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Estimating Future Water Demand Using Population and Economic Growth Projections: A Guide for Municipal, Rural and Industrial (MR&I) Water Assessments

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This needs assessment guide provides methods for projecting water demands as influenced by changes in population and in commercial and industrial activity. This guide includes a description of factors that determine water demand and detailed information on techniques for estimating current and future water demand. The population projection techniques presented in this guide include the use of projections from state and local sources, trend analyses, demographic modeling, combined demographic and economic modeling, and probabilistic methods. Particular attention is paid to procedures applicable to Native American areas because many needs assessments have been completed for reservations.

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Estimating Future Growth Using Population and Economic Growth Projections: A Guide for Municipal, Rural and Industrial (MR&I) Water Assessments

United States
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EXECUTIVE SUMMARY

The primary purpose of this needs assessment guide is to provide methods for projecting water demands as related to changes in population and in commercial/industrial activity. This guide includes a description of the components typically included in a needs assessment, a summary of the information and data that should be used to characterize water supply conditions and problems. Most important, it provides a description of factors that determine water demand and detailed information on techniques for estimating current and future water demand. Although this guide focuses on the demand component of needs assessments, it should be recognized that water supply issues and use rates are also an important part of these assessments.

Various population projection methods and applications are presented, and the advantages and shortcomings of each are described. These techniques include the use of population projections at the state and county levels provided by state agencies or other groups, simple trend analysis based on historical rates of growth, demographic modeling, combined demographic/economic models that include modifications for labor supply and demand factors within a region. Also included in the techniques are population projection scenarios which reflect varying demographic assumptions, and the use of probabilistic techniques where historical data or the judgment of experts is used to estimate the probability of changes in demographic variables that influence population growth. Each of these methods is applied in an example to demonstrate their use.

Techniques for projecting the level of commercial and industrial activity in the future are also presented. The type of establishment has a significant effect on water demand because there is a wide variation in water use for different types of activities. Therefore, projections must be made in terms of both the number and the type of activities likely to be located in the study area. Although the exact number of commercial and industrial establishments in the future cannot be predicted with any certainty, general trends in the growth of these establishments in a region can be evaluated and used to determine future commercial and industrial water demands. These trends can then be extrapolated to the future using linear or nonlinear models. Future commercial and industrial demands can also be evaluated by looking at current and projected future growth on a statewide or national level and applying that level of growth to similar local activities. Some types of businesses such as retail trade and services may mirror changes in population. Therefore, in some cases projected population growth rates can be used to estimate business growth.

Particular attention is paid to procedures applicable to Native American areas because many needs assessments have been completed for Indian reservations. Last, applications of the population and commercial/industrial projection techniques are presented for the Jackson County area of Kansas, which includes the Prairie Band of the Potawatomi Indian Reservation.

INTRODUCTION

This needs assessment guide serves several purposes. First, it provides a general description of the components in a typical municipal, rural, and industrial (MR&I) needs assessment. Second, it presents insight into the types of variables that should be used to characterize water supply conditions; water supply issues and problems encountered in many needs assessments are described. Third, the guide describes factors that influence water demand and techniques for estimating current and future water demand. The primary factors that influence future demand are per capita (or per household) water use, population growth (or decline) and changes in the number and type of commercial and industrial water users.

This guide focuses on the demand component of MR&I needs assessments as related to population growth and changes in commercial and industrial water use. However, it should be recognized that water supply issues and water use rates addressed in a needs assessment are equally important. Various population and commercial/industrial projection techniques and applications are presented and the advantages and shortcomings of each are described. Particular emphasis is given to procedures applicable to Native American areas because many needs assessments have been completed for Indian reservations.

Background: What Is Included in an MR&I Needs Assessment

The primary purpose of an MR&I water needs assessment is to estimate current and future water demand and supply within a study area and to identify problems and needs based on these estimates. MR&I water needs can be the result of insufficient water supplies, poor water quality, insufficient treatment, or distribution systems that do not deliver water in sufficient quantities to areas where demand exists or is expected in the future. To identify whether there are current or future shortages and to estimate the magnitude of these shortages, if they exist, water supply and demand must first be characterized and estimated. Demands can be compared with available supplies to determine whether there are existing water shortages or if shortages will occur in the future.

An MR&I water needs assessment must provide enough information for policymakers to determine the need for water supply/system improvements and must also provide a basis for proceeding to a feasibility level study with specific objectives and alternatives. A needs assessment is generally based on existing data. Most needs assessments include a discussion of water quality, current and potential water sources, characteristics of the current water supply system including distribution and treatment systems, and estimates of future demands. A description of existing wastewater treatment systems and problems associated with treatment may also be included if those systems are a source of water quality problems or a source of water supplies for reuse. Some past needs assessments have included a cursory review of possible water supply alternatives that could help meet the needs identified in the assessment.

A needs assessment provides documentation for correcting current and future water supply shortages or for water quality problems that may require action. The need may arise from a shortage of available water or a shortage of water of a particular quality needed for specific water uses. Need is also identified as a result of a deteriorating distribution system, an insufficient treatment system, or expected changes in the current source of water supply. Raw water supplies may be sufficient, but an inability to get treated water to the users will result in unmet demand. Also, current water supplies may be adequate for current demand, but future needs may exceed existing supplies.

Water demands are evaluated by examining current and future population levels, current and future commercial/industrial activities, per capita or per employee water use rates and potential future economic development. Current water demands can generally be estimated using data from the water utility providing MR&I service or from published water demand studies. Therefore, estimating current needs is relatively straightforward. Projecting future population and commercial/industrial activity are the most difficult aspects of estimating future water demands.

The type of commercial activity in an area has a significant impact on water demands and needs. For example, a food processing plant requires a much greater amount of water than a department store. An electronics manufacturing plant may require better quality water than an assembly plant. Therefore, projections of the types of economic activities expected in a region are needed to determine future water quantity and quality needs.

An additional consideration that must be addressed in a needs assessment is the location of future population and commercial growth. Location is an important consideration because needs can also be reflected through water distribution systems that are not located where current or future water users are located. A system that has sufficient water supplies but an inadequate distribution system will not meet water demands any more effectively than a system that has insufficient water supplies.

Many needs assessments are carried out for Indian reservations where information is frequently not available from standard sources on the reservations. As a result, methods for estimating water use and projecting future population and commercial growth in areas with limited information is needed for many Indian reservations and other sparsely populated rural areas. These methods must be rigorous enough to be defensible, but they must also rely on fairly basic input data. In some rural areas, U.S. Bureau of the Census data may be sufficient for generating population projections. However, census data can undercount rural population, especially on Indian reservations. Therefore, special procedures must be considered when projecting population on Indian reservations.

Analysis of Water Supplies

As mentioned above, the primary focus of this guide is the demand side of a needs assessment. However, this short section on the supply side of a needs assessment is included to highlight some of the most important water supply considerations. An analysis of water supplies within a study area should include enough detail that existing water supply shortages and water quality problems can be identified and potential future shortages can be predicted. An evaluation of water resources requires an inventory of the current water supply. Factors that must be considered include the current source of water supplies and the reliability of that supply, water quality, the condition of existing facilities including pipeline and treatment systems. The evaluation also must consider potential health problems related to water quality, the overall age and condition of the facilities, the current population served, the types of water uses in the area and applicable water laws.

The current source of water supplies and the reliability of supplies are important considerations. Some sources, such as groundwater, may be difficult to increase to meet future demands whereas others, such as surface water, can be increased more easily. Many rural areas and small municipalities in the western United States depend on diminishing groundwater supplies for their municipal and industrial water. In some cases new wells have been drilled or existing wells drilled deeper to meet current demands. Increased groundwater pumping within a limited aquifer would generally not be considered a reliable source for increased future water supplies. On the other hand, increasing surface water supplies may require increasing diversion and water treatment capacity, or perhaps buying water rights to the surface water supply. The physical constraints associated with groundwater supplies do not generally apply to surface water supplies. The constraints on surface water expansion are related more to the availability of facilities to divert water and to institutional and legal constraints. Such constraints to expanding future water supplies must be considered when evaluating the quantity and reliability of the current water supply.

Water quality is an important consideration. Therefore, water quality can represent a water supply need when poor water quality represents a constraint to the production of goods and services vital to the economy of the study region or when the water cannot be used for domestic purposes. Any water use adversely affected by poor water quality must be documented through public health records, records of business closures or relocations due to water quality concerns, or other verifiable evidence.

Determining the capacity of the existing system to identify whether it is capable of meeting projected future water demand is important. If the system is not adequate, then this represents a future water supply need for the study area. Capacity may be defined in terms of how much water can be moved through the system, treatment capacity, the area covered by the distribution system, or the ability to get water to the faster growing areas that need the water most. The types of water treatment needed and anticipated, water quality at the current level of treatment, water quality standards, and the costs of treatment are also factors in the assessment of existing supplies. Water treatment capacity and the ability to expand that capacity is a particularly important consideration when evaluating the overall ability of the system to meet current and future needs.

