CE 356 Fundamentals of Environmental Engineering

Population Projection and Water Demand

Ricardo B. Jacquez
Professor, CE Dept
New Mexico State University

Teaching Assistant: M.T. Myint

Learning Objectives

- Identify sources for conducting research on historical population and water use and other general characteristics of a community.
- Analyze historical population data to predict a community's future growth trends.
- Comprehend and explain general categories and quantities for water demand in a typical community.
- Evaluate characteristics, population growth, and water use to synthesize a planning document projecting future water demand for a community.

Overview of Topics

- Objectives of Population Projections
- Period of Design (Service)
- Sources of Information
- Water Consumption Purposes
- Fire Fighting Needs
- Variations in Water Demand
- Forecasting Models

Objectives of Population Projections

- Establish a period of design/service (years) for the treatment system
- Design water and wastewater systems to adequately and economically serve the present and future population of the community.

Period of Design

- Public Water Sources:
  - Ground water 25-50 years.
  - Surface water 50+ years.
- Pipelines from source: 20-25 years.
- Water treatment plant: 15-25 years.
- Pumping plant: 10-15 years.
- Storage tanks: 30-50 years.
- Distribution system: indefinite (30-50years)

Sources of Population Information

- U.S. Census Bureau.
- City Planning Offices.
- County Planning Offices.
- Chamber of Commerce.
- UNM Bureau of Business and Economic Research.

Forecasting Models:

Estimate the future growth
based on historical data and trends.

- Arithmetic Method.
- Uniform Percentage Method.
- Declining Growth Method.
- Logistic Method.
- (Detailed information is provided in the class handout).

Data Analysis Guidelines

- Plot all data to identify the "trend line" that best matches the model.
- Use a broad range of "good fit" data to determine growth rates and coefficients.
- Use the model to predict a line through "good fit" historical population points and future growth.
- Look for evidence of change in growth rate and therefore more than one phase of growth

