Water Demand Forecasting

Image from USGS - Georgia

West Virginia Water Resources Training Workshops

Presented by the Interstate Commission on the Potomac River Basin

Sponsored by the West Virginia Department of Environmental Protection

With funding from the American Reinvestment & Recovery Act

Outline

- Introduction
- Data needs
- Forecasting average annual demand
- Estimating seasonal and daily variations in demand
- Resources

Image from USEPA

Introduction

- Who does water demand forecasts?
  - Water providers (municipalities, PSDs, private providers)
  - Regions
  - States

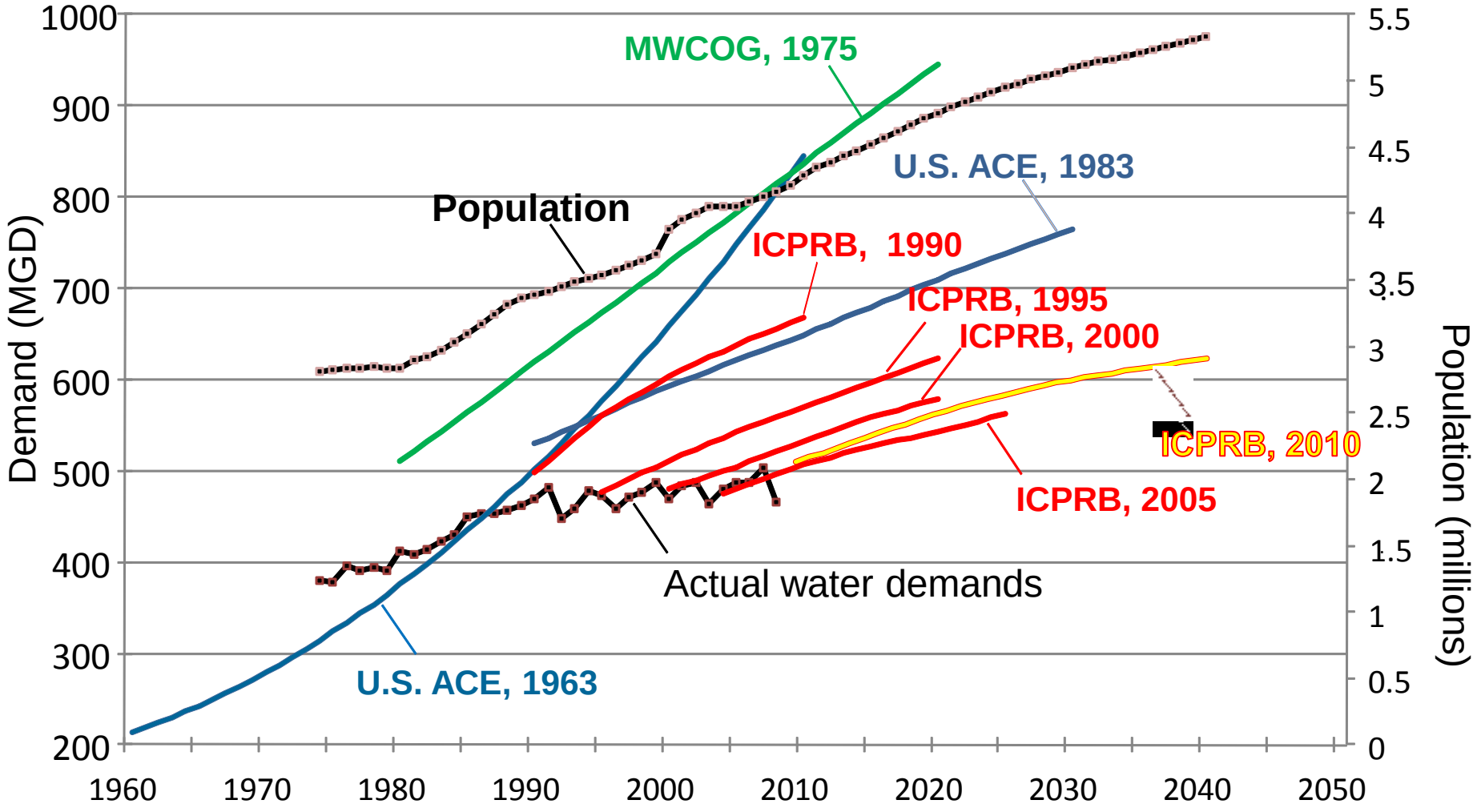
- Why do demand forecasts?
  - To evaluate ability of existing sources to meet future needs
  - To provide basis for planning future system improvements