Similar to the capacity of the system is the need to evaluate the overall condition of the distribution system. Clearly, an older system that has not been well maintained or uses outdated technology represents a greater potential for problems and a greater potential for unmet needs.

Wastewater treatment is not generally a primary consideration in a needs assessment. However, wastewater treatment should be addressed to the extent that wastewater reuse can be a viable solution to a water shortage. In this case, the evaluation of wastewater treatment is actually a water supply issue because reuse can increase the supplies available for other MR&I uses.

To determine the adequacy of existing systems to meet water demands, the water supply information described above must be combined with estimated water demands. Techniques which can be used to project future population, to estimate per capita use rates, and to estimate future commercial and industrial activity are presented below. The combination of current and future demands with available water supplies determine need. The evaluation of existing water systems provides information on both the current conditions and the adequacy of the system given estimates of future demands. In many cases adequate water supplies or treatment will have to be expanded in the future.

Analysis of Current and Future Water Demand

To evaluate the ability of current water supplies to meet future demand, future water demand must be estimated. Two factors are used to determine the level of residential water demand in the future: water use per household (or per capita) and the number of people who will depend on the water supply in the future. Changes in per capita or per household water use depend on water conservation practices; changing attitudes about water use; the price of water; changes in income levels, which might allow the purchase of larger homes with larger yards; and changes in social variables such as household size. Changes in population size are caused by a wide variety of factors including fertility rates, mortality rates, and migration. These changes are influenced by many factors, including the health of the population, economic conditions, traditions, and the characteristics of the region.

Per capita usage estimates. – Possible sources of per capita use rates include information from local water suppliers or standard water use rates from private water service or research organizations and government agencies. Local water suppliers in the study area are likely to have records indicating total water use and the number of water users by the type of use. This information can be obtained for a representative year or can be used to estimate an average over a period of years. Per capita use rates based on local information provide the best way to represent the true water demands for that area.

more general sources, such as state or regional averages, can be used to estimate demands.

Per capita use rates generally include a commercial or industrial water use component that accounts for water use attributable to these sectors. Using these per capita use factors assumes that the commercial/industrial sector of water use will change at the same rate as the change in population. When industrial or commercial growth is expected to increase at a rate different from the population, water demands for these sectors can be adjusted based on projections of future commercial and industrial development. These adjustments are not always easy because of the difficulty in estimating future changes in commercial and industrial activities.

Location of commercial and industrial development. – The location of commercial and industrial development does not always follow a predictable pattern. Factors that influence the location of industries include accessibility to transportation, tax structure, availability of raw materials, a work force with the skills and education necessary, infrastructure such as roads and utility service, and the existence of more competitive areas which may lure away businesses with superior features. Any change in these factors has an impact on commercial and industrial growth.

Economic development plans are a potentially useful source of information that can help in estimating future commercial and industrial growth and the location of growth. These plans provide documentation of desired growth patterns, of the types of economic activities that will be encouraged to locate in the area, and of the future availability of an infrastructure which will support development. Although these development plans do not guarantee where growth is likely or the type of growth likely, they do document the amount and type of growth that will be encouraged.

In many cases economic development plans are not available. In some cases, however, local planning agency personnel can provide the same type of information that would be in a development plan. When neither development plans nor planning personnel are available for information, trends of past growth and the availability of an infrastructure in the study area can be used to estimate the amount and location of future growth. County business pattern data from the Bureau of the Census, employment data by type of business and occupation from the Bureau of Labor Statistics and the Bureau of the Census, and net taxable sales data from various state departments of revenue can all be good sources of data for determining trends in commercial and industrial activity.

The location of growth is important when determining the capability of current facilities to meet future demands. Future commercial, industrial or residential development occurring in an area which does not currently have water service also represents a need. Therefore, in addition to estimating the number and types of activities in a region, as described above, the future location of growth also must be predicted. Obviously this is a difficult task, and in many cases the availability of an infrastructure will dictate the difficult task, and in many cases the availability of an infrastructure will dictate the pattern of growth. However, to the extent possible the analyst must determine which areas are particularly attractive for future growth or have been targeted by local planning agencies for future growth.

Analysis of Future Water Demand

Estimating future water demand in a MR&I water needs assessment actually includes several different analyses. Residential population growth must be projected and per capita or per household water use rates must be estimated. Commercial and industrial activity must also be projected, both in terms of the number and types of activities likely to locate in the area. The type of establishment has a significant effect on water demand because water use varies significantly for different types of retail, service, manufacturing, assembly, processing, and other activities. Last, per capita water use estimates must be projected based on use trends, future socio-economic conditions, and other factors.

Changes in water use rates. – Future water use rates can be difficult to predict because they are based on changes in attitudes and technology. However, a few generalizations can be made. Typically, per capita use rates will increase with income that translates to larger homes with more bathrooms and landscaping, more water-using appliances, and less incentive to reduce water consumption to keep water bills low. However, per capita or per household water use is likely to increase more when incomes rise to a moderate level than if incomes rise from a moderate to a high level or from a high level from a low to a very high level.

In those cases where a system has significantly higher water use rates than the average for similar systems, future water use rates may be reduced through conservation measures. In some cases water conservation (demand side management) may solve future needs and supplies may be considered adequate even though demand currently exceeds supplies.

The rate of water use can vary widely from region to region because of climatic differences, cultural differences, and variations in population density, and economic conditions. The United States Geological Survey estimates of per capita water uses by state provide a basis from which water use rates in a specific area can be evaluated. A relatively high water use rate in a study area may be an indication that water conservation measures could result in reduced water demand. Estimates of water use for the 17 contiguous Western States from 1975 to 1995 are presented in Table 1.

Table 1. – Public-supplied freshwater use for the
17 Western States (gallons/capita/day)

	1975	1980	1985	1990	1995*
Arizona	211	230	200	208	192
California	185	183	218	229	175
Colorado	200	233	245	213	188
Idaho	236	231	302	262	163
Kansas	170	168	158	167	145
Montana	267	273	257	226	165
Nebraska	248	213	167	251	175
Nevada	321	322	326	344	306
New Mexico	236	240	225	226	184
North Dakota	130	116	135	158	114
Oklahoma	130	130	184	193	173
Oregon	190	193	214	212	164
South Dakota	126	167	147	137	121
Texas	176	335	194	192	176
Utah	331	375	285	308	254
Washington	256	246	271	221	217
Wyoming	191	256	298	260	188

* Preliminary Estimate Source: United States Geological Survey (USGS) Circulars 765, 1001, 1004, 1081 and Open-File Report 97-645, Reston, VA.

Influence of the price of water on demand. – The price of water can have a significant impact on the quantity of water demanded. Higher prices have a tendency to reduce demand. Therefore, a change in the water price structure in the future can have an impact on future per capita water use. The impact of retail water prices on water use can be described using the price elasticity of demand. The price elasticity of demand is the ratio of the percentage change in quantity of water used to the percentage change in the price of water.

Price elasticity characterizes the responsiveness of quantity demanded for a product to changes in the price of a product. Most studies of municipal water supplies have indicated that the price elasticity is relatively low, meaning a change in price has a small impact on the quantity demanded.

In general, the price elasticity of demand for domestic water in an urban setting has been estimated to range from 0.11 to 0.86. A value less than 1.0 indicates demand is price inelastic, where the percentage change in quantity is less than the percentage change in price. The range in elasticities is a result of different conditions for different cities and whether the elasticities are short-run or long-run. In addition, short-run elasticities are typically smaller than long-run elasticities because demand does not respond as quickly to price changes over a short period as it does over the long-run. Price elasticities can be used to adjust future water use rates when future water price changes are anticipated.

As an example, assume a representative elasticity is the midpoint of the range (0.11 to 0.88) or .48. If a 10 percent increase in the price of water were expected, then a 4.8 percent reduction in water use would be the estimated result. If water use were 150 gallons per capita per day (gpcd) before the change in price, consumption after the price change would be estimated to be 143 gpcd. The lower use figure (143 gpcd) that accounts for the effect of expected higher prices on quantity demand, would be appropriate for estimating future water demands.

Water conservation. – Water conservation can be a factor in determining current and future water supply needs. Water conservation focuses on the demand side of the water supply question. Implementing water conservation measures, such as the installation of more efficient plumbing fixtures, low-water landscaping, or conservation pricing (where the price per unit of water consumed increases with increasing usage) can reduce water supply needs by reducing demand. In some cases the average quantity of water used over a month or a year may not change, but the pattern of consumption through time may require modification to better match the seasonality of water supplies.

Changing socio-economic conditions. – Changes in the regional economy and changing attitudes can have a large impact on water use. As people become more aware of water supply problems and actually experience problems, water use tends to fall. Water-saving plumbing fixtures and general recognition of water conservation have reduced water use in many areas. In addition, as incomes rise water use has a tendency to increase due to larger lots, more landscape plants requiring water, and more water-consuming appliances and luxuries (for example, swimming pools) are used.

