pipe trench (Sloping Trench)		571,000	CY	$3.50	$1,998,500.00
		Backfill in pipe trench (Vertical Trench)		5,630	CY	$5.00	$28,150.00
		Backfill in pipe trench (Sloping Trench)		567,000	CY	$2.50	$1,417,500.00
		Moderately compacted backfill in pipe trench (Vertical Trench)			CY		
		Moderately compacted backfill in pipe trench (Sloping Trench)		443,000	CY	$2.50	$1,107,500.00
		Compacted backfill in pipe trench (Vertical Trench)		5,310	CY	$7.00	$37,170.00
		Compacted backfill in pipe trench (Sloping Trench)		114,000	CY	$3.50	$399,000.00
		Repair of road surface					
		6" aggregate base		2,890	CY	$30.00	$86,700.00
		3" asphaltic concrete		1,440	CY	$110.00	$158,400.00
		Provide Outlets in line pipe		45	EA	$2,000.00	$90,000.00
		US Highway Crossing (jacked)		7	LS	$36,000	$252,000.00
		3" Pressure Reducing Valves with vaults		2	EA	$7,000.00	$14,000.00
		4" Pressure Reducing Valves with vaults		1	EA	$8,000.00	$8,000.00
		6" Pressure Reducing Valves with vaults		4	EA	$9,000.00	$36,000.00
		Furnish and Install sectionalizing valves					
		6"		38	EA	$1,100.00	$41,800.00
		8"		22	EA	$1,300.00	$28,600.00
		10"		2	EA	$1,600.00	$3,200.00
		Furnish and Install Fire hydrant assemblies		100	EA	$6,500.00	$650,000.00
		Subtotal for Sheet 1					$10,615,740.00

QUANTITIES		PRICES	
BY: D.L. Gesundheit	CHECKED	BY: Craig A. Grush	CHECKED: [signature] 7/1/2002
DATE PREPARED: 04/04/2001	APPROVED	DATE: 07/01/2002	PRICE LEVEL: Appraisal

ESTIMATE WORKSHEET

FEATURE: 01-Jul-2002

Omaha Tribal of Nebraska
Tribal Water System
Pipeline Distribution System

Upgrade for Year 2040 - Macy

PROJECT: BIA

REGION: BIA

FILE: H:\D8170\EST\SPREAD~1\COPELAND\OMAHA\ESTNEW1.WK3

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Furnish and install 940,000 gal 55 ft. from Ground					
		to bottom of tank, and 30 ft. high with a 73 ft Diameter					
		Elevated steel water storage tank		1	EA	$1,500,000	$1,500,000.00
		Furnish and install 3,000,000 gal 20 ft. from Ground					
		to bottom of tank, and 30 ft. high with a 131 ft Diameter					
		Elevated steel water storage tank		1	EA	$3,000,000	$3,000,000.00
		Furnish and install 550,000 gal 60 ft. from Ground					
		to bottom of tank, and 30 ft. high with a 56 ft Diameter					
		Elevated steel water storage tank		1	EA	$800,000	$800,000.00
		Furnish and install 110,000 gal 56 ft. from Ground					
		to bottom of tank, and 25 ft. high with a 56 ft Diameter					
		Elevated steel water storage tank		1	EA	$250,000	$250,000.00
		Aerator, 750 gpm, steel: A-283 grade B steel w/Tnemec #77		3	EA	$58,000	$174,000.00
		ext primer & #272 polyamide cured coal tar epoxy int paint					
		Filter, 750gpm, vertical filter w/2gpm/sf of bed		3	EA	$200,000	$600,000.00
		General Filter Co. (Jerry Stegge: 515-232-4121)					
		Lime equipment: Liquid lime equipment for 225 lb/day		1	EA	$28,000	$28,000.00
		Chlorination equipment 28 lb/day		1	EA	$12,500	$12,500.00
		Complete metal building, 3000 SF		1	EA	$270,000	$270,000.00
		Construct Wells, 8" Diameter, 300 ft. deep,					
		32 horsepower pump		4	EA	$30,000	$120,000.00
		Subtotal for Sheets 1 & 2					$17,370,240.00
		Mobilization	5%	+/-			$870,000.00
		Subtotal with Mobilization					$18,240,240.00
		UNLISTED ITEMS	15%	+/-			$2,759,760.00
		CONTRACT COST					$21,000,000.00
		CONTINGENCIES	25%	+/-			$5,000,000.00
		FIELD COST					$26,000,000.00
		NONCONTRACT COSTS	30%	+/-			$8,000,000.00
		CONSTRUCTION COST					$34,000,000.00

QUANTITIES		PRICES	
BY B. Jurenka D.L. Gesundheit	CHECKED	BY K. Copeland Craig A. Grush	CHECKED [signature] 7/1/2002
DATE PREPARED 06/24/2002	APPROVED	DATE 07/01/2002	PRICE LEVEL Appraisal

CODE:D-8230

ESTIMATE WORKSHEET

FEATURE: 01-Jul-02
City of Pender water system quantities
Appraisal level study

PROJECT:
Omaha Water and Wastewater Needs Assessment

DIVISION:

FILENAME:
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PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1.0	Water Treatment for Arsenic, Nitrate, .34 MGD					
	1.1	Chlorination equipment: Liquid chlorine (Sodium	D8230	1	each	$4,000.00	$4,000.00
		Hypochlorite) equipment to feed					
		10 pounds per day of Cl2					
	1.2	Coagulent/polymer equipment: Liquid polymer equipment for		1	each	$9,000.00	$9,000.00
		60 pounds per day of polymer					
	1.3	Plant pumps and motors, 250 gpm, 150' TDH		1	each	$11,000.00	$11,000.00
	1.4	Clearwell below ground, concrete, 8000 gallons		1	each	$15,000.00	$15,000.00
	1.5	Water treatment					
		Aerator capacity , 250-300 gpm. Steel construction: A-283		1	each	$25,000.00	$25,000.00
		grade B steel with Tnemec #77 exterior primer and #272					
		polyamide cured coal tar epoxy interior paint.					
		General Filter company, Ames, IOWA					
		(JERRY STEGGE 515-232-4121)					
	1.6	Filter capacity, 300 gpm		1	each	$100,000.00	$100,000.00
		Vertical filter w/ 2 gpm per sq. ft. of bed area.					
		General filter company, Ames, IOWA					
		(JERRY STEGGE 515-232-4121)					
	1.7	Ion exchange to lower nitrate conc. @ 250 gpm (from		1	each	$150,000.00	$150,000.00
		water treatment cost estimation program) (installed cost)					
	1.8	Plant piping, valves & instrumentation	D-8230	1	each	$7,000.00	$7,000.00
	1.9	Complete Metal Building, 1500 SF		1	each	$150,000.00	$150,000.00
	1.1	Sludge disposal lagoons, 4150 CF each		2	each	$4,000.00	$8,000.00
		Subtotal Sheet					$479,000.00
		Mobilization (5%)					$24,000.00
		Unlisted (15%)					$77,000.00
		Contract cost					$580,000.00
		Contingencies (25%)					$140,000.00
		Field cost					$720,000.00
		Non-Contract Cost (30%)					$220,000.00
		Construction Cost					$940,000.00

QUANTITIES		PRICES	
BY Bob Jurenka	CHECKED	BY K. Copeland	CHECKED [signature] 7/1/2002
DATE PREPARED 6/24/2002	APPROVED	DATE 07/01/2002	PRICE LEVEL Appraisal 2002

CODE:D-8230

ESTIMATE WORKSHEET

FEATURE: 01-Jul-02

City of Walthill water system quantities
Appraisal level study

PROJECT:
Omaha Water and Wastewater Needs Assessment

DIVISION:

FILENAME:
H:\D8170\EST\Spreadsheet\Copeland\omaha\[omahawater.xls]Walthill1

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Storage tanks					
		815,000 gallon ground concrete tank	D8230	1	each	$500,000	$500,000.00
	2	Pipeline for water distribution	D8230				
	2.1	12" Diameter, AWWA C900 PVC pipe		15180	LF	$21.00	$318,780.00
	2.2	6" Diameter, AWWA C900 PVC pipe		47025	LF	$9.00	$423,225.00
	2.3	Pipe trench excavation (62205x3x6)	D8230	41,470	yd3	$4.00	$165,880.00
	2.4	Pipe trench backfill and compaction		41,470	yd3	$7.00	$290,290.00
	2.5	Air relief valves (1")		12	each	$430.00	$5,160.00
	2.6	Vaults for valves (6' diameter and 6' deep)	D8230				
	2.7	Excavation (volume +10%), total for 12 vaults		83.0	yd3	$15.00	$1,245.00
	2.8	Backfill and compaction, total for 12 vaults		8.0	yd3	$25.00	$200.00
	2.9	Concrete wall (6" wall thickness), total for 12 vaults		36.0	yd3	$500.00	$18,000.00
	2.10	Vaults covers (2' diameter)		12	each	$375.00	$4,500.00
	3	Wells	D8230				
	3.1	well at 100 feet deep, w/ 4 inch casing		1	each	$4,100.00	$4,100.00
	3.2	Pump and motor at 30 gpm, 150 feet of TDH		2	each	$2,850.00	$5,700.00
	3.3	Well house		1	each	$25,000.00	$25,000.00
	4	Chlorination equipment: Sodium hypochlorite	D8230	1	each	$4,300.00	$4,300.00
		equipment for 7 pounds per day of Cl2					
	5	Lime equipment: Liquid lime equipment for	D8230	1	each	$15,000.00	$15,000.00
		60 pounds per day of lime					
	6	Gate valves for isolation (every 1000 feet)	D8230	62	each	$1,100.00	$68,200.00
	7	Fire hydrants assemblies (every 2000 feet)	D8230	31	each	$4,000.00	$124,000.00
		Subtotal Sheet 5 of 6					$1,973,580.00

QUANTITIES		PRICES	
BY B. Jurenka Qian Zhang	CHECKED	BY K. Copeland R.Baumgarten	CHECKED MAtH ✓ Cg 7/1/2002
DATE PREPARED 06/24/2002	APPROVED	DATE 07/01/2002	PRICE LEVEL Appraisal 2002

CODE:D-8230

ESTIMATE WORKSHEET

FEATURE: 01-Jul-02
City of Walthill water system quantities
Appraisal level study

PROJECT:
Omaha Water and Wastewater Needs Assessment

DIVISION:

FILENAME:
H:\D8170\EST\Spreadsheet\Copeland\omaha\[omahawater.xls]Walthill2

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	8	Water treatment					
		Aerator capacity , 264 gpm. Steel construction: A-283		2	each	$28,000.00	$56,000.00
		grade B steel with Tnemec #77 exterior primer and #272					
		polyamide cured coal tar epoxy interior paint.					
		General Filter company, Ames, IOWA					
		(JERRY STEGGE 515-232-4121)					
	9	Filter capacity, 142 gpm. (Total capacity required, 450 gpm)		3	each	$39,500.00	$118,500.00
		Vertical filter w/ 2-4 gpm per sq. ft. of bed area.					
		General filter company, Ames, IOWA					
		(JERRY STEGGE 515-232-4121)					
	10	Complete Metal Building, 1000 SF		1	each	$110,000	$110,000.00
		Subtotal Sheet 6 of 6					$284,500.00
		Subtotal Sheet 5 of 6					$1,973,580.00
		Mobilization (5%)					$115,000.00
		Unlisted Items (15%)					$326,920.00
		Contract cost					$2,700,000.00
		Contingencies (25%)					$700,000.00
		Field cost					$3,400,000.00
		Non-Contract Cost (30%)					$1,000,000.00
		Construction Cost					$4,400,000.00

QUANTITIES		PRICES	
BY B. Jurenka Qian Zhang	CHECKED	BY K. Copeland R.Baumgarten	CHECKED Math ✓ Coz 7/1/2002
DATE PREPARED 06/24/2002	APPROVED	DATE 07/01/2002	PRICE LEVEL Appraisal 2002

CODE:D-8230

ESTIMATE WORKSHEET

FEATURE: 01-Jul-02
City of Rosalie water system quantities
Appraisal level study

PROJECT:
Omaha Water and Wastewater Needs Assessment

DIVISION:

FILENAME:
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PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Storage tanks					
		141,000 gallon elevated steel tank	D8230	1	each	$250,000	$250,000.00 ✓
	2	Pipeline for water distribution	D8230				
	2.1	12" Diameter, AWWA C900 PVC pipe		1700	LF	$21.00	$35,700.00 ✓
	2.2	6" Diameter, AWWA C900 PVC pipe		12600	LF	$9.00	$113,400.00 ✓
	2.3	Pipe trench excavation (25,000'x3' wide x6' deep)	D8230	9600	yd3	$4.50	$43,200.00 ✓
	2.4	Pipe trench backfill & compaction		9600	yd3	$8.00	$76,800.00 ✓
	2.5	Air relief valves (1")		2	each	$430.00	$860.00 ✓
	2.6	Vaults for valves (6' diameter and 6' deep)					
	2.7	Excavation, total of 2 vaults		14	yd3	$15.00	$210.00 ✓
	2.8	Backfill & compaction, total of 2 vaults		12	yd3	$25.00	$300.00 ✓
	2.9	Concrete wall (6" thickness), total of 2 vaults		6	yd3	$500.00	$3,000.00 ✓
	2.10	Vaults covers (2' diameter)		5	each	$375.00	$1,875.00 ✓
	3	Chlorination equipment: Liquid chlorine (Sodium	D8230	1	each	$4,000.00	$4,000.00 ✓
		Hypochlorite) equipment to feed					
		1 pounds per day of Cl2					
	4	Lime equipment: Liquid lime equipment for	D8230	1	each	$11,000.00	$11,000.00 ✓
		6 pounds per day of lime					
	5	Gate valves for isolation (every 1000 feet)	D8230	15	each	$1,100.00	$16,500.00 ✓
	6	Fire hydrants assemblies (every 2000 feet)	D8230	8	each	$4,000.00	$32,000.00 ✓
		Subtotal Sheet 1 of 6					$588,845.00 ✓

QUANTITIES		PRICES	
BY Bob Jurenka	CHECKED	BY K. Copeland R.Baumgarten	CHECKED Elizabeth Tran 7/1/02
DATE PREPARED 6/24/2002	APPROVED	DATE 06/28/2002	PRICE LEVEL Appraisal 2002

CODE:D-8230

ESTIMATE WORKSHEET

FEATURE: 01-Jul-02
City of Rosalie water system quantities
Appraisal level study

PROJECT:
Omaha Water and Wastewater Needs Assessment

DIVISION:

FILENAME:
H:\D8170\EST\Spreadsheet\Copeland\omaha\[omahawater.xls]Rosalie 2

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	7	Water treatment					
		Aerator capacity , 62.5 gpm. Steel construction: A-283		1	each	$25,000.00	$25,000.00 ✓
		grade B steel with Tnemec #77 exterior primer and #272					
		polyamide cured coal tar epoxy interior paint.					
		General Filter company, Ames, IOWA					
		(JERRY STEGGE 515-232-4121)					
	8	Filter capacity, 62.5 gpm. Vertical filter w/ 2 gpm per sq.		1	each	$28,000.00	$28,000.00 ✓
		ft. of bed area.					
		General filter company, Ames, IOWA					
		(JERRY STEGGE 515-232-4121)					
	9	Complete Metal building, 300 SF		1	each	$45,000.00	$45,000.00 ✓
		Subtotal Sheet 2 of 6					$98,000.00 ✓
		Subtotal Sheet 1 of 6					$588,845.00 ✓
		Mobilization (5%)					$34,000.00 ✓
		Unlisted (15%)					$109,155.00 ✓
		Contract cost					$830,000.00 ✓
		Contingencies (25%)					$220,000.00 ✓
		Field cost					$1,050,000.00 ✓
		Non Contract Costs (30%)					$300,000.00 ✓
		Construction Cost					$1,350,000.00 ✓

QUANTITIES		PRICES	
BY Bob Jurenka	CHECKED	BY K. Copeland R.Baumgarten	CHECKED Elizabeth K. Tran 7/1/02
DATE PREPARED 6/24/2002	APPROVED	DATE 06/28/2002	PRICE LEVEL Appraisal 2002

ESTIMATE WORKSHEET

FEATURE: 28-Aug-00

City of Macy, NE
Wastewater Quantities
Year 2040 Projections

PROJECT:
Omaha Tribe of Nebraska Needs Assessment

DIVISION:
MACYWW1.XLS

UNIT:

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Sewer Collection System	D8230				
	1.1	PVC Sewer pipe, SDR35					
	1.1a	8"		22700	LF	$6.50	$147,550.00
	1.1b	6"		165500	LF	$5.00	$827,500.00
		manholes @ 400' spacing, 471 req'd					
	1.2	manhole frame and cover		471	ea	$375.00	$176,625.00
		-excavation for:					
	1.3	MHs, 6'diax8'deep=8cu.yds @471x		3950	CY	$8.00	$31,600.00
	1.4	pipe, 3' wide x 5' deep		105000	CY	$4.00	$420,000.00
		backfill & compaction for:					
	1.5	MHs 8cy-4cy=4cy/mh		1900	CY	$12.00	$22,800.00
	1.6	pipe		105000	CY	$6.00	$630,000.00
	1.7	-flexible couplings, 2 per MH, 4"		942	ea	$300.00	$282,600.00
		precast reinf'd conc mh riser, 5' ID w/					
	1.8	flat top and base		471	ea	$3,000.00	$1,413,000.00
	2	Lift Station, duplex 102gpm @ 90' TDH					
		4' dia. 10'deep					
	2.1	excavation= 25*3.14/4*11/27		8	cy	$25.00	$200.00
	2.2	backfill		1	cy	$50.00	$50.00
		-manhole risers with flat slab top/integral bottom					
	2.3	5' ID x 10' deep		1	ea	$3,500.00	$3,500.00
	2.4	-CI heavy duty manhole frame and cover, 24" dia		1	ea	$375.00	$375.00
	2.5	-flexible couplings, 3 per lift sta.		3	ea	$300.00	$900.00
	2.6	Pump and Motor per quote from		1	ls		$50,000.00
		Canyon Systems material $34000					
		Inc Power, controls, startup , submittals					
		Subtotal Sheet 1 of 2					$4,006,700.00

QUANTITIES		PRICES	
BY Rjurenka	CHECKED	BY RAB R. Baumgarten	CHECKED MU
DATE PREPARED 8/17/2000	APPROVED	DATE 8/22/00	PRICE LEVEL Appraisal 2000

CODE:D-8230

ESTIMATE WORKSHEET

FEATURE: 28-Aug-00

City of Macy, NE
Wastewater Quantities
Year 2040 Projections

PROJECT: Omaha Tribe of Nebraska Needs Assessment

DIVISION: MACYWW1.XLS

UNIT:

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	3	Wastewater Lagoons	D8231				
	3A	26 mg volume needed for year 2020					
	3B	104 mg vol needed for year 2040					
		For 26 mg and equal cut and fill					
	3.1	Excavation		64500	cy	$ 3.50	$ 225,750
	3.2	backfill & compaction		64500	cy	$ 3.00	$ 193,500
		clay liner at 18" thick, area of sides and bottom					
		=8x10exp.5 x(2x1293+639)=26x3864=100464sf					
		bottom area = 624x1278=797472 sf					
	3.3	total = 897936x1.5/27		50000	cy	$ 17.50	$ 875,000
		Ininlet/outlet control structures					
		Assume manholes at 4' dia., 10'deep					
	3.4	excavation= 25*3.14/4*11/27		8	cy	$ 25.00	$ 200
	3.5	backfill		1	CY	$ 50.00	$ 50
		-manhole risers with flat slab top/integral bottom					
	3.6	4' ID x 10' deep		2	ea	$ 3,500.00	$ 7,000
	3.7	-CI heavy duty manhole frame and cover, 24" dia		2	ea	$ 375.00	$ 750
	3.8	-flexible couplings, 3 per lift sta.		6	ea	$ 540.00	$ 3,240
	3.9	slide gates for control on 8" dia pipe		4	ea	$ 1,800.00	$ 7,200
		Subtotal for 26 mg pond					**$ 1,312,690**
		Subtotal Sheet 1 of 2					**$ 4,006,700**
		Mobilization					**$ 265,000**
		Unlisted Items (15%)					**$ 815,610**
		Contract Cost					**$ 6,400,000**
		Contingencies (25%)					**$ 1,600,000**
		Field Cost					**$ 8,000,000**
		Non-Contract Cost (30%)					**$ 2,500,000**
	3A	**Construction Cost - Total for 26 mg (year 2020 system)**					**$ 10,500,000**
		For 104 mg pond (4*(26 mg pond)*0.95)					**$ 4,988,222**
		Subtotal Sheet 1 of 2					**$ 4,006,700**
		Mobilization					**$ 450,000**
		Unlisted Items (15%)					**$ 1,555,078**
		Contract Cost					**$ 11,000,000**
		Contingencies (25%)					**$ 2,500,000**
		Field Cost					**$ 13,500,000**
		Non-Contract Cost (30%)					**$ 4,000,000**
	3B	**Construction Cost - Total for 104 mg (year 2040 system)**					**$ 17,500,000**

QUANTITIES		PRICES	
BY R. Jurenka		**BY** R. Baumgarten	**CHECKED** MU
DATE PREPARED 8/17/2000	**APPROVED**	**DATE** 8/22/00	**PRICE LEVEL** Appraisal 2000

CODE:D-8230

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 01-Jul-02

City of Pender, NE
Wastewater Quantities
Year 2040 Projections

PROJECT:
Omaha Tribe of Nebraska Needs Assessment

DIVISION:
PNDERWW.XLS

UNIT:

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			D8230				
	3	0.09 mgd activated sludge wwtp complete		1	ls		$500,000.00
		(based on JEO in 1988, $3.70/gpd for a 0.165 mgd					
		wwtp) 0.2 mgd 1988 cost =$740,000.					
		Subtotal Sheet 1 of 1					$500,000.00
		Mobilization					$25,000.00
		Unlisted Items (15%)					$75,000.00
		Contract Cost					$600,000.00
		Contingencies (25%)					$150,000.00
		Field Cost					$750,000.00
		Non-Contract Cost (30%)					$230,000.00
		Construction Cost					$980,000.00

QUANTITIES		PRICES	
BY R. Jurenka		BY K. Copeland	CHECKED DCD 7-1-02
DATE PREPARED 6/24/02	APPROVED	DATE 7/1/2002	PRICE LEVEL Appraiasal 2002

CODE:D-8230

ESTIMATE WORKSHEET

FEATURE: 25-Aug-00

City of Walthill, NE
Wastewater Quantities
Year 2040 Projections

PROJECT: Omaha Tribe of Nebraska Needs Assessment

DIVISION: WALTHILLww.xls

UNIT:

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Sewer Collection System	D8230				
	1.1	PVC Sewer pipe, SDR35 , ASTM3035					
	1.1a	8"		4000	LF	$7.00	$28,000.00
	1.1b	6"		25000	LF	$5.50	$137,500.00
		Manholes @ 400' spacing, 238 req'd					
	1.2	manhole frame and cover		73	ea	$375.00	$27,375.00
		-excavation for:					
	1.3	MHs, 6'diax8'deep=8cu.yds @ 75x		630	CY	$12.00	$7,560.00
	1.4	pipe, 3' wide x 5' deep		16100	CY	$4.50	$72,450.00
		-backfill & compaction for:					
	1.5	MHs 8cy-4cy=4cy/mh		300	CY	$12.00	$3,600.00
	1.6	pipe		16100	CY	$8.00	$128,800.00
	1.7	-flexible couplings, 2 per MH, 4"		146	ea	$300.00	$43,800.00
		precast reinf'd conc mh riser, 5' ID w/					
	1.8	flat top and base		73	ea	$2,750.00	$200,750.00
	2	Lift Station, duplex 180 gpm @ 30 ' TDH					
	2.1	4' dia. 10'deep					
	2.2	excavation= 25*3.14/4*11/27		8	cy	$25.00	$200.00
	2.3	backfill		1	cy	$50.00	$50.00
		-manhole risers with flat slab top/integral bottom					
	2.4	5' ID x 10' deep		1	ea	$3,500.00	$3,500.00
	2.5	-CI heavy duty manhole frame and cover, 24" dia		1	ea	$375.00	$375.00
		-flexible couplings, 3 per lift sta.		3	ea	$300.00	$900.00
	2.6	Pump, motor, power & controls. Per		1	ls		$50,000.00
		Quotes from Canyon Systems, Use					
		$34,000 for above materials plus					
		startup assistance, O&M manual and					
		submittals					
		Subtotal Sheet 1 of 2					$704,860.00

QUANTITIES		PRICES	
BY: Rjurenka	CHECKED	BY: R. Baumgarten	CHECKED
DATE PREPARED: 8/10/2000	APPROVED	DATE: 8/22/00	PRICE LEVEL: Appraisal 2000

FEATURE: 25-Aug-00

City of Walthill NE
Wastewater Quantities
Year 2040 Projections

PROJECT: Omaha Tribe of Nebraska Needs Assessment

DIVISION: WALTHILLWW.XLS

UNIT:

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			D8230				
	3	0.15 mgd activated sludge wwtp complete (based on JEO in 1988, 3.70/gal for a 0.165 mgd wwtp) 0.15 mgd 1988 cost =$550,000. Escalate to 2000 pricing is needed).		1	ls		$765,000.00
		Subtotal Sheet 2 of 2					$765,000.00
		Subtotal Sheet 1 of 2					$704,860.00
		Mobilization					$73,000.00
		Unlisted Items (15%)					$207,140.00
		Contract Cost					$1,750,000.00
		Contingencies (25%)					$450,000.00
		Field Cost					$2,200,000.00
		Non-Contract Cost (30%)					$700,000.00
		Construction Cost					$2,900,000.00

QUANTITIES		PRICES	
BY Rjurenka		BY R. Baumgarten	CHECKED
DATE PREPARED 8/18/00	APPROVED	DATE 8/22/00	PRICE LEVEL Appraisal 2000

CODE:D-8230

ESTIMATE WORKSHEET

FEATURE: 01-Jul-02

City of Rosalie, NE
Wastewater Quantities
Year 2040 Projections

PROJECT:
Omaha Tribe of Nebraska Needs Assessment

DIVISION:

FILE:
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PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			D8230				
		Wastewater Stabilization Pond					
		dual celled, discharging, facultative					
		Cell 1 volume =1.845 mg					
		excavation, 307'x307'x8'/27/2		14,000	CY	$ 4.00	$ 56,000.00
		backfill and compaction		14,000	CY	$ 3.00	$ 42,000.00
		Fence, 3 strnd, barbed wire 6 ' tall w/ gate(4X330')		1,400	LF	$ 2.00	$ 2,800.00
		Access road					
		8' wide gravel surface		1,400	LF	$ 7.00	$ 9,800.00
		clay liner		6,200	cy	$ 17.50	$ 108,500.00
		sides slopes from toe to top o berm					
		plus bottom areas					
		=8x10exp.5(4(327)					
		plus 280exp2					
		=111,490 sf x 1.5' thick/27					
		Subtotal (sheet 2 of 2)					$ 219,100.00 ✓
		Subtotal (sheet 1 of 2)					$ 241,976.00
		Mobilization					$ 23,000.00 ✓
		Unlisted Items (15%)					$ 75,924.00 ✓
		Contract Cost					$ 560,000.00 ✓
		Contingencies (25%)					$ 140,000.00 ✓
		Field Cost					$ 700,000.00 ✓
		Non-Contract Cost (30%)					$ 210,000.00 ✓
		Construction Cost					$ 910,000.00

QUANTITIES		PRICES	
BY R. Jurenka		BY K. Copeland	CHECKED TA 7/1/02
DATE PREPARED 6/24/02	APPROVED	DATE 7/1/2002	PRICE LEVEL Appraisal 2002

CODE:D-8230

ESTIMATE WORKSHEET

FEATURE: 01-Jul-02

City of Rosaile, NE
Wastewater Quantities
Year 2040 Projections
Treatment Alternatives

PROJECT: Omaha Tribe of Nebraska Needs Assessment

DIVISION:

FILE: H:\D8170\EST\Spreadsheet\Copeland\omaha\[rosalieww.xls]A

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Sewer Collection System	D8230				
		PVC Sewer pipe, SDR35 , ASTM 3035					
	1.1a	4"		2900	LF	$4.00	$11,600.00
	1.1b	6"		5500	LF	$5.50	$30,250.00
		manholes @ 400' spacing, 44 req'd					
	1.2	manhole frame and cover		21	ea	$375.00	$7,875.00
		-excavation for:					
	1.3	MHs, 6'diax8'deep=8cu.yds @21x		168	CY	$13.00	$2,184.00
	1.4	pipe, 3' wide x 5' deep		4700	CY	$4.50	$21,150.00
		backfill & compaction for:					
	1.5	MHs 8cy-4cy=4cy/mh		84	CY	$13.00	$1,092.00
	1.6	pipe		4650	CY	$8.00	$37,200.00
	1.7	-flexible couplings, 2 per MH, 4"		42	ea	$300.00	$12,600.00
		precast reinf'd conc mh riser, 5' ID w/					
	1.8	flat top and base		21	ea	$3,000.00	$63,000.00
	2	Lift Station, duplex 86 gpm @ 100 ' TDH					
		4' dia. 10'deep					
	2.1	excavation= 25*3.14/4*11/27		8	cy	$25.00	$200.00
	2.2	backfill		1	cy	$50.00	$50.00
		-manhole risers with flat slab top/integral bottom					
	2.3	5' ID x 10' deep		1	ea	$3,500.00	$3,500.00
	2.4	-CI heavy duty manhole frame and cover, 24" dia		1	ea	$375.00	$375.00
	2.5	-flexible couplings, 3 per lift sta.		3	ea	$300.00	$900.00
	2.6	Pump motor, power & controls		1	ls		$50,000.00
		Per Quotes from Canyon Systems,					
		Use 34,000 for above material including					
		startup assistance, and submittals					
		SUBTOTAL					$241,976.00 ✓