Uncertainties in Demand Forecasts

- Population growth
- Economic changes
- Changes in water use habits, attitudes
- Natural weather fluctuations
- Government programs & regulations
- Climate change

Prediction is very difficult, especially if it's about the future.
(Nils Bohr, Nobel laureate in Physics)

Forecasts of Washington, DC, Metropolitan Area Average Annual Water Demand



Some Definitions

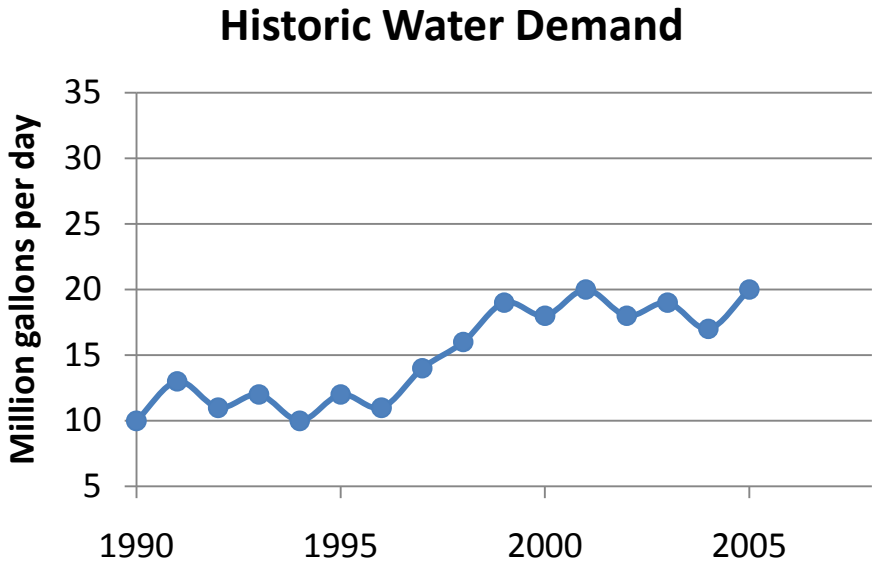
- *Water demand (water use)* Total amount of water needed or used within a geographic area, measured in million gallons per day (mgd), or gallons per day (gpd)
- *Public water systems (PWS) (EPA:)* providers of water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year.
  - *Community Water System,* e.g. municipalities, PSDs
  - *Non-Transient Non-Community Water System* e.g. schools, factories
  - *Transient Non-Community Water System* e.g. gas stations, campgrounds
- *Self-supplied users* Individual homes and non-community systems that obtain water via individual wells or intakes

Consumptive Use

- West Virginia: “Consumptive withdrawal” means any withdrawal of water which returns less water to the water body than is withdrawn.
- Less water may be returned because of
  - Evaporation or transpiration by plants
  - Incorporation into products or crops
  - Consumption by humans or livestock
  - Transfer to other watershed
- Primarily a watershed-based concept
- Important to downstream users

Steps in Demand Forecasting

- Define objectives
- Compile available data
  - Water use
  - Demographics
  - Weather
  - Water conservation
- Select forecast method based on:
  - Availability of data
  - Required accuracy
  - Resources