Number of water users. – In most cases, the number of water users, including both households and businesses, is the primary factor in determining future residential water demands. As a result, projections of future population and business growth are very important parts of a MR&I needs assessment and are the focus of this guide. The level of sophistication that should be used for projecting future population depends on the time and funds available for the analysis, the population range, and the complexity of the local economy. Other criteria used for projecting population include the desired precision of the estimates, the factors complicating population migration and settlement patterns, and the data available for projecting future population and business/industrial growth. Methods for projecting population and business growth are presented in detail below.

Projecting Population in the Future

The reliability of a set of population projections depends on the applicability of the assumptions used in the projection technique. Assumptions are required for migration, fertility, and mortality. All three of these factors, particularly migration, are affected by economic growth. Therefore, assumptions about future economic conditions must also be made when projecting population growth. Migration rates are generally the least predictable of these three factors and mortality rates are typically the most stable.

Migration patterns can change quickly as a result of economic fluctuations, political factors, or social conditions. For example, a decline in the agricultural sector may cause migration from rural to urban areas. In the case of Indian reservations, a change in the requirements to become a tribal member may change migration into the reservation. Another aspect of migration with little certainty is the characteristics of the population migrating into (or out of) the area. The migration of a relatively young population into an area will have more of an effect on population growth than the migration of a very old population. As a result, unpredictable and potentially rapid changes in factors that influence migration can easily lead to errors in population projections.

Fertility levels tend to change abruptly over time, although not as abruptly as migration patterns. Changes in birth rates can result from improved medical care, changing attitudes towards having children, the existence of two-wage-earner families and other factors. These changes have a tendency to occur in cycles that may be somewhat more predictable than changing migration patterns.

Mortality rates are the most stable of the factors influencing population growth. Mortality rates can vary over time because of advances in health care, but these changes are typically fairly gradual and predictable. However, as projections move further into the future, abrupt changes in mortality rates are more likely.

Population projection techniques. – A variety of techniques are available for projecting future population. Six techniques are described in detail below and applications are also presented to illustrate each. The six techniques are individually evaluated based on the difficulty associated with applying the method (including time requirements and ensuring the reliability of the results) the relevance of economic growth in applying the technique, assumptions that must be made by the analyst, data requirements, applicability of the method to rural areas with a small population, and the ease of understanding the methodology by public policy makers and the public.

The 6 (six) techniques are:

1. Population projections at the state and county levels provided by state agencies or other groups and applied to the area under consideration.

2. Simple trend analysis based on historical rates of growth.

3. Demographic modeling, which is typically the cohort-component method. The cohort-component method involves separate projections for mortality, fertility, and migration for separate age-sex groups.

4. Combined demographic/economic models, which involves estimation of population changes based on the demographic factors modified by labor supply and demand factors in the economy which may place constraints on future growth.

5. Population projection scenarios, where different assumptions are used with trend or demographic projection techniques to produce a range of projections based on a variety of assumptions.

6. Probabilistic techniques where historical data or the judgements of experts are used to estimate the probability of changes in demographic variables that influence population growth.

Each technique is applied to the same region of analysis so the results may be compared. In some cases, a more sophisticated model may not improve the performance of a projection because factors included in a sophisticated technique may not be relevant to that area.

Below, the six techniques are explained and include several modified hybrid techniques.

Population projections at the state and county levels. – If little time or resources are available to generate population projections for a specific area, then projections that have been generated by state or county agencies may be used to project future population. County level projections are generally available from state planning or budget agencies. Occasionally, projections are also available for larger towns and cities. When county-level projections are available and must be used as a basis for population projections at a specific site, then some criteria are needed for evaluating the reliability of the county-level projections.

The basic criterion is a comparison of historical growth rates in the county with rates in the specific study area. The first step is to compute historical growth rates and demographic attributes for the county and for the study area over several years. The second step is to compare the historical rate of change in county population with the rate of change in population at the study site. If the population characteristics and rates of change are similar, then the county level growth rate projections can be applied to the study site. If the historical rates of change of the county and study site are not similar, then the county projections should not be applied to the area of study. Similarity in historical growth rates (or rates of decline) implies that the areas have an underlying similarity in demographic factors, which will result in comparable growth (or decline) in the future.

Demographic information, in addition to historical population changes that can be used to compare general county conditions and the specific area under consideration, include the age of the population, the percentages of the female population in child bearing years

(15 to 44 years), the percentages of male and female residents, and indicators of migration. Applying county level population projections to a specific site is more defensible if there are underlying demographic similarities between the two sites.

The rate of population growth at the county level may be a reasonably good measure of population changes for municipalities under certain conditions. For example, in cases where one municipality represents a majority of the county population, rates of municipal population growth or decline may closely follow the county rates of change. It is possible that a county may be relatively homogeneous and, therefore, county projections are applicable to most municipalities within the county. It is also a possibility that all municipalities within a county are influenced by conditions that effect the county as a whole, which results in similar patterns of population growth (or decline) throughout the county.

It is possible for county population to be growing, while a few towns within the county remain stable or even decrease in population. If the historical percentage changes in population and the demographic characteristics of the county and the study site are not consistent, then county level projections should not be applied to the study site. Predicting the growth or decline of a city or town is complicated by the fact that local conditions are not fully reflected by county averages.

Trend analysis. – If county-level projections are not available or determined inappropriate for projecting the study area population, then a simple trend analysis may be used to project the population. This technique requires only historical population for the study area over a long enough period to obtain a statistically significant trend. At least 25 years is desirable, though a longer period would increase the reliability of the projections.

A simple linear regression, which fits a linear function between two variables (for example, time and population), can be used to determine whether there is a significant trend. Non-linear models can also be used if necessary. Historical population estimates are regressed with the time period as the independent variable. The first year of population data is designated as year 1. This results in a trend model where population is a function of time. This technique decreases variations in population that occur over time, resulting in a smooth trend line. If there is no significant trend, then a stable population can be projected.

The error associated with the predicted population for any single year is due to the variation that has occurred historically and would be expected to occur in the future. The basic structure of the population could change as a result of changes in the economy from development. These economic changes would not be accounted for in a trend analysis.

This procedure assumes that past age, sex, fertility, mortality, and migration trends of the population will continue into the future. However, these relationships can vary significantly over time. Therefore, assuming past trends will continue can result in unrealistic projections. For example, assume a small rural town (say, 7,000 people) has experienced an average population decline of 2 percent annually over the last 20 years. A simple trend analysis would project a population of only 3,200 people in 40 years. However, those people who have left the area during the last 20 years may be all of those who leave. So, assuming past out-migration will continue at the same rate will under estimate future population. Conceivably, assuming the past rate of population decline will continue can result in a projected population of zero within the planning horizon of a needs assessment.

The same type of problem may occur for moderately sized towns that have grown rapidly in the recent past. If recent growth is due to rapid economic development that is not expected in the future, then using the average rate of past growth may vastly overstate the population projections. Therefore, the results of a trend analysis must be checked to ensure they are reasonable.

Modified trend analysis. – A more rigorous trend analysis uses the change in the rate of growth from year to year to adjust the average historical rate of growth used to project the population. The change in the rate of growth from year to year may better identify changes in growth over time. In other words, the percent change in population from one year to the next is likely to better predict population than the change in population over several years.

For example, assume that the rate of growth of a town from 1975 to 1980 is 2.5 percent annually; the rate from 1981 to 1985 is 1.50 percent annually; the rate from 1986 to 1990 is 1.00 percent annually; and the rate from 1991 to 1995 is 0.75 percent annually. The average rate of growth from 1975 to 1995 is 1.49 percent annually. However, the rate of growth is declining over time. Therefore, projecting future growth at the average 21-year growth rate of 1.49 percent annually will probably overestimate future population given that growth is decreasing over time.

The change in the rate of growth between 5-year periods (1 percent from the 1975 to 1980 rate to the 1981 to 1985 rate, 0.50 percent from the 1981 to 1985 rate to the 1986 to 1990 rate, and 0.25 percent from the 1986 to 1990 to the 1991 to 1995 rate) is a better predictor of the change in the population relationships likely in the future. Continuing the pattern of change in the rate of growth over the next 40 years (0.625 percent from 1996 to 2000, 0.562 percent from 2001 to 2005, etc.) results in an average projected growth rate of 0.53 percent annually. This result is very different from the simple average growth rate (1.49 percent) and is likely to be a more accurate population projection.

Where population growth (or decline) has been fairly stable, a simple trend analysis based on total population and an analysis based on rates of population change from year to year will not result in very different population projections. However, the modified trend analysis can be very useful for rural study areas which experienced rapid population declines in the late 1970s and the 1980s but have recently experienced stabilized or even increasing population levels. A simple trend analysis would likely show a projected decrease in population for these types of areas, while the modified trend analysis may show a stabilized or slight increase in population levels.