QUANTITIES		PRICES	
BY: R. Jurenka	CHECKED	BY: K. Copeland	CHECKED: TA 7/1/02
DATE PREPARED: 6/24/02	APPROVED	DATE: 7/1/2002	PRICE LEVEL: Appraisal 2002

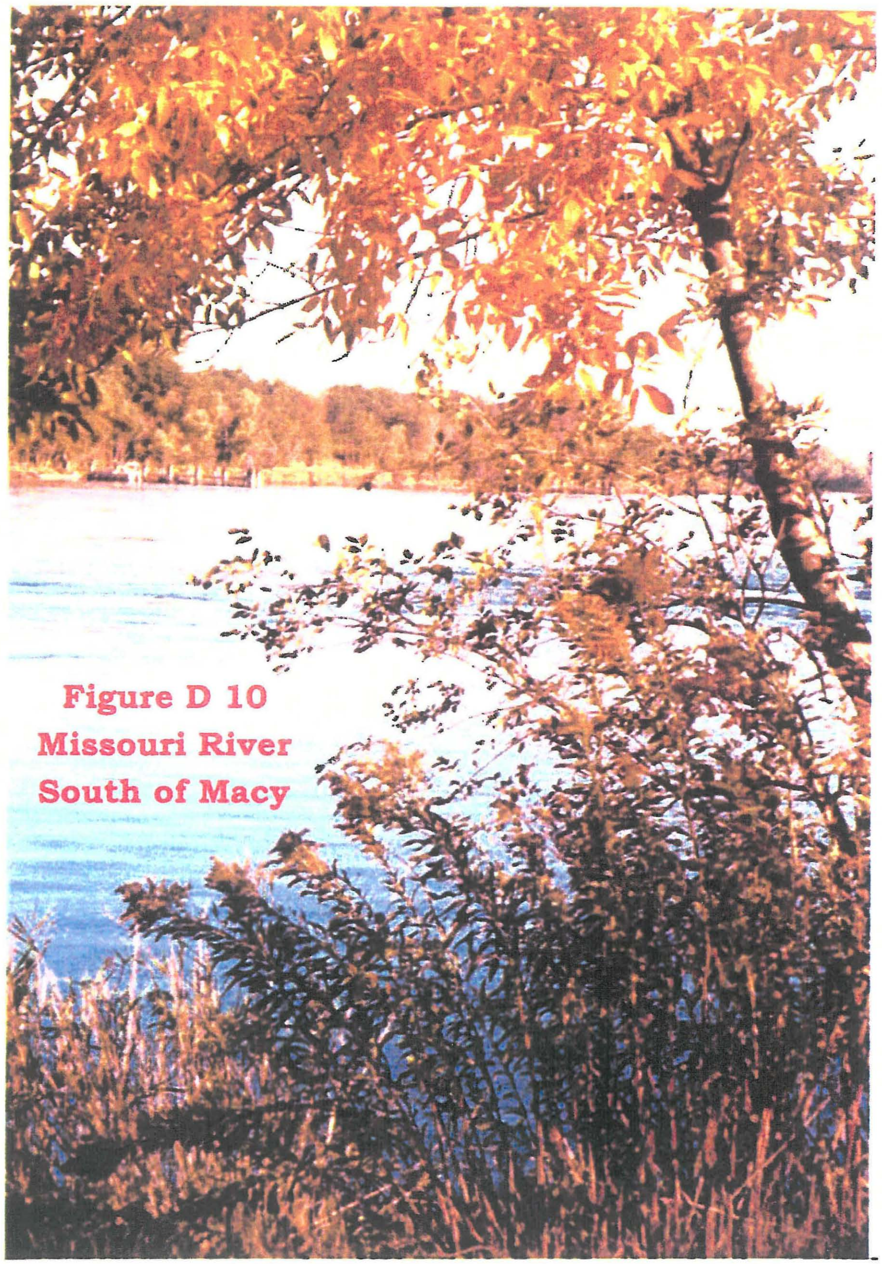

Figure D 10
Missouri River
South of Macy

Figure D 11
Macy Commercial
Establishment

Figure D 12
Missouri River
South of Macy

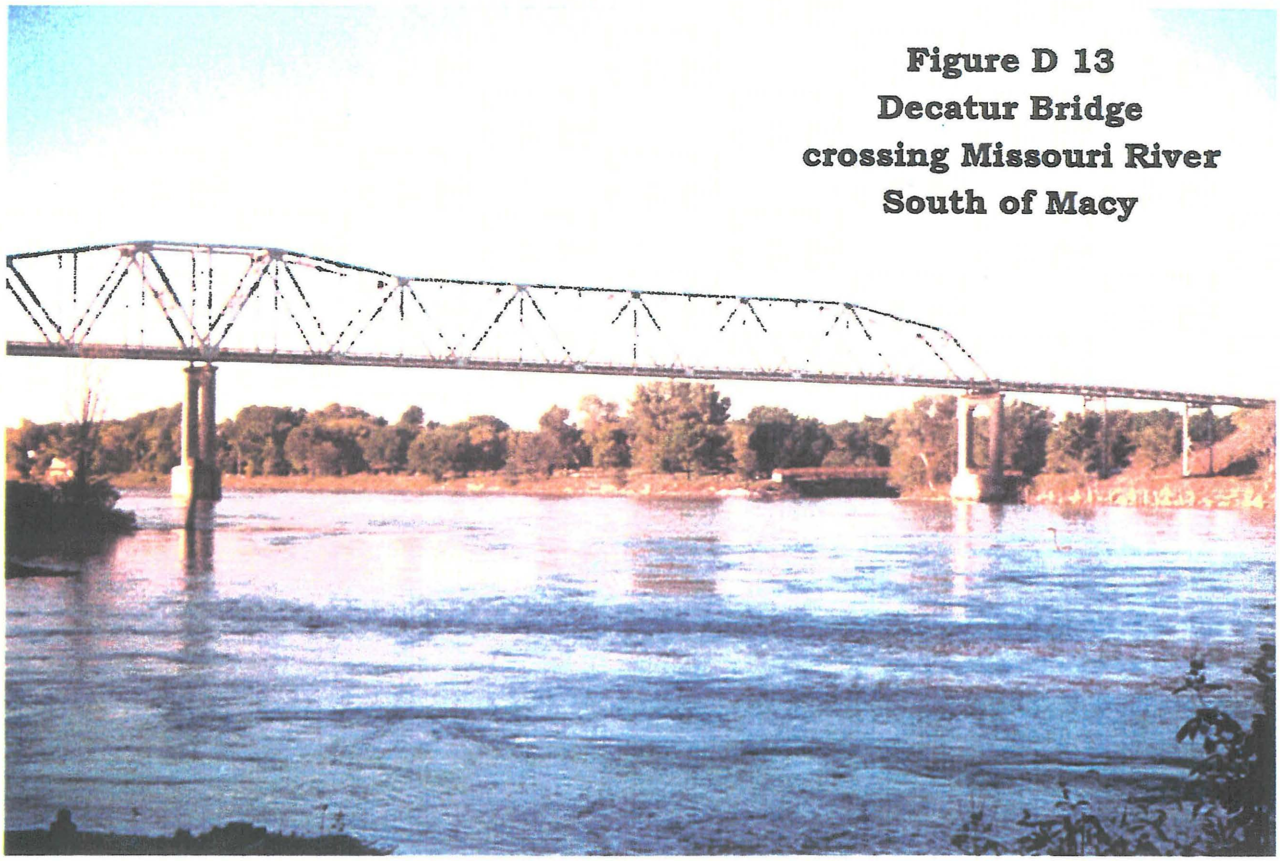

Figure D 13
Decatur Bridge
crossing Missouri River
South of Macy


Figure D 20. Pender Wastewater Treatment Plant

Figure D 21. Pender Utility Superintendent Bob Fendrick and BOR Project Manager Berril Gold