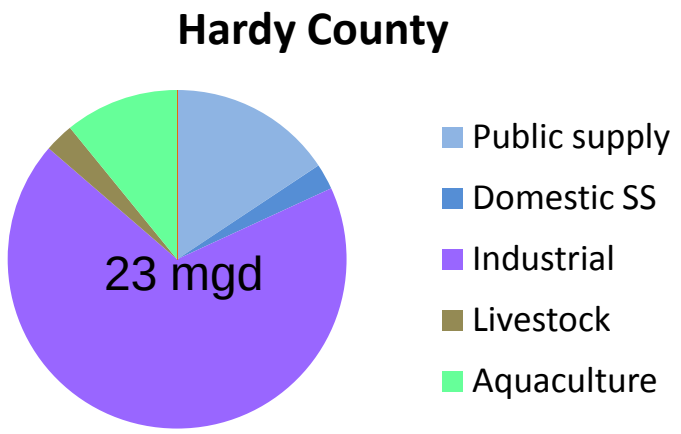
Data Sources

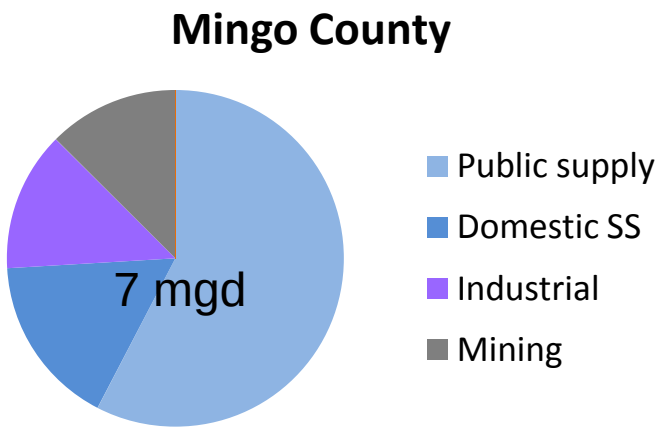
- Water use
  - Individual providers
    - Consumption data (from billing records), annual, quarterly, monthly
    - Production data (well or stream withdrawals), monthly or daily
  - WVDEP - water use registration data for large users (>750,000 gallons per month), by month
  - USGS water use data - average annual demand, by county, by use category - 1985, 1990, 1995, 2000, 2005
- Demographic data
  - US Census website
  - WVU, Bureau of Business Research
  - Development agencies, local planning

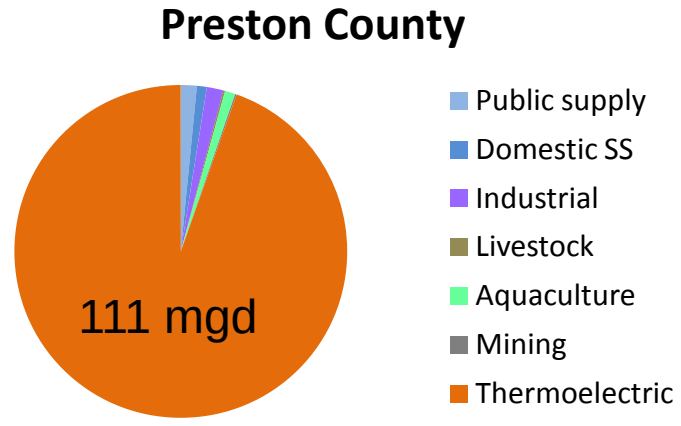
WVDEP Water Use Inventory – Tygart Valley

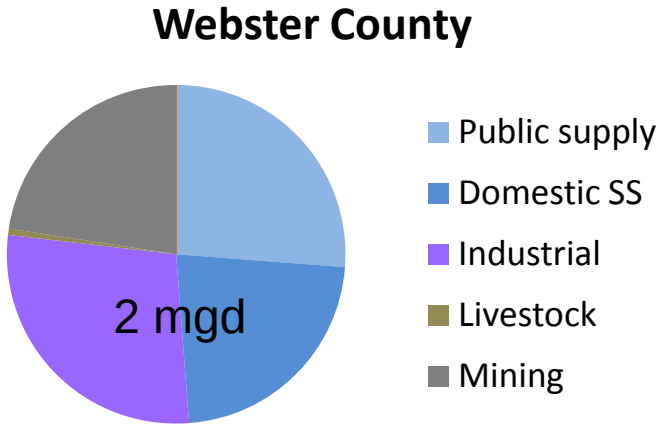
- Counties of
  - Marion
  - Taylor
  - Preston
  - Barbour
  - Upshur
  - Randolph
- Data includes
  - Monthly withdrawals
  - Water source
  - Consumptive use info