Simple techniques with frequent revisions. – Some analysts believe trend analyses (simple or modified to account for changing growth patterns over time) are not rigorous enough to generate sound population projections. However, it is recognized that a trend analysis is necessary in situations where budget or information constraints do not allow the use of more sophisticated methods. As a result, some experts suggest that these simple analyses be revised frequently and the most recent empirical information available.

The reasoning behind trend analysis is the tendency for demographic characteristics to continue. A trend analysis can be fairly accurate over a short period. But as the time horizon increases the accuracy of the projection decreases. If the simple trend projection techniques are revised frequently, then the errors associated with projections can be corrected over time.

This approach is of limited use from a planning perspective. If a municipality is considering construction of a new distribution system or water treatment plant, providing population projections only 5 to 10 years in the future at 5 to 10 year intervals will not be very useful for projecting future demands. Knowing that the projections will be revised frequently will not help current planning decisions. Municipalities and rural water systems need reasonably accurate estimates of future demand to preclude having to expand facilities in the near future and to avoid incurring high costs due to over-capacity. Water supply planning generally requires projections for 40 to 50 years or more into the future.

Demographic modeling. – Demographic modeling involves the estimation of relationships between demographic characteristics and population levels to project future population. Population projections are frequently generated using the cohort-component method. A cohort represents a group of individuals having a specific factor (such as age) in common. For example, males aged 19 to 25 represent a cohort. The cohort-component method involves separating the population under consideration into cohorts, looking at the demographic components of each cohort, and projecting the population of each cohort for successive periods into the future.

Demographic modeling is superior to trend analysis because the factors which influence population are identified and can be varied to reflect expectations for the future. Trend analysis assumes all the underlying factors that influence population levels are static. Demographic components include mortality, fertility, and migration. The migration component actually represents net migration. These three components are evaluated for each age-sex category. Age categories are typically 5-year intervals (for example, 0 to 4 years, 5 to 9 years, etc.). The female child-bearing years are generally considered to be 15 to 44 years of age.

The first step in implementing the cohort-component method is to apply specific age-sex survival rates to each group and carry that population forward to the next age group. Next, the net number of migrants is added to the population carried forward in the first step to derive the projected population. Projecting the future 0-to 4-year-old age group is complicated because this future group does not currently exist. Consequently, the future 0-to 4-year-old age cohort is projected by applying the age-specific birth rates to the 15-44 female population of childbearing age. Then the projected births are multiplied by the appropriate survival and net migration rates.

The simple formula applied to each cohort in the cohort-component method is:

$$P_1 = P_0 + B - D + NM \tag{1}$$

Where:
P_1 = Population at the end of the period
P_0 = Population at the beginning of the period
B = Births during the period
D = Deaths during the period
NM = Net migration during the period.

The three demographic components are described below.

- Fertility - Fertility rates are used in demographic models to project births within specific age groups. The fertility rate for an age group combine with the population of females within that age group can be used to estimate births. The total fertility rate is an estimate of the average number of children that would be born to a group of women at the end of their childbearing years if they conform to the current age-specific fertility rates.

  Fertility rates for the total female population of child-bearing age are available for each state from the U.S. Bureau of the Census. Specific fertility rates are also available by age group, race, region of residence, labor force status and occupation. These sources of information can be used to estimate birth rates by state and age group. Historical data can be used to evaluate any birth rate trends that become apparent. These trends can be incorporated into future fertility rate estimates. Projections of future fertility are available by race and age group for the United States from the United States Bureau of the Census. Future projections can be combined with current state and, possibly, county fertility rates to project fertility at the state or county level.

- Mortality - Mortality rates are applied to specific age-sex groups to estimate survival for each group. Mortality rates indicate the percentage of a specific age-sex group that would be expected to die. Mortality rates have been decreasing (life expectancy is increasing) a trend expected to continue in the future.

  The U.S. Bureau of the Census has historical death rates by age, sex, and race for the U.S. The Bureau projects life expectancy at birth and at age 65 through the year 2050 for the U.S. population. The Centers for Disease Control and Prevention publishes death rates by state and by month. This data can be used to evaluate historical state trends. The Centers for Disease Control and Prevention also publishes the U.S. Decennial Life Tables for 1989 to 1991 for each state. These tables include rates of death for by sex, age, and race.

  The current and projected future life expectancy data for the U.S. population, death rates for the U.S. population by age, the current life expectancy of individual states, and the death rates for the individual states by age can be combined to estimate current and future mortality rates by state. Current and future mortality rates could also be estimated at the county level if county mortality rates and life expectancy data are available.

- Migration - Generally, changes in birth and mortality rates are usually slow and predictable. However, outside influences can cause rapid and significant changes in migration rates with little advance warning. Therefore, migration is the most difficult demographic component to project with confidence. In addition, there is a scarcity of time-series data, which reports accurate migration patterns by age and sex at a detailed level of analysis. The U.S. Bureau of the Census provides future net immigration estimates for the entire United States by age, sex, and race, but these projections do not help in estimating net immigration for a specific site.

  The U.S. Bureau of the Census 1990 census data includes information on the location of residents in 1985 compared with 1990. The data identifies (1) the resident is living in the same house as in 1985; (2) the resident is in the same county as in 1985; (3) the resident was in a different county in the same state as in 1985; (4) the resident was in a different state in 1985 and from what region did the resident migrate; (5) and the resident came from a foreign country. The 1980 Census provides similar data for changes from 1975 to 1980, where migration is broken down into those that moved within the same county, those that moved from a different county in the same state, and those that moved from a different state. Net migration estimates are also available at the county level from the 1970 Census for the 1960 to 1970 period, and supplemental Census data are available for net migration during the 1970 to 1975 period.

This information is sufficient to estimate net migration rates at the county level over five- or ten- year intervals from 1960 to 1990. The most detailed data are available for the 1985 to 1990 period, where the percentage of the population in the study area that has remained in the county from 1985 to 1990, the percentage that moved into the county from another county in the state, and the percentage that moved into the county from another state and the region of that state in the U.S. This information combined with county level population estimates for 1985 and 1990 can be used to estimate a net migration rate over the 1985 to 1990 period. This migration rate can be extrapolated into the future. Age and sex distribution tables for the state or region from which the individual came can be used to adjust the future county population after accounting for migration.

The projected migration rates based on historical data and trends do not account for any future structural changes that could affect migration. For example, if employment and income growth in a region are greater than has existed historically, then migration into the area is likely to rise above historic levels as a result of people taking advantage of new economic opportunities. Therefore, some consideration must be given to the strength of the regional economy and the possibility that historic migration patterns may change unexpectedly.

Demographic modeling is preferable to trend analysis because it accounts for changes in fertility, mortality, and migration which are assumed constant in a trend analysis. In addition, the modeling approach provides a basis for evaluating the reliability of the projections. Models based on statistically significant relationships are easier to defend than simple trend estimates.

Combined demographic/economic models. – Population is influenced by characteristics such as fertility (birth rates) mortality (death rates) and net migration, each of which is effected by economic factors. Of the three, migration is most influenced by the condition of the economy. A healthy regional economy can result in increased labor demand and, therefore, increased net migration. Labor is attracted by employment opportunities and the higher wages associated with increased labor demand. Consumption, investment, and production levels have a significant influence on employment and income, both of which effect population.

Mortality rates may decrease as a result of improved health care associated with increased income. Mortality rates may also decrease as a result of health care facilities that can be supported by a large population base resulting from a growing economy. The effect of economic growth on birth rates is uncertain because both positive and negative effects on birth rate are possible. There are data that indicate higher income households tend to have fewer children – a negative effect. However, higher income makes having children financially more viable – a positive effect.

Population projections must also consider the potential consequences of the planning environment in the area under consideration. Plans that promote economic growth are expected to have a positive influence on future population levels, and plans limiting growth should have a negative effect. Assumptions incorporated into population projections must take into account the feedback of planning policies so the projection is consistent with relevant economic development plans.

Adjustments to population growth as a result of economic development projections can be made entirely outside the population projection model. Economic development can be treated as an exogenous variable affecting population trends but not affecting the relationships within the population growth model. Migration assumptions in the demographic model described above could simply be adjusted to account for expected economic growth.

A more systematic method for incorporating economic growth considerations and the effect on migration rates involves including an estimate of labor supply along with an economic model of labor demand. The supply of labor can be estimated using the estimated working-age population from the demographic model and assumed age-sex specific labor force participation rates. The demand for labor can be projected using an econometric model that relates the region's industrial structure to demand for that sector's output at the state and national level. The demographic model projects the future working-age population based on participation assumptions. Where demand for labor exceeds supply, equilibrium is restored by migration into the region. Where the supply exceeds demand, out-migration is assumed to occur. As a result, net migration is determined in large part by projected labor supply and demand.