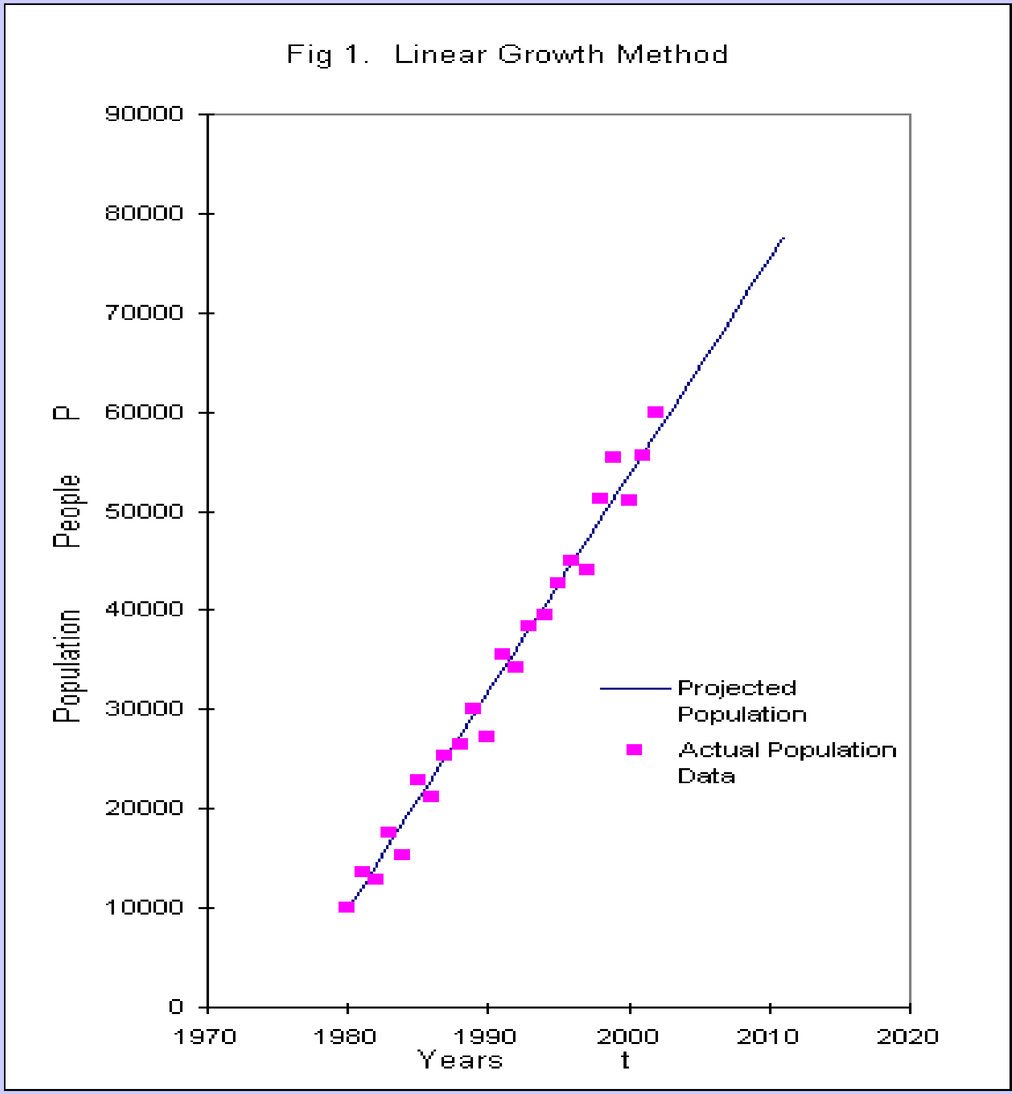
Model 1. Arithmetic Method

$$K = \frac{\Delta P}{\Delta t}$$

$$K = \frac{56000 - 8000}{22}$$

$$K = 2182 \ People / year$$

$$P_t = P_0 + K t$$

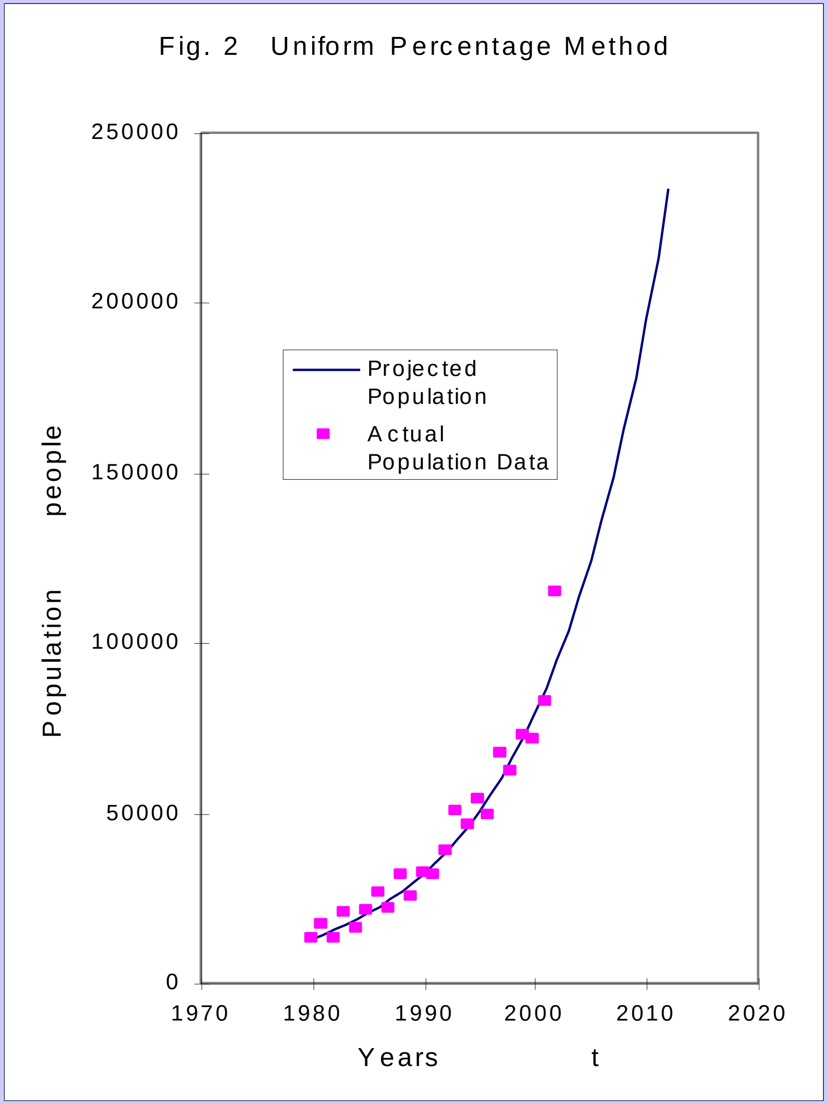


Model 2. Uniform Percentage Method

$$Initial K' = \frac{\ln P_1 - \ln P_0}{\Delta t} =$$

$$LnP_t = LnP_0 + K' \Delta t$$

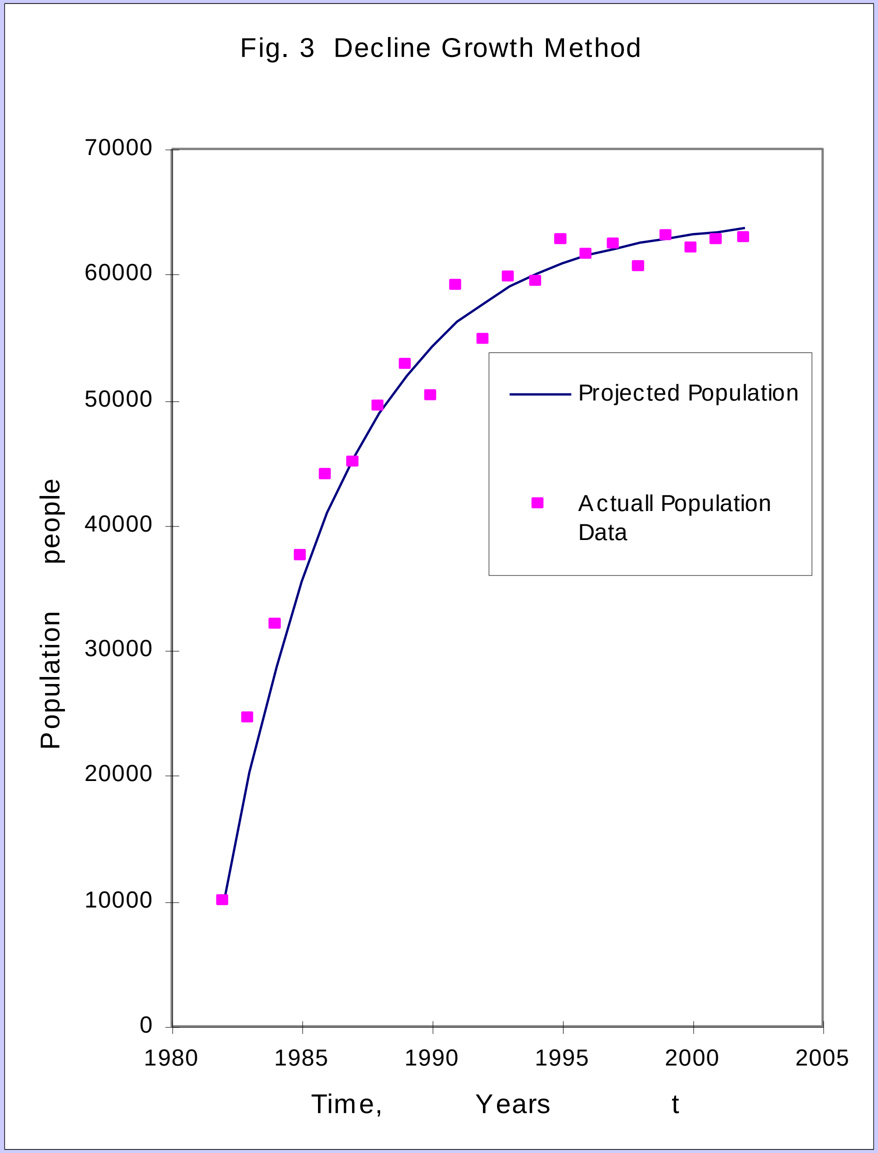
$$P_t = e^{LnP_0 + K' \Delta t}$$



Model 3. Declining Growth method

$$K'' = -\frac{1}{\Delta t} \ln \frac{P_{sat} - p_1}{P_{sat} - P_0}$$

$$P_t = P_0 + \left(P_{sat} - P_0\right)\left(1 - e^{-k'' \Delta t}\right)$$



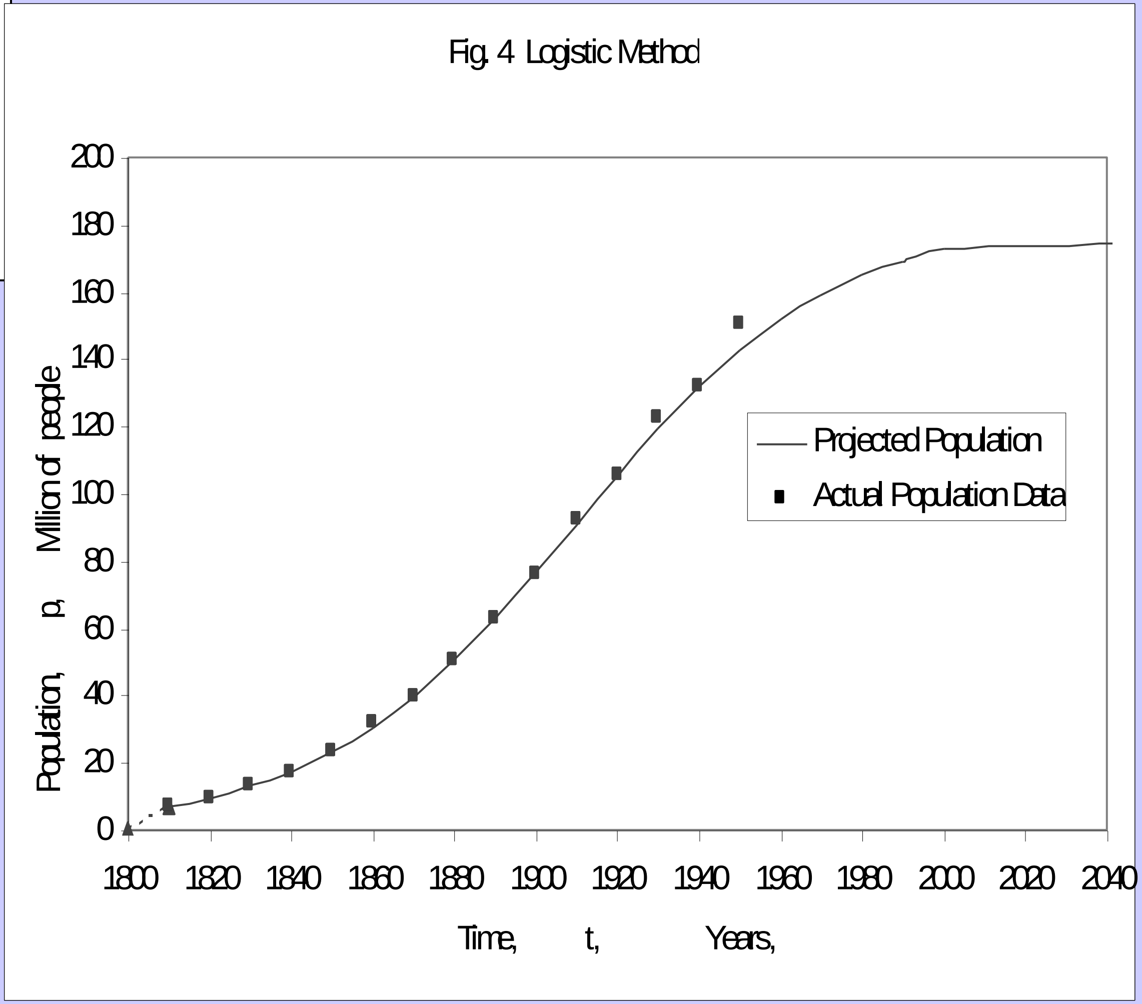
Model 4. Logistic Method

$$P_{sat} = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2}$$

$$a = LN\left(\frac{P_{sat} - P_0}{P_0}\right)$$

$$b = \frac{1}{n} LN\left(\frac{P_0(P_{sat} - P_1)}{P_1(P_{sat} - P_0)}\right)$$

$$P_t = \frac{P_{sat}}{1 + e^{a+b*n}}$$



Domestic Water Demand

- Water used for drinking, washing and flushing toilet ----- *40 gallons* per person.