USGS - Water Use Data - Categories









*Derived from USGS 2005 data base

Methods for Forecasting Average Annual Demand

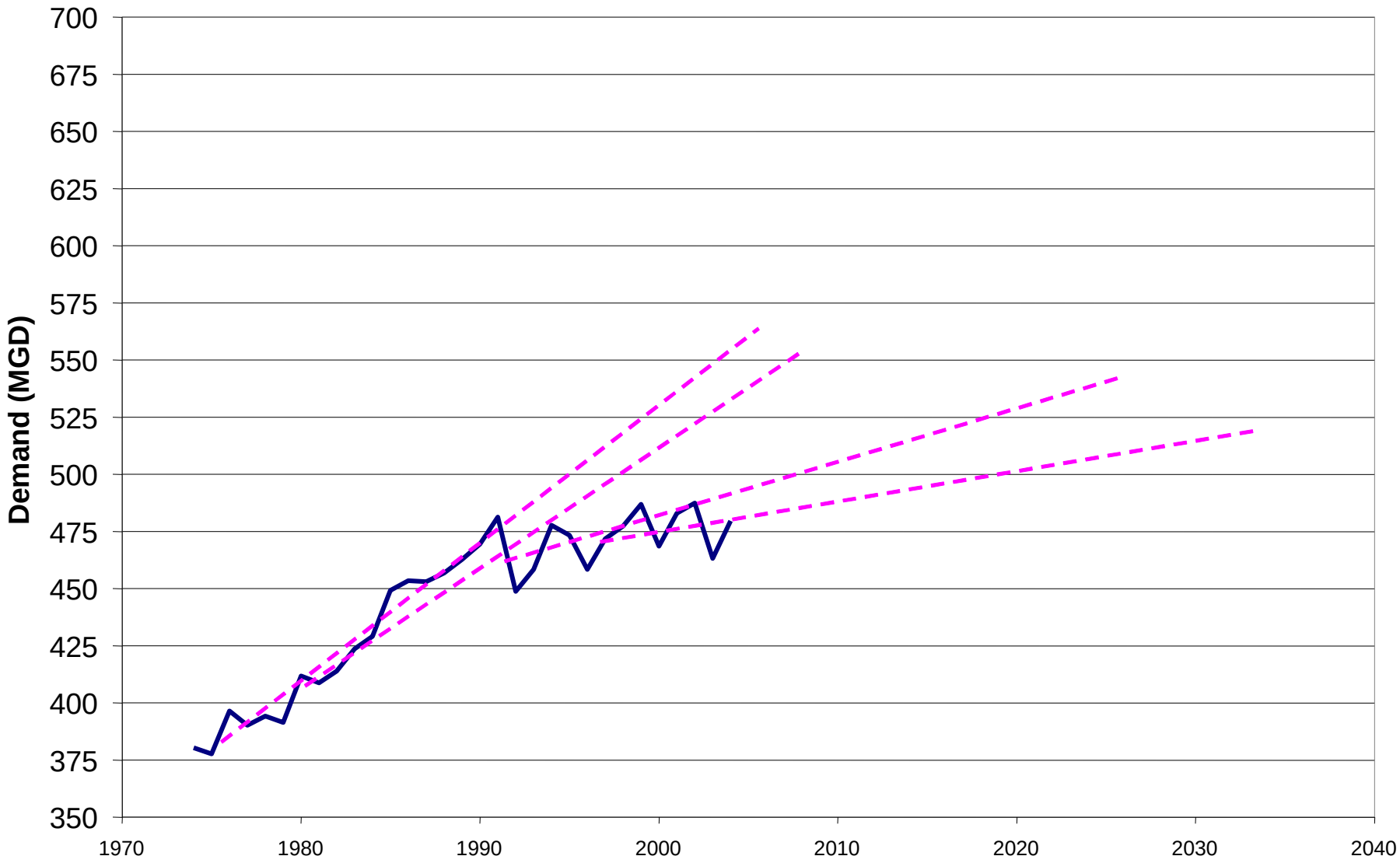
- Extrapolation of past growth in total demand
- Forecasts based on past per capita use
- Forecasts based on past use per land use type per acre
- Forecast based on past use by user category
  - Requires data on water use by customer category (e.g. residential, commercial, industrial)
  - Requires current and forecast of units in each category
- Causal models - statistical models of use based on income, water prices, etc.