The purpose of the economic model is to account for the effect of economic growth (or decline) on the labor market, which effects net migration and population. The model requires a large amount of information about current and projected future employment needs at the county, state, and national levels. Current data on production and labor requirements are needed to estimate the production/labor relationships between the nation, the state, and the specific region under consideration. Labor demand is based on current relationships between employment in a specific industry and state or national variables. For example, if employment in a specific industry is significant in the area, the state level of production in that industry is a significant portion of total U.S. production, and that industry is projected to increase at the national level, then future labor demand for that industry in the study area would be projected to increase according to the current relationship between the state and the nation. Occasionally, projections of future production are available at the state level. Those state level projections can be used to estimate future labor demand in a specific region.

The supply of labor provided by the indigenous population is based on first-round population projections using the demographic model combined with labor force participation rates. This labor supply is then compared with labor demand estimates, which are based on regional-state-national production relationships. If the labor supply of the indigenous population is not large enough to meet the labor demand, then migration rates can be changed to bring labor supply and demand into equilibrium. Net migration and labor force limits can be implemented to avoid unrealistic changes that would be needed to bring supply and demand into balance. For example, if the level of net migration needed to bring labor supply and demand into equilibrium is unreasonably high, then the labor participation rate can be increased to allow a larger portion of the indigenous population to work. The assumed age-sex ratio of the population migrating into the region can also be changed to bring labor supply and demand into balance.

Unless better information is available, current employment patterns can be assumed to continue. Current county level employment as a percentage of total state employment can be applied to projections of labor demand to estimate future labor demand at the county level. Information available regarding expected changes in patterns of economic activity in the future, should be incorporated into estimates of future labor demands. The Bureau of Economic Analysis generates projections of employment. income, and total gross state product to the year 2045 along with historical estimates back to 1969 for each state and for the entire United States. These projections and historical estimates are broken down into separately and can be used to evaluate future labor demands. Regional/county economic forecasts are based on the regions historical percentage of jobs relative to the entire state. The number of employed people by region is forecast on the basis of the number of jobs. Total effect on employment from net migration is forecasted based on total household members per worker.

Combining demographic and economic models allows economic growth to be accounted for in the population projections. Using a demographic model alone does not allow for the possibility of changing employment opportunities in a region over time. Therefore, including a model of labor supply and demand as a net migration factor accounts for a potentially important population factor. However, including an economic model in an analysis of an area with a small population base and no specialized industry will have little, if any, impact on the population projections. The added sophistication of an economic component is justified only in areas likely to be affected by labor shortages resulting from increased demand in specific sectors.

Population projection scenarios. – The population projection scenario technique essentially shows if-then relationships where different projections are generated based on different assumptions. Upper and lower projections can be generated and projections can be produced using a variety of assumptions for factors not well understood. For example, a projection may be made assuming constant mortality rates while another may be made using decreasing mortality rates. This technique is useful for a better understanding of the consequences of certain demographic assumptions that can be judged by policymakers for their applicability.

The strength of the population projection technique is the ability to better understand the consequences of certain demographic assumptions. The magnitude of the results can help choose between scenarios. However, the accuracy of the projections is still not known, and the burden of making assumptions is simply shifted from the analyst to the policy maker. A range of projections can be presented that depend on the scenario and at least portrays the uncertainty associated with population projections. However, it should be noted that presenting a best or most likely estimate is essentially the same as presenting a single population projection, which would theoretically be based on the most reliable information. The scenario approach can educate those not familiar with demographic techniques of the consequences of different assumptions. It can also be used as a sensitivity analysis to provide variations of the assumptions used.

Probabilistic methods. – Probabilistic population projection methods are based on estimates of the probability of certain demographic events and applying those probabilities to a demographic model. Probabilities are typically estimated for changes in fertility rates, mortality rates, and the rate of net migration. These probabilities can be applied to different rates of change for each of the variables to obtain a weighted rate of change. A fertility rate weighted by rate probabilities would be estimated by estimating probabilities for fertility rates from zero to the highest possible rate, multiplying the probabilities by the associated fertility rates, and summing the results. The result is a weighted fertility rate that accounts for each rate probability.

There are two frequently used methods for estimating the probability of a certain demographic event. The first is to use information from past changes in fertility, mortality, and net migration to estimate the probability of certain changes in the future. For example, the dispersion of data on past fertility rates can be used to model probabilities of future fertility. Changes in the trend of fertility rates will be reflected through changing probabilities over time, which can be extrapolated into the future. The second method relies on expert opinion from the fields of demography, public health, geography, and others to determine the probabilities of future demographic events.

Historical changes in demographic variables can be used to estimate a time series model of probabilities. The time series probability model is used to estimate future conditions, which are input into the demographic model from which population projections are obtained. It needs to be recognized that this technique has the same problem as trend analysis: there is no certainty that past relationships will continue into the future.

Asking experts for opinions on the probability of changes in levels of fertility, mortality, and migration also presents problems. There is no reason to expect it to be much easier to estimate a probability of a demographic event occurring than to estimate future population levels. Experts must make assumptions about future fertility, mortality, and net migration rates to estimate demographic models. Therefore, there is very little difference between using a model of probabilities based on expert opinion and estimating a demographic model using professional judgement about changes in demographic variables.

Probability-based projections attempt to use methodological sophistication to solve the problems associated with predicting human behavior. However, probability models depend on either historical data or expert opinion for information about future uncertainties. As a result, the problem is to predict future probabilities of human behavior, which may be no less difficult. Probability modeling may be more sophisticated, but may not be any more accurate or reliable than other projection methods.

Analysis of Future Commercial/Industrial Water Demand

Future commercial and industrial water demand is dependent on the number and types of establishments in the region. Growth in the number of commercial and industrial establishments in an area is difficult to predict because many factors can influence business location decisions. Some of these location factors include availability of adequate transportation links, the size and education level of the labor force, the availability of support industries including financial institutions, the natural resource base, physical factors such as climate, and location incentives provided by state and local governments. Although some of these factors may be known with some certainty and can be used to assess the potential for future business and industry growth (for example transportation links and labor force), others cannot be predicted with any confidence.

Although the exact number of commercial and industrial establishments in the future cannot be predicted with any certainty, general trends in the growth of these establishments in a region can be evaluated and used to determine future commercial and industrial water demands. Current and historical business pattern data can be used to develop trends in commercial and industrial activity. Trends may be obtained for total employment by sector, earnings by sector or value of output by sector. These trends can then be extrapolated to the future using linear or nonlinear models. Current trends can be bounded by existing limitations to growth, which provide a ceiling to potential commercial and industrial activity. In addition, past trends may not be realistically projected into the future if there has been unusually high growth in commercial and industrial activity in the region in recent years.

Future commercial and industrial demands can also be evaluated by looking at current and projected growth on a statewide or national level and applying that level of growth to similar local activities. This technique is similar to the application of county-level population projections to a specific municipality, where it is assumed that historically similar rates of growth (or decline) will continue into the future. This technique may work reasonably well for activities that are not specialized and are spread out over a large area.

Some types of businesses closely follow changes in population over time. Retail trade, services, and some utilities, which provide goods and services primarily to the regional population, are significantly influenced by population size. Food, gasoline, clothing, and various small items are likely to be purchased by local residents at the closest location (within the region) because of the potential cost savings and the inconvenience of traveling a greater distance. High cost or specialized goods and services such as automobile sales and repair, large appliances, furniture, major home repairs, and finance and real estate are more likely to be purchased further away because of potential cost savings and specialization.

Changes in the population of the study area are likely to translate into a change in business activity to supply those items demanded by the local population. The rate of population change in the local region should not be used to project future commercial and industrial activity that is not directly tied to local demand. If the study area includes major trade centers, projected population growth for the larger service region can be used as an approximation of future growth for those activities.

An analysis of commercial and industrial water demands may actually require several separate analyses. Existing limitations to growth (excluding water supplies) must be documented. These limitations may be the result of limited infrastructure, a small labor force, the lack of natural resources in the region, insufficient transportation links, or the lack of support industries. If state or national growth rates are applied to regional activities, then an analysis is needed to determine the employment level and value of output associated with different types of establishments in the study region. These data provide a basis from which projections of future commercial and industrial activity can be made using state or national growth rates for specific activities. If an industry is very important to a study region and that industry is expected to grow nationally or on a statewide basis, then earnings and employment related to that industry would also be expected to grow within the local region.

The most difficult commercial and industrial demand to project is the location of new industries in a region. Future markets and resource requirements cannot be predicted with any degree of certainty. Changes in consumer demands may result in new industries locating in a region or may lead to industries closing. As a result, all commercial and industrial demand projections should include a caveat about the uncertainty associated with future activities and the associated water demands.

Other Issues: The Location of Growth

A needs assessment provides an appraisal-level estimate of water demand within a study area. As previously discussed, population is a major factor in determining current and future water demand. However, the location of the population within the study area may also play an important role in a needs assessment because water supplies must be delivered to the point of demand.