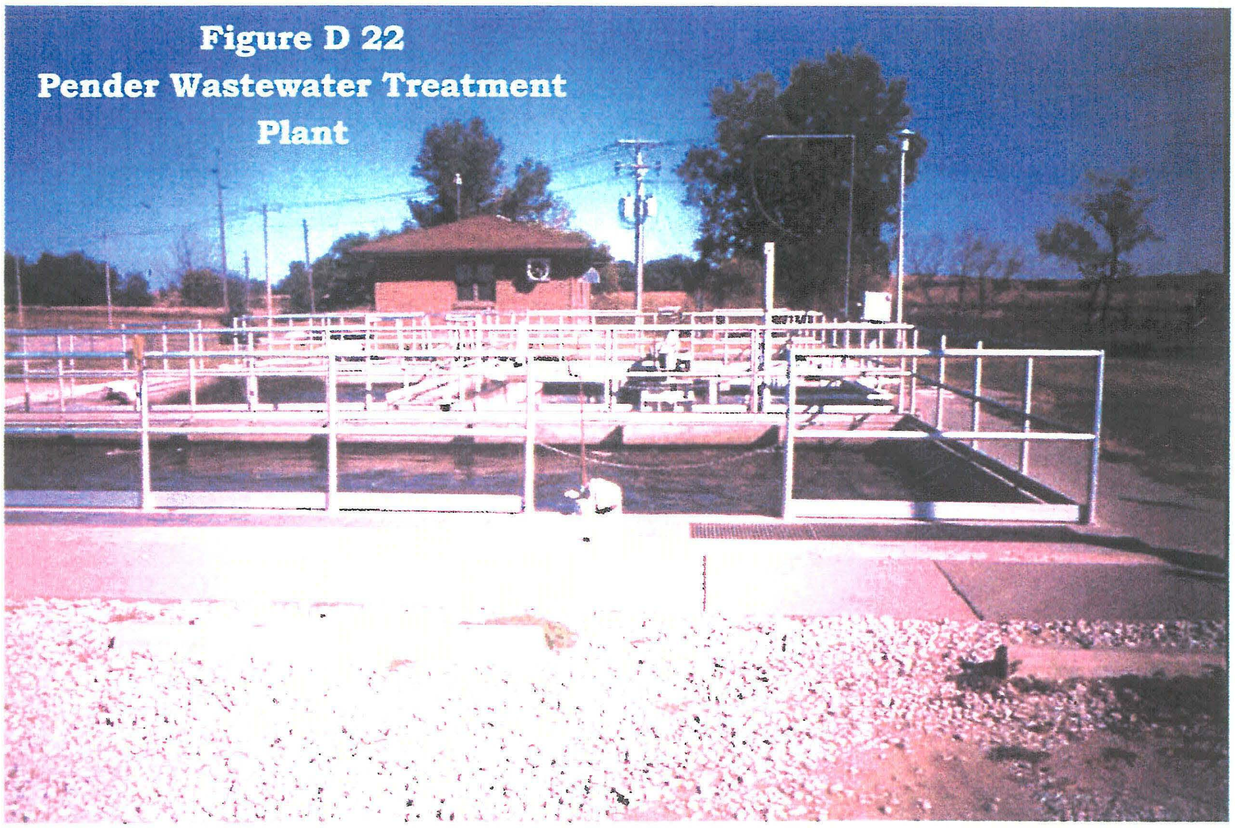

Figure D 22
Pender Wastewater Treatment Plant

Figure D 23
Pender Concrete Water
Storage Tanks

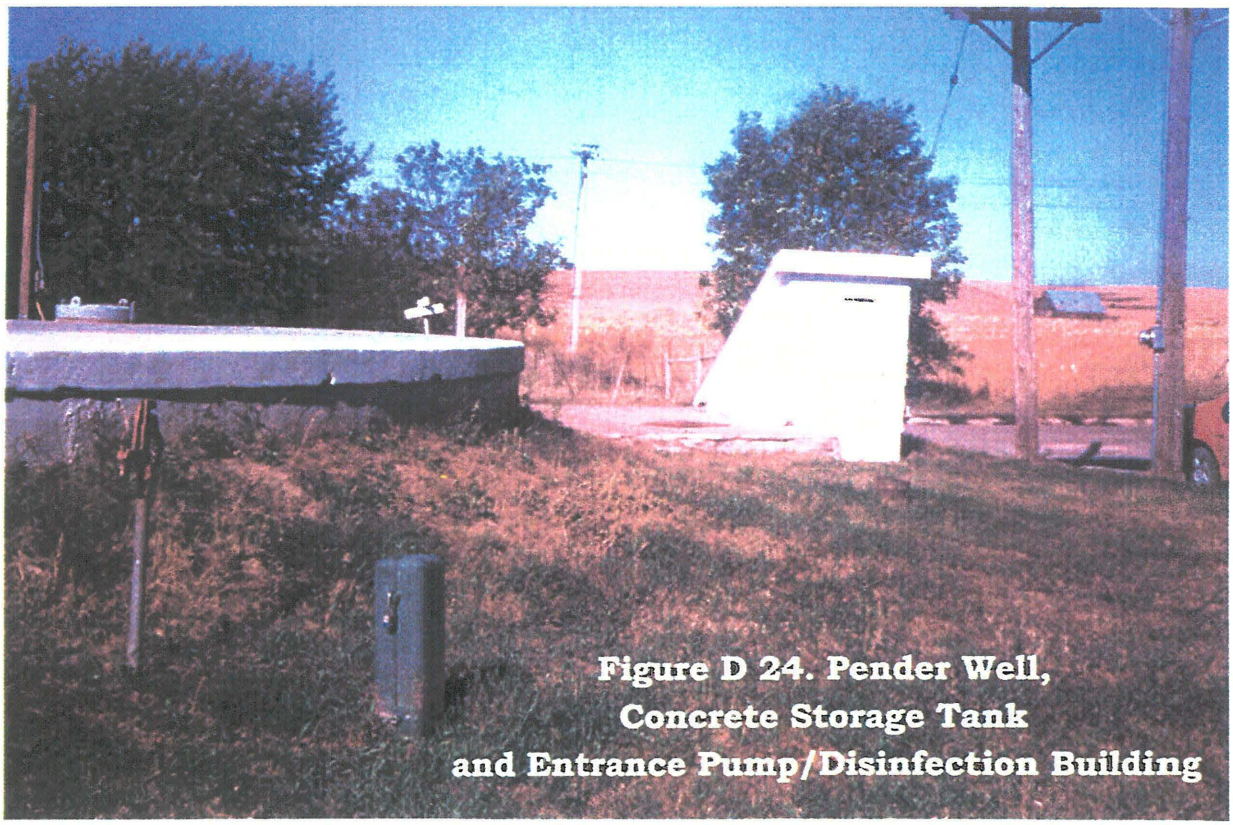

Figure D 24. Pender Well, Concrete Storage Tank and Entrance Pump/Disinfection Building