Extrapolation method

Predict future water use by extrapolating past data

- Data needs
  - 10 to 20 years of average annual demand
- Advantages
  - Minimal data needs
  - Uses simple statistical methods to extrapolate past growth
- Disadvantages
  - Assumes indefinite growth (or decline)
  - Doesn't identify underlying causes
    - Changes in population?
    - Changes in per capita use?
    - Changes in industrial or commercial sectors?

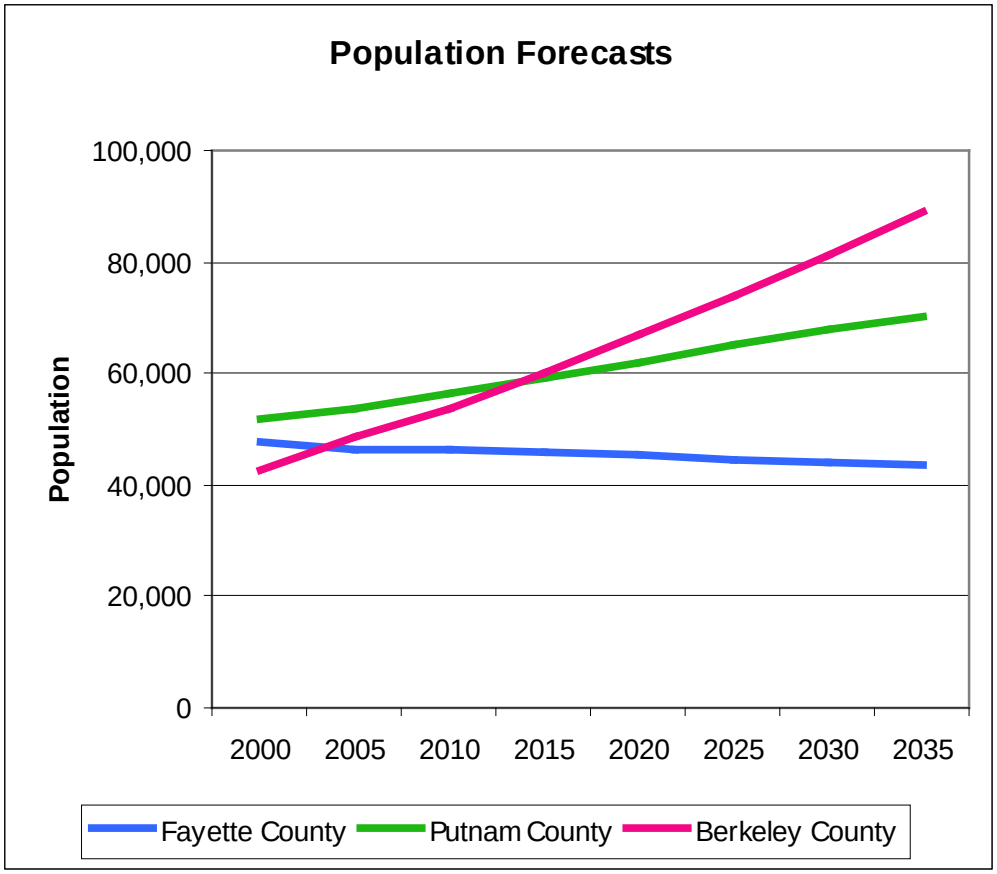
Average Demand by Year for the WMA Utilities



Per Capita Use Method

Multiply future population by per capita use to get total future demand

- Data needs
  - Population projections
  - Historical billing and population data
- Advantages
  - Simple data needs
  - Simple calculations
- Disadvantages
  - Assumes factors driving demand are well correlated with population



Derived from data in Cristiadi, 2009

Per Capita Use Examples

County	Total Population	Total Groundwater withdrawals, mgd	Total Surface Water Withdrawals, mgd	Total Water Withdrawals, mgd	Overall Per Capita Water Use, gpd
Boone	25,703	1.45	3.68	5.13	200
Clay	10,356	0.71	0.81	1.52	147
Fayette	46,823	1.40	38.88	40.28	860
Greenbrier	35,027	3.14	6.19	9.33	266
Kanawha	193,559	2.88	499.31	502.19	2,595
McDowell	24,273	4.31	1.26	5.57	229
Pocahontas	8,851	0.61	5.48	6.09	688
Putnam	54,443	0.99	55.96	56.95	1,046
Raleigh	79,167	1.85	13.59	15.44	195
Roane	15,407	0.71	1.58	2.29	149

Derived from USGS data for 2005

Unit Use Per Customer Type Method

Project growth in demand by customer category: e.g. residential, industrial, commercial, etc.