Predicting the location of future population growth, or decline, requires information about zoning ordinances, roads and transportation linkages, current distribution of population, future development plans, physical growth limitations, and location of amenities in the study area. Zoning ordinances and physical growth limitations provide information about the maximum possible housing and commercial growth. Roads and transportation linkages provide insight about the areas likely to experience population growth in the near future. Development plans indicate where planners would like development to occur and where development will be encouraged. Last, in the absence of development plans, the current distribution of population and commercial activity can be assumed to continue until zoning or physical limitations are reached.

Some Characteristics Unique to Indian Reservations

In some cases, future demands on Indian Reservations must be estimated with little or no information from which to derive population projections. For example, a large percentage of eligible tribal members may not actually live on a reservation when a needs assessment is completed due to limited availability of housing, services, or other constraints. However, if future development plans for a reservation include housing projects, infrastructure, or other development that will attract more people, then simply using past trends and relationships will not adequately account for the basic structural changes in the population of the reservation. If housing has been a constraint to population growth in the past (for example, there are tribal members who would move onto the reservation if housing were available) and more housing is planned, then lifting the housing constraint will result in greater than historical population growth rates.

Other factors specific to Indian reservations may complicate population projections and, therefore, complicate projections of future demands. For example, changes in the requirements to become a tribal member will affect tribal enrollment and potentially the number of people moving onto the Reservation. Tribal policies to attract tribal members onto the Reservation through business incentives, some type of entitlement payments to tribal members, or other incentives will also affect future population numbers.

One method of dealing with the housing constraint problem is to first determine whether there is enough housing demand to occupy all of the housing units planned by the tribe or all of the housing units that could reasonably be expected to be built over the study period. If there is enough demand, as evidenced by indicators such as waiting lists for properties or large tribal enrollment for people who currently live off of the Reservation, then population growth could be assumed to continue until all of the available housing units are occupied. Considerable judgment is needed to determine the actual demand for housing on a Reservation. The analyst must rely heavily on local agencies and tribal information to determine the extent of housing demand.

Population Projection Applications

This section provides applications of the population projection techniques presented above for Jackson County, Kansas, and Holton, Kansas. Population projections are also presented for the Pottawatomi Indian Reservation in Jackson County to illustrate the special circumstances that must be considered when projecting future population in Native American areas. A variety of areas were chosen so different projection techniques could be demonstrated and some of the potential estimation problems illustrated. Data at the state and county levels were used for the more sophisticated demographic modeling techniques, such as the cohort-component technique, because the demographic detail needed to capture birth rate, death rate, and migration patterns are not generally available at a site-specific level.

The results of the projection methods are compared to illustrate the differences in projections that may be obtained. The applications do not include the combined demographic/economic model, the population projection scenarios, or the use of probabilistic techniques, because these are essentially modifications of the cohort-component model. However, the use of these techniques is described qualitatively.

County-level projections applied to a specific site. – Holton, the Jackson County Seat and the largest town in the county, accounts for over 26 percent of the total Jackson County population. As a result, Holton is an important part of the county but does not dominate the demographics of the county. County-level population projections are available for all Kansas counties from the State of Kansas, Division of the Budget (1992) up through the year 2030. The first step in applying county-level population projections to a specific town is to compare the historical population changes of the two groups. Table 2 shows a comparison of Jackson County and Holton populations since 1960.

Table 2. – Jackson County and
Holton, Kansas populations

Year	Jackson County	Holton
1960	10,311	3,028
1970	10,342	3,063
1975	10,800	3,042
1980	11,644	3,132
1990	11,506	3,196
1991	11,514	3,177
1992	11,461	3,159
1993	11,573	3,157
1994	11,669	3,145
1995	11,762	3,131
1996	11,980	3,166

The historical data in Table 2 indicate similar movements in the population of the two areas. The correlation between the change in population of the two areas was tested by estimating a simple correlation coefficient, which is a measure of the linear association between two variables (in this case, the populations of Holton and Jackson County). A correlation coefficient greater than the critical value indicates a statistically significant correlation. The correlation coefficient between the historic population levels of the two areas was 0.657, greater than the critical value of 0.499. Therefore, correlation is statistically significant and the two populations can be projected to move in the same direction in the future.

The correlation test indicates changes in Jackson County population have historically been a reasonable indicator of changes in the Holton population. Therefore, the application of Jackson County population projections to the Town of Holton can be defended based on past correlation. The projected population of Holton based on the Jackson County projections is presented in Table 3. The Jackson County projections are also presented as a basis for comparison.

Table 3. – Holton and Jackson County population projections

Year	Jackson County	Holton using county projections
2000	11,472	3,180
2010	11,438	3,170
2020	11,641	3,230
2030	12,025	3,330
2040	12,420*	3,440
2050	12,830*	3,560

* Population projections for Jackson County were provided out to the year 2030. Projections for 2040 and 2050 are based on the same rate of growth as from 2020 to 2030.

Trend analysis. – As described above, a trend analysis is a simple extrapolation of historical population changes into the future. The extrapolation may be linear or nonlinear, depending on the historical pattern of change. A trend analysis can be accomplished by using regression analysis, where the change in population is estimated as a function of time. The results of a simple regression represent the line that best fits the relationship between time and population. A nonlinear relationship can be estimated by converting time or population into natural logs, taking the inverse of time or population, estimating a quadratic relationship, or using some other conversion and then applying the regression technique. Population trend model results for three different functional forms are presented in Table 4 for Jackson County.

Table 4. – Population trend model results

Year	Jackson County linear model	Jackson County semi-log model	Jackson County log-log model
2000	12,060	12,080	11,810
2010	12,500	12,570	11,940
2020	12,940	13,080	12,050
2030	13,380	13,600	12,140
2040	13,830	14,150	12,220
2050	14,270	14,720	12,280

The same procedure was followed for estimating a Holton, Kansas trend model. Only a linear model was estimated because fewer historical data points were available for Holton and other functional forms did not result in significantly different projections. Population trend model results for Holton are presented in Table 5.

Table 5. – Holton population projections

Year	Holton using historical trend
2000	3,176
2010	3,217
2020	3,258
2030	3,300
2040	3,340
2050	3,382

Cohort-component model application. – The information needed to put together a cohort-component model includes the distribution of the current population by age and sex, current and projected birth and death rates by age and immigration rates. These data can be obtained from a variety of sources, including but not limited to study area surveys, U.S. Bureau of the Census data, statistics compiled by state and local government agencies and, possibly, from planning groups. The source of data depends on the budget and time available for the study. Completing an individual survey (using primary data) requires more time and money than using secondary data. However, secondary data sources may be somewhat dated and can miss recent changes in population characteristics.

The application illustrated here uses data from the Bureau of the Census, the National Center for Health Statistics, and the Kansas Division of the Budget. These sources represent readily available secondary data that can be obtained at relatively low cost. The Bureau of the Census population reports data (1996) were used to determine the current sex and age distribution of the population, current distribution of population by race, projected future sex and age distribution, projected future distribution by race, and birth rate trends and projections by race. Bureau of the Census 1990 data (Bureau of the Census 1998) were used to help estimate migration patterns. Current and projected life-expectancy data were obtained from the National Center for Health Statistics (1997) and U.S. Bureau of the Census population reports data (1996).

Age distribution of males and females. – The distribution of population by sex and age is an important piece of information in a cohort-component analysis because all the other factors, which influence population growth, are determined in large part by the proportion of the population fitting into each age and sex category. For example, a population with a large percentage of females 15 to 44 years of age would be expected to grow faster than a population with a very large percentage of females 45 to 64 years of age because 15 to 44 years is considered prime child-bearing years. This translates into a relatively large number of births and more rapid population growth. Another example is the difference in life expectancy for males and females and for different age groups. The distribution of population by age and sex represents the baseline population conditions from which future population is estimated and is the primary data needed to complete a cohort-component model. The distribution of population by age and sex for Jackson County and Holton is presented in Table 6.

Table 6. – Distribution of population by age and sex for Jackson County and Holton

Age	Jackson County		Holton	
	Male	**Female**	**Male**	**Female**
Under 1 year	100	88	8	20
2-4 years	390	264	97	86
5-9 years	477	471	132	100
10-14 years	532	493	107	109
15-19 years	425	373	81	94
20-24 years	282	251	86	50
25-29 years	355	354	82	94
30-34 years	427	508	106	172
35-39 years	471	441	126	119
40-44 years	370	378	84	76
45-49 years	351	291	52	63
50-64 years	734	843	164	236
65-79 years	611	747	199	359
80+ years	170	338	86	209
Total	**5695**	**5840**	**1410**	**1787**
Percentage of total population	49.4%	50.6%	44.1%	55.9%

Birth and mortality rates. – Birth and mortality rates represent the natural rate of increase and decrease of a population. Birth and mortality rates vary by age, and mortality rates also vary by sex. Mortality rates increase with age, with the exception of children less than one year old, and males have higher death rates than females. Birth and mortality rate projections from the U.S. Bureau of the Census are available at the national level by age and race to the year 2050. Generally, mortality rates are projected to decrease over time while birth rates are expected to increase. Current (1990) mortality rates by age and race are also available by state. State-level projections can be estimated by applying the rate of national level changes to the current state rates. The most detailed level of birth and mortality rate data is at the state level. The projected birth rates for Kansas are presented in Table 7. Kansas mortality rates by age for males and females are presented in Tables 8 and 9.