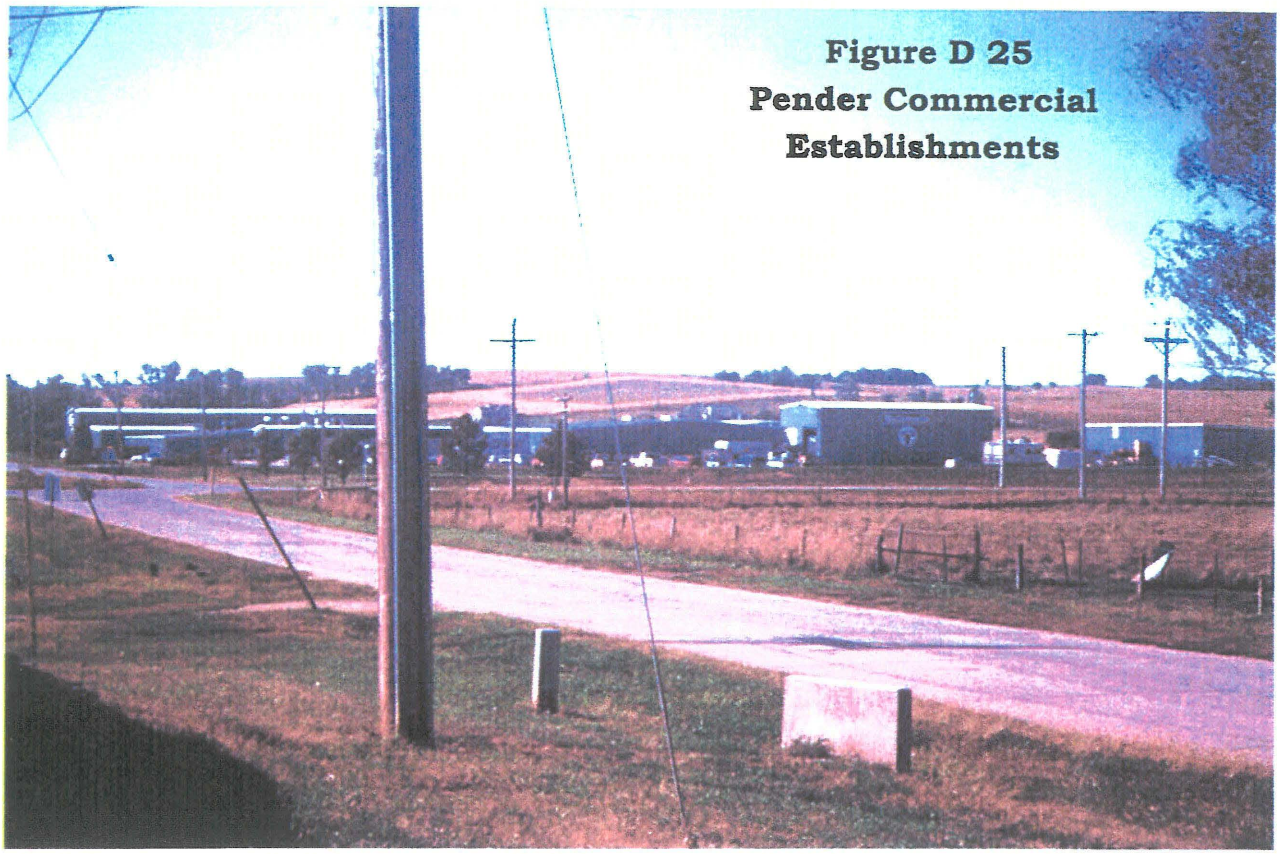

Figure D 25
Pender Commercial Establishments

Figure D 26
Pender Well house

Figure D 27
Pender Well & Concrete
Storage Tank

Figure D 30
Walthill, Looking east,
from Walthill Water
Storage Tank

Figure D 31
Walthill Water
Storage Tank, east side

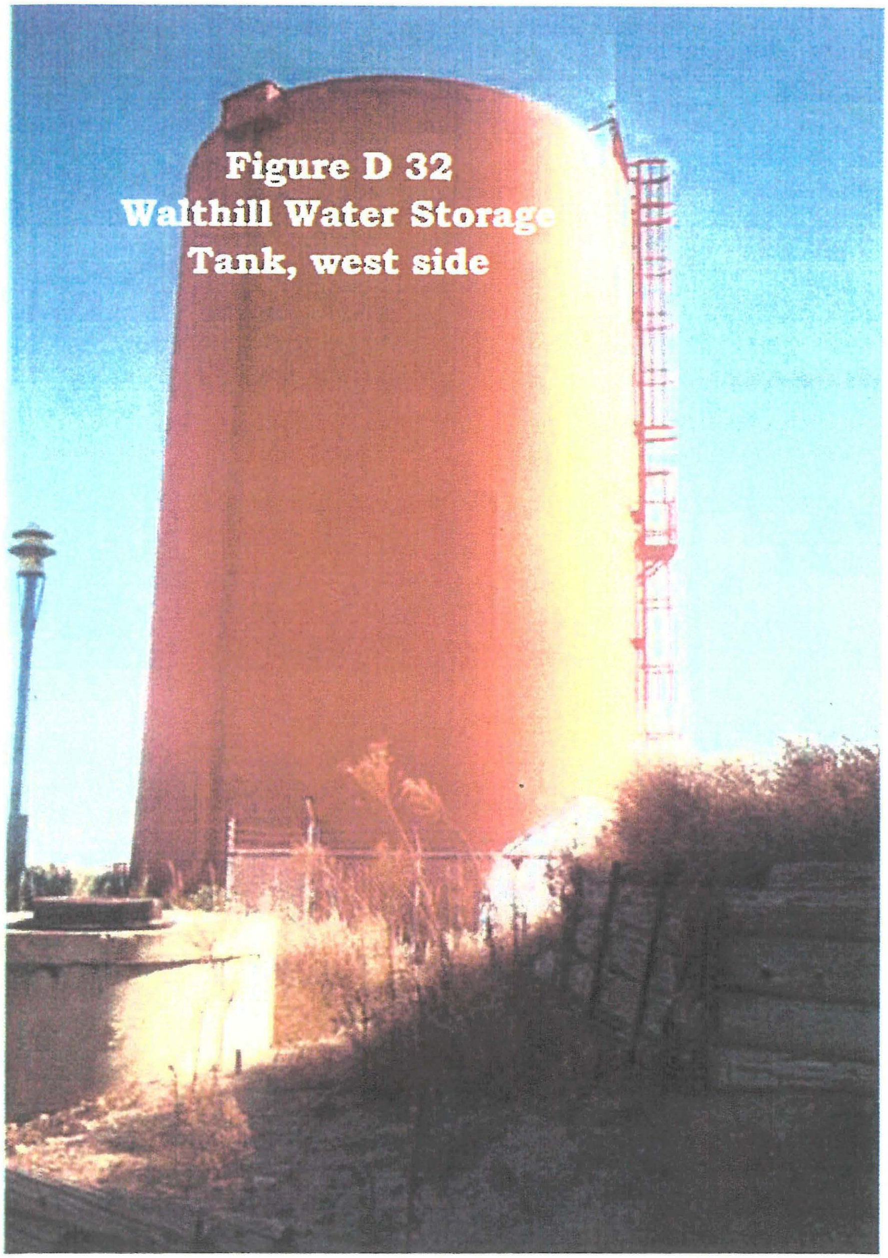

Figure D 32