- Data needs
  - Water billing data by customer category
  - Demographic data by customer category
  - Projected growth for each customer category
- Advantages
  - Disaggregation addresses more trends in water use
- Disadvantages
  - Requires more detailed data and analyses

Unit Use Rates

- Examples
  - Coal production: 95 gallons per ton (WVDEP)
  - Milk cows: 35 gpd (Penn State University)
  - Accommodation and food services, per employee: 187 gpd (USGS)
  - Construction, per employee: 20 gpd (USGS)
  - Commercial use per employee: 42 gpd (PA State Water Plan)
  - Industrial use per employee: 665 gpd (PA State Water Plan)
- Vary widely across the country
- Valid only for statistical purposes – for large number of units
- West Virginia per capita uses (USGS, 2005)
  - PWS's – county median = 123 mgd
  - PWS's – 90% of counties in range, 43 – 237 mgd (USGS 2005)
  - Domestic self-served: 80 gpd

Important Considerations

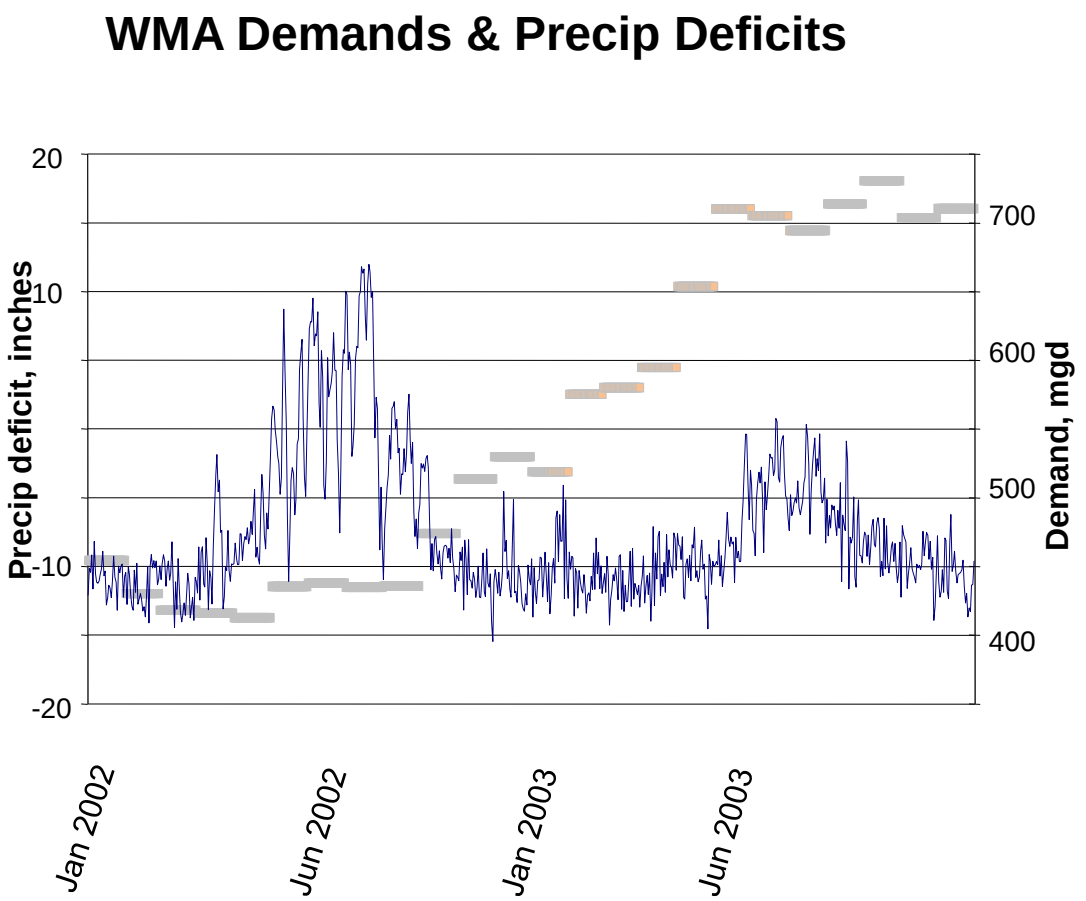
- Estimate of unaccounted for water (system losses)
  - Fire hydrant use, system flushing, illegal connections, leaks
  - Computed as difference between production and consumption
  - Typically 10% of production, but can be higher
- Impact of water conservation programs
  - Temporary: education, drought rate structures, gray water use
  - More permanent: education, promotion of xeriscaping and mulching, low-flow plumbing fixtures