- Water use per capita in suburban Australia (including lawn sprinklers, swimming pools etc.) ----- *90 gallons*. Same water use in the United States ----- *100 gallons*.

Agricultural Water Demand

GALLONS OF WATER	TO PRODUCE
250 to 650 gallons	One pound of rice
130 gallons	One pound of wheat
65 gallons	One pound of potatoes

Agricultural Water Demand

GALLONS OF WATER	TO PRODUCE
3,000 gallons	A quarter-pound hamburger
From 500 to 1,000 gallons	A quart of milk
650 gallons	A pound of cheddar or brie or camembert

Agricultural Water Demand

GALLONS OF WATER	TO PRODUCE
400 gallons	A pound of sugar
2,650 gallons	One-pound of coffee
265 gallons	A glass of milk
40 gallons	The bread in a sandwich
400 gallons	An ice cream

Virtual Water

- *Virtual water* – an economical term for water used in growing and manufacture of products traded around the world.
- The global virtual-water trade is estimated to be around *800 million acre-feet* a year, or twenty Nile Rivers.
- Nearly a tenth of all water used in raising crops goes into the international virtual-water trade.

Virtual Water

- The biggest net exporter of virtual water is the US: exports one third of all water withdrawn from the natural environment (grains, either directly or via meat).
- Other major exporters of virtual water: Canada (grain), Australia (cotton, sugar), Argentina (beef), Thailand (rice).
- Major importers of virtual water include Japan, EU, middle east, and others.

Water Consumption Categories

Purpose	gal/capita/day	% of Total
Domestic	80	45
Commercial	25	15
Industrial	50	25
Public Use	20	10
Loss & Waste	15	5
Total	190 gpcd	100

Water Consumption Categories Continued

- Average day (treatment plant) = 150-200 gpcd
- Maximum day (treatment plant) = 180% average day
- Maximum hour (distribution system) =150 % max day

- Use historical metering data kept by the municipality to determine the specific demand.
- Consider variations:
  - Seasonal:Winter =80 % Avg vs. Summer =125 % Avg
  - Diurnal variation.

Domestic, Commercial and Public Water Uses:

- Drinking
- Cooking
- Sanitary needs: bathing, washing, flushing, cleaning
- Lawn watering
- Swimming pools
- Street cleaning
- Fire fighting
- City and park maintenance

Community vs Household Water Use

- Public water use withdraw = 11% nations fresh water

- 1975=170 gpcd Household (family of 4)=90gpcd
- 1990=185 gpcd Household (family of 4)=105gpcd

Fire Fighting Needs: National Board of Fire Underwriters

- Annual requirements - small
- During fire - heavy demand
- Rate: 500-3,000 gpm depending on population, surface area, and material of construction (see Table 2.3 in handout, Eqns 4.1 & 4.2 in text).
- Pressure in the distribution system: 20-100 psi (pumper vs no pumper).
- Duration: up to 10 hours.
- Coincident draft : maximum day occurs at the same time.

Variations in Water Demand

- Hourly: see Figs 4.2 & 4.3
  (two peaks at 7 am-1 pm and 5-9 pm).
- Day to day: Avg day, Max day, Min day
- Seasonal: Summer vs. Winter (see Fig 4.2)
  - Impact of lawn sprinkling in the evening.
- Weather: Rainfall (see Fig 4.3)