Table 7. – Projected Kansas birth per thousand women

Age of mothers	1995	2000	2010	2020	2030	2035 to 2050
10-14 years	0.7	0.7	0.8	0.8	0.85	0.85
15-19 years	57.74	58.91	61.83	62.99	64.45	65.33
20-24 years	121.75	122.60	124.71	127.66	130.51	131.67
25-29 years	122.60	123.12	124.37	125.83	126.97	127.60
30-34 years	74.12	74.69	76.10	76.38	76.85	77.32
35-39 years	28.82	28.82	29.28	30.28	30.65	31.01
40-44 years	4.8	4.8	5.06	5.31	5.40	5.49
45-49 years	0.3	0.3	0.3	0.3	0.3	0.3

Table 8. – Projected Kansas mortality rates for males

Age	1995	2000	2010	2020	2030	2040	2050
0-1 year	.00923	.00917	.00903	.00885	.00869	.00861	.00845
2-4 years	.00195	.00194	.00191	.00187	.00183	.00181	.00177
5-9 years	.00117	.00116	.00114	.00112	.00110	.00108	.00102
10-14 years	.00156	.00155	.00153	.00151	.00148	.00147	.00144
15-19 years	.00626	.00622	.00613	.00601	.00589	.00583	.00571
20-24 years	.00822	.00816	.00800	.00787	.00772	.00764	.00749
25-29 years	.00897	.00891	.00878	.00862	.00846	.00838	.00822
30-34 years	.01164	.01156	.01138	.01116	.01096	.01085	.01063
35-39 years	.01455	.01445	.01423	.01396	.01370	.01357	.01331
40-44 years	.01849	.01836	.01808	.01774	.01742	.01726	.01704
45-49 years	.02407	.02390	.02350	.02310	.02268	.02247	.02205
50-64 years	.06000	.05957	.05867	.05756	.05650	.05590	.05470
65-79 years	.19700	.19623	.18946	.18590	.18248	.18080	.17262
80+ years	.27338	.26630	.26231	.25740	.25270	.25030	.24590

Table 9. – Projected Kansas mortality rates for females

Age	1995	2000	2010	2020	2030	2040	2050
0-1 year	.00742	.00738	.00729	.00720	.00711	.00707	.00698
2-4 years	.00157	.00156	.00154	.00152	.00150	.00149	.00147
5-9 years	.00095	.00094	.00092	.00090	.00088	.00087	.00085
10-14 years	.00095	.00094	.00092	.00090	.00088	.00087	.00085
15-19 years	.00227	.00226	.00224	.00222	.00220	.00218	.00215
20-24 years	.00257	.00256	.00253	.00250	.00247	.00245	.00241
25-29 years	.00323	.00321	.00317	.00313	.00309	.00307	.00303
30-34 years	.00433	.00431	.00426	.00421	.00416	.00413	.00408
35-39 years	.00608	.00605	.00598	.00591	.00584	.00580	.00520
40-44 years	.00848	.00844	.00835	.00826	.00817	.00812	.00803
45-49 years	.01296	.01289	.01275	.01261	.01246	.01238	.01223
50-64 years	.03506	.03489	.03449	.03411	.03370	.03350	.03310
65-79 years	.12300	.12160	.12020	.11891	.11760	.11680	.11514
80+ years	.17702	.17420	.17220	.17033	.16847	.16744	.16550

Migration patterns. – The migration patterns used in this analysis are based on 1990 U.S. Bureau of the Census data on place of residence in 1985 compared with that data for 1990. The 1990 Census data indicated 55.9 percent of Holton residents lived in the same house that they did in 1985, 27.1 percent lived in the same county as in 1985, and 17 percent moved in from outside the county. The Census data showed 66.5 percent of Jackson County residents lived in the same house as in 1985, 16.9 percent lived in the same county, and 16.6 percent moved in from outside the county. The relatively small number of Holton residents who lived in the same house at both times indicates some people may have moved to the town from other areas within the county. As a result, the net migration of people into Holton is probably larger than for all of Jackson County.

The migration rate for Holton over the 1985 to 1990 period appears to be at least 3 percent annually. However, assuming some of the migration into Holton has been from other parts of Jackson County, this rate of in-migration would not be expected to continue indefinitely. Jackson County in-migration has been slower than for Holton. The assumed migration rates used for this analysis are presented in Table 10.

Table 10. – Estimated Jackson County and Holton migration rates (% of residents)

Years	Jackson County	Holton
1996 to 2000	2%	3%
2001 to 2010	1%	1.5%
2011 to 2020	0.5%	1%
2021 to 2030	0.25%	0.5%
2031 to 2040	0%	0.25%
2041 to 2050	0%	0%

Cohort-component based population projection for Jackson County and Holton. – The data presented above were input into a spreadsheet that generated population estimates for Jackson County and Holton. The birth, mortality, and migration rate estimates were applied to the current population, and estimates were generated for each age and sex group for the next year. This procedure was followed to the year 2050. Population estimates are presented in Table 11.

Table 11. – Cohort-component model population estimates for Jackson County and Holton

Year	Jackson County	Holton
2000	11,750	3,060
2010	12,050	3,100
2020	12,520	3,320
2030	12,970	3,490
2040	13,310	3,660
2050	13,810	3,800

Combined demographic/economic model. – A combined demographic/economic model would include an analysis of future change in demand for labor in the study area due to business/industry growth. The change in business/industry growth could be due to changes in the national economy affecting overall levels of production and consumption, changes in demand for goods and services produced within the study area, or local economic development and planning polices.

The economic model must convert a change in commercial/industrial activities into corresponding changes in labor demand. U.S. Bureau of the Census County Business Pattern data can be used to estimate a simple model correlating the number of employees for each establishment by type of establishment. A projected increase in business activity can then be translated into an increase in labor demand. Regression models, which use historical relationships to model commercial/industrial production with macroeconomic variables, can also be estimated. A projected change in labor demand estimated using the economic model can then be compared with labor supply. If the supply is not sufficient to meet demand, then migration can be assumed to meet the shortage. The population associated with each worker (that is, the number of dependents that would be expected with each worker) can then be multiplied by the employment requirements to estimate population impacts. Future labor demands in Holton and Jackson County would not be expected to grow at a rate that would create chronic labor shortages. Therefore, the cohort-component model does not require modification to the migration assumptions.

Population projection scenarios. – Population projection scenarios represent a range of projections based on different assumptions of birth rates, mortality rates, and migration. For example, if the net migration rates for Holton are assumed to be only one-half the rates shown in Table 10 up to the year 2040, then the projected population would be significantly less than previously estimated. Table 12 shows the original population projections and new projections for Holton under the lower migration scenario.

Table 12. – Holton population projection scenario results

Year	Original projections	Low migration scenario
2000	3,060	2,840
2010	3,100	2,680
2020	3,320	2,720
2030	3,490	2,860
2040	3,660	2,970
2050	3,800	3,080

Probabilistic techniques. – The application of probabilistic techniques could include estimation of a model of historical changes in factors that affect population growth or use professional judgment to evaluate the probability of certain events. In either case, the probabilities are used to modify the demographic assumptions used in the cohort-component analysis. Probabilities of various demographic events can be used to derive weighted population projections.

Comparison of results. – The population projections using the various techniques presented above can be compared to illustrate the variation that would be expected using different projection techniques. The variation results from the different assumptions implicit in each technique. The Holton projections are presented in Table 13, and the Jackson County projections are presented in Table 14.

The population projections for Holton vary by as much as 12 percent for the year 2000 and increase by as much as 23 percent by the year 2050 (see Table 13). Population projections for Jackson County vary by about 5 percent in the year 2000 and increase to 20 percent by the year 2050 (see Table 14). This level of variation is not unusual.

Typically the variation is greater for smaller population areas. This is due to reduced reliability associated with applying general state and national characteristics to specific sites.

Table 13. – Holton population projections

Year	Using county level projections	Trend	Cohort-component	Low migration scenario
2000	3,180	3,180	3,060	2,840
2010	3,170	3,220	3,100	2,680
2020	3,230	3,260	3,320	2,720
2030	3,330	3,300	3,490	2,860
2040	3,440	3,340	3,660	2,970
2050	3,560	3,380	3,800	3,080

Table 14. – Jackson County population projections

Year	Using county level projections	Trend	Cohort-component
2000	11,472	11,810 - 12,080	11,750
2010	11,438	11,940 - 12,570	12,050
2020	11,641	12,050 - 13,080	12.520
2030	12,025	12,140 - 13,600	12,970
2040	12,420	12,220 - 14,150	13,310
2050	12,830	12,280 - 14,720	13,810

An Indian Reservation Application: Population Projections for the Prairie Band of the Potawatomi Indian Reservation

The Prairie Band of the Potawatomi Indian Reservation is located in northeast Kansas in Jackson County, about 20 miles north of Topeka. Unemployment is relatively high on the Reservation compared with the rest of Kansas. Per capita income is low: $7,814 per year on the Reservation in 1990 compared with $13,300 for all of Kansas.