Walthill Water Storage
Tank, west side

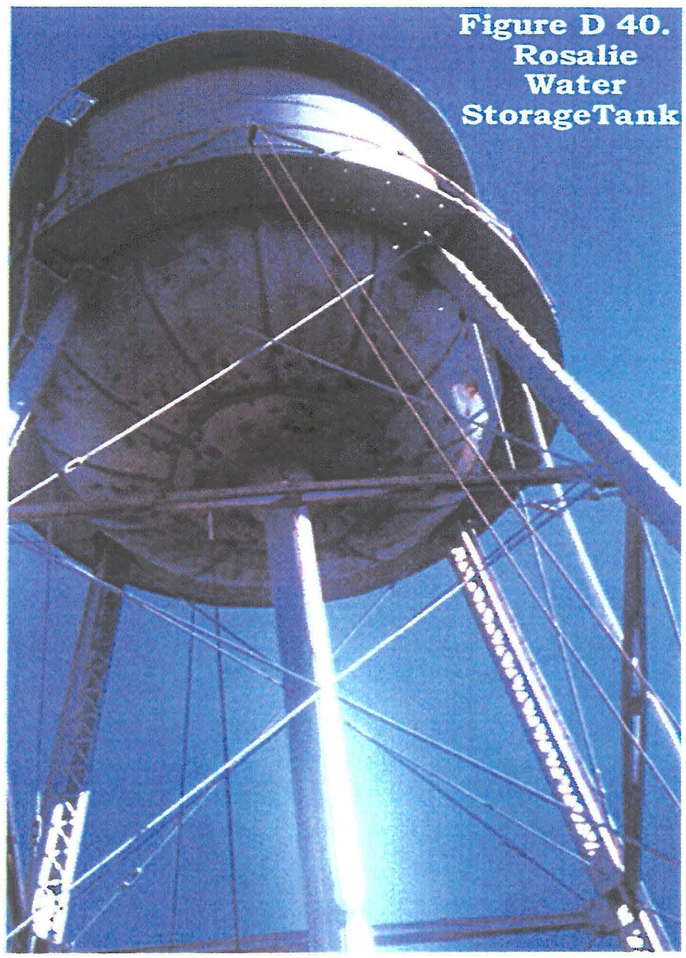

Figure D 40. Rosalie Water StorageTank

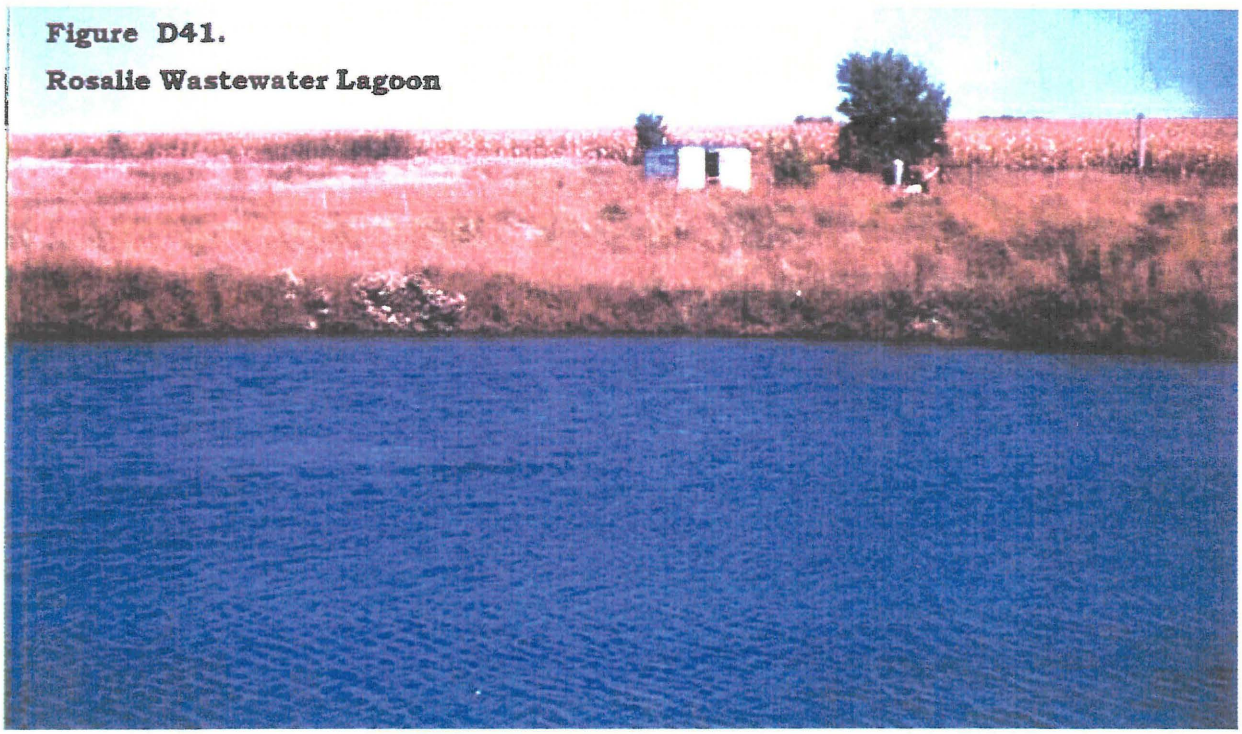

Figure D41.

Rosalie Wastewater Lagoon

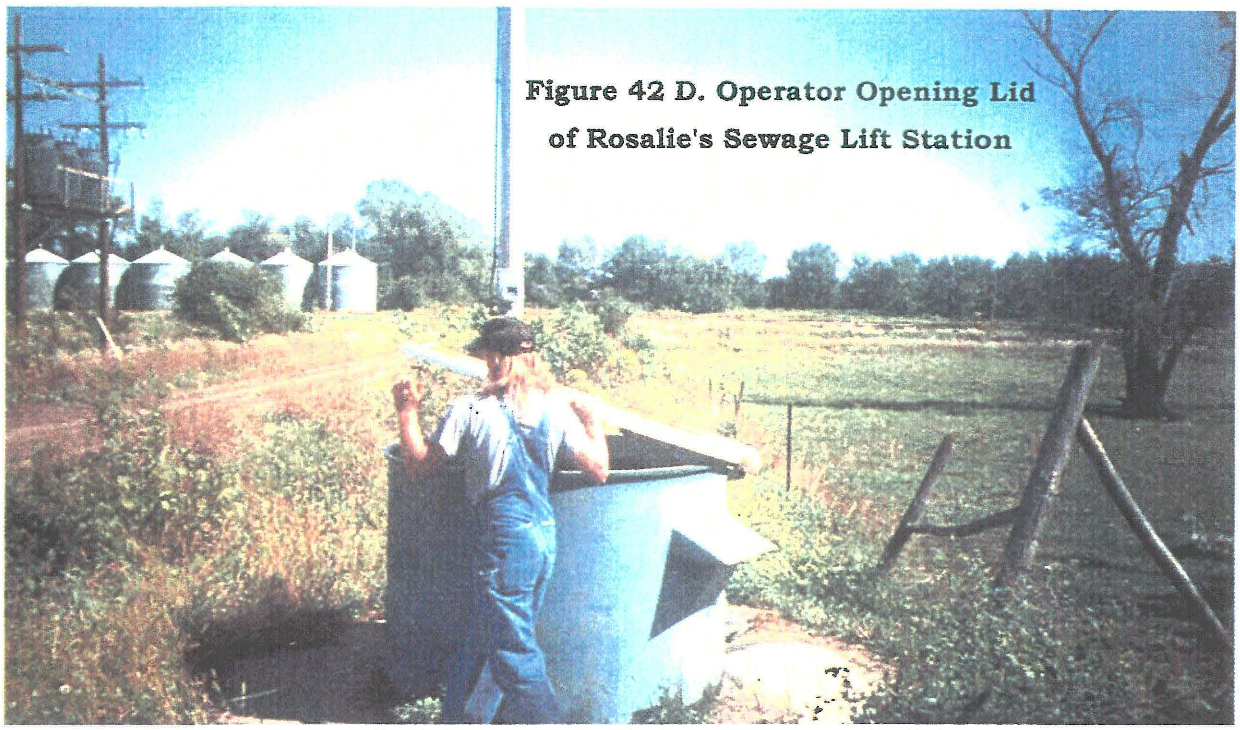

Figure 42 D. Operator Opening Lid of Rosalie's Sewage Lift Station

Figure D 43.
Rosalie's Commercial Establishments