Historical Changes in Water Use

- U.S. unit use rates have declined over time
- Energy Policy Act of 1992
  - Mandated low-flow plumbing fixtures in new construction
- EPA WaterSense program (2006)
  - Promotes adoption of water-efficient products and practices
  - Encourages innovation in manufacturing
  - Includes certification program

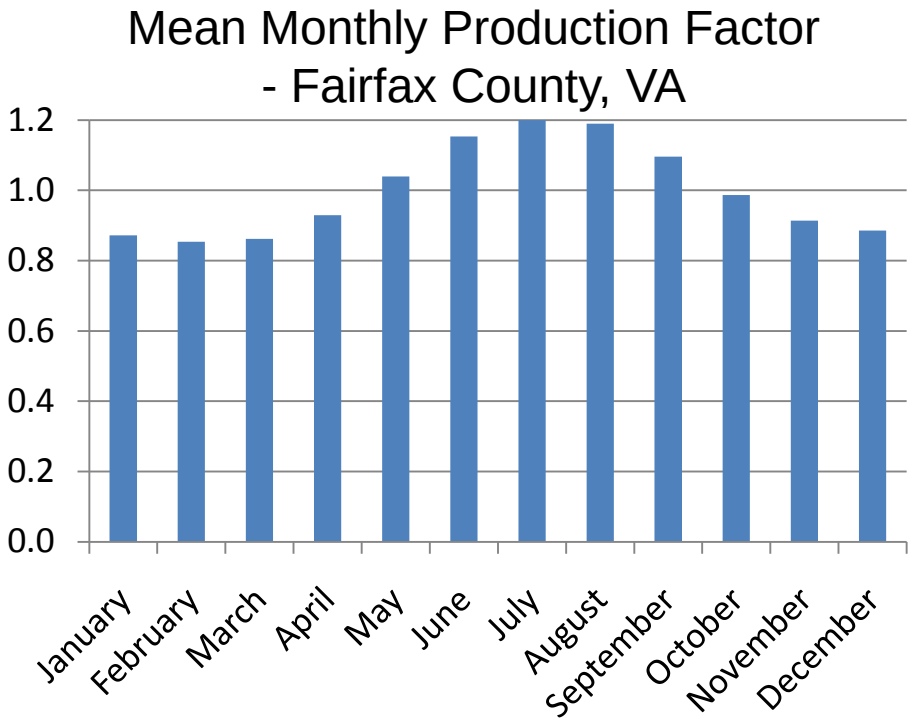
Second Part of Demand Forecasting: Seasonal and Daily Variations

- Average annual demand
  - Reflects changes in population, industry, new regulations, changing behavior
- Seasonal/monthly/daily variations in demand
  - Due to variations in season and weather conditions
  - Necessary for planning system capacity/storage



Seasonal/Daily Variations

- Monthly production factors
  - Ratio of average monthly to annual
  - Lowest typically in winter – indoor use
  - Highest in summer – outdoor use
- Peak day factor
  - ratio of peak day to average annual
  - Typically 1.2 to 2.5



Resources

- National Handbook of Recommended Methods for Water Data Acquisition -- Chapter 11 - Water Use, USGS – at http://pubs.usgs.gov/chapter11/
- Water Resources Planning – Manual of Water Supply Practices (M50), American Water Works Association, 2001
- Water use data, by county, by use category, from USGS – at http://water.usgs.gov/watuse/data/
- West Virginia population forecasts: WVU, Bureau of Business & Economic Research (State demographer, Dr. Christiadi) – at http://www.be.wvu.edu/bber/