As of July 1994, an estimated 4,118 Tribal members were enrolled in the Prairie Band of the Potawatomi Tribe, and a total of 463 Tribal members lived on the reservation. The most recent Bureau of Indian Affairs data estimated tribal enrollment at 4,312 people. The U.S. Bureau of the Census estimated a total population of 952 people on the Reservation in 1980 and a 1990 population of 1,082 people, 502 of whom were Native American. Census population data are suspected of undercounting population on Indian

Reservations due primarily to errors in estimating the number of people living in each housing unit. As a result, the true population of the reservation is likely to be larger than indicated by the Census figures.

Bureau of Indian Affairs (BIA) 1995 data estimated the Indian service population for the Reservation at 1,702. Part of the difference between the Census and BIA estimates is that some of the people included in the BIA estimates were outside Reservation boundaries. Some of the difference could also be due to population from 1990 to 1995. However, most of the difference between estimates is likely due to differences in Census and BIA sampling and estimation methods. Because it is not known how much the Census estimates may underestimate population and how much BIA may overestimate population, an average of the two are used to represent the 1995 Reservation population. Applying the 1980 to 1990 Census data reservation growth rate to the 1990 Census estimate results in an estimated 1995 population of 1,134. The average of the 1995 estimate based on the Census data and the 1995 BIA estimate is about 1,400, which is used as the best estimate of the current reservation population.

The U.S. Bureau of the Census estimates that the number of Native American residents on the reservation increased from 331 in 1980 to 502 in 1990, while the number of non-Indians decreased from 654 to 580. Assuming this trend continued to 1995 and 1,400 is an accurate estimate of the Reservation population, there were 742 Native Americans and 658 non-Indians living on the Reservation in 1995.

The Census data indicates that any population projections for the Reservation must actually include two projections, one for the Native American population and one for non-Native Americans. The cohort-component technique could be used to project the Native American and non-Native American population separately. The appropriate birth and mortality rates could be applied to each group (Native American and non-Native American) and migration rates assumed for both groups. Migration rates for Native Americans into Reservations are complicated by tribal membership and other cultural considerations, which may make location on a Reservation more (or less) desirable. Cultural considerations can also play a part in migration into non-Indian Reservation areas, but typically economic conditions play the largest role. In addition, using two migration rates for one area can result in complicated migration patterns that are difficult to justify using available data.

As a result, a simple trend analysis for the Native American and non-Native American Reservation population may be the best technique for this application. Using historical population data for the Indian and the non-Indian populations, linear population trends were estimated. Overall, the population of Jackson County has remained relatively stable since 1980. The population declined by 119 (1 percent) from 1980 to 1990, and increased back up to the 1980 level by 1994. Over this same period the percentage of Native American population has increased significantly, from 4.5 percent of the total county population in 1980 to 6.2 percent by 1994. This translates into an increase in the Indian population from 529 in 1980 to 717 in 1994.

Assuming that past growth rate trends (or decline in the case of non-Indians) continue, the reservation population is projected to increase to 2,360 by the year 2050, an increase of about 41 percent from the 1995 level and an annual growth rate of about 0.95 percent. About 86 percent of the total Reservation population is projected to be Native American. Table 15 shows population growth projections to the year 2050.

Table 15. – Population projections for the Prairie Band of the Potawatomi reservation

Year	Total population	Indian population	Non-Indian population
1995	1,400	740	660
2000	1,470	850	620
2010	1,610	1,060	550
2020	1,770	1,280	490
2030	1,940	1,510	430
2040	2,140	1,760	380
2050	2,360	2,030	330

Application of Commercial/Industrial Establishment Projections: The Prairie Band of the Potawatomi Reservation

Current businesses on the Prairie Band of the Potawatomi Reservation include a hunting club/preserve, a county-operated landfill, two gasoline service stations with convenience stores, a nursery, a racetrack, and the Potawatomi Bingo Hall. The Tribe is the single largest employer on the Reservation, employing about 100 people. The bingo hall is the second largest employer, providing jobs for about 50 people.

Industry employment as reported in the 1990 Census can be used as an indicator of regional business activity and the importance of different types of businesses to the Reservation. Manufacturing businesses accounted for about 15 percent of Reservation employment, agriculture related businesses employed about 11 percent of those working, construction and health services each employed 10.6 percent of the total, and retail trade employed about 10 percent of the total. Educational services and other professional services each represented about 7.4 percent of total employment.

These data are an important part of projecting future commercial and industrial activity because they indicate the relative importance of different sectors to the local economy as measured through employment. County Business Patterns data from the U.S. Bureau of the Census can also be used to evaluate county level historical trends which may influence the site under consideration. The total number of business establishments in Jackson County increased 23.8 percent from 197 in 1980 to 244 in 1994. Over the same period the number of people employed increased from 1,330 to 1,786, an increase of 34.3 percent. The number of establishments in the services, construction, and finance/insurance/real estate sectors grew substantially from 1980 to 1994 in Jackson County. The number of establishments in the other sectors has remained relatively constant or declined slightly. Employment in the service and retail trade sectors has grown substantially, combining to account for an increase in 398 new jobs in the county. The location of the Reservation relative to Topeka and Kansas City provides some economic opportunities due to the large potential market represented by these areas. However, the location of these cities near the Reservation also represents competition for businesses and industry that wish to locate in the region. Larger cities are more capable of providing infrastructure and support industries for new businesses.

Economic opportunities on the Reservation have been somewhat limited over the last 30 years. Bingo has been the major tribal enterprise since the late 1980s. Some development of natural gas fields occurred in the 1970s. Although this activity was discontinued, the potential for future development exists. The Potawatomi Tribe (Tribe) has recently begun to expand its land base. About 60 percent of the land in the Reservation is owned by non-Indians, compared with 80 percent in 1978. If the trend of obtaining land continues, future crop production is likely to increase - this will result in the growth of agricultural supply businesses in the area.

Other areas of potential future growth exist. Several small ponds and lakes on the Reservation provide good recreation opportunities and revenue potential. In addition, the introduction of buffalo to some pastures on the Reservation is under consideration. This could generate tourism revenues. The greatest source of future growth is the new casino complex located southwest of Mayetta. The casino is a joint venture between the Prairie Band Potawatomi Tribe and Harrah's Entertainment. The casino is expected the eventually employ as many as 800 people.

The General Plan for the Prairie Band of the Potawatomi Indians produced by the Prairie Band of the Potawatomi Nation Planning Department includes a land use plan which indicates that the rural character of the area is very important to the local people. The new casino will create opportunities for economic development and population growth. However, the desire to maintain a rural character will probably be a limiting factor for future growth. Future business growth may be limited to new or larger convenience stores, service stations, and other service based establishments targeted for the local Reservation population.

Approximately 50 percent of those on the Reservation who are employed work in sectors, which could be considered dependent upon the local population. These sectors include retail and wholesale trade, health services, educational services, and construction. The population growth rate for the Reservation was projected to be about 0.95 percent annually. This would result in a 68 percent increase in employment in these activities by the year 2050. Agriculture currently accounts for about 11 percent of total employment on the Reservation. Assuming the Tribe continues to purchase land, employment in this activity can be assumed to grow by a modest 10 percent by the year 2050. Public administration currently accounts for 9 percent of total employment and is projected to remain stable at that level.

Projections of future activities for about 30 percent of the employment sectors are not easily accounted for. That 30 percent includes potentially high water-use activities such as manufacturing and repair services. A range of growth projections for these activities up to some maximum level indicated by land use plans or physical constraints may be presented. If growth is projected to be 10 percent by the year 2050 for these activities, overall employment would be projected to increase by 40 percent on the Reservation by the year 2050.

SUMMARY

This needs assessment guide presents an overview of the information typically included in a needs assessment. It also describes techniques for estimating current and future water demands, from which need can be documented. Methods for projecting future population and commercial/industrial activity are presented in detail along with an application of the techniques.

The ideal situation occurs when enough detailed data are available so that a demographic model with a labor supply adjustment component can be used. However, in many cases such detailed data will not be available and more simplified modeling techniques must be used. The methods of last resort which can be used in the absence of detailed information include the use of projections obtained for a larger area which includes all or part of the study area, projections obtained for areas similar to the study area, and trend analysis. Although there is a considerable amount of potential error in projections of future population and economic activity, these projections are still needed to understand the potential change in water demand and the need for expanding water supplies and distribution systems.

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