LECTURE NOTES
Water Uses, Demands, and Demand Forecasting

Learning objectives

1. List water uses
2. Define water demand
3. Describe reasons engineers forecast water demands
4. Disaggregate demand into its components
5. Forecast water demand using three engineering methods

1. Water Uses

How do humans use and why do we need to manage water?

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-
-
- Navigation
- Flood damage reduction
-
-
-
- Drainage
- Others?

2. Defining water demand

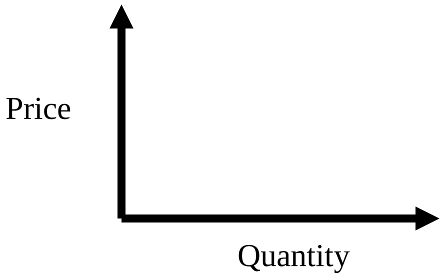
1. How much water is used?
2.
3. is the water used?
4. is the water used?
5. How might all of the above ?
6. How will use change with , or other ?

Engineer's definition: Water demand is the of water needed or used for a particular in a particular over a particular (invariant with).

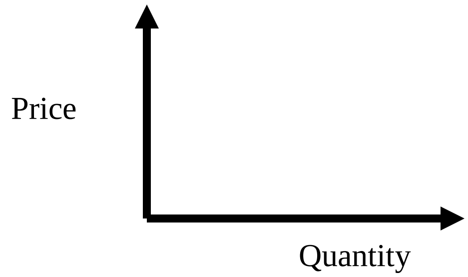
Units: $[L^3 T^{-1}]$

Economist's definition: Water demand is the volume of water needed for a particular activity in a particular place over a particular time and depends on [i.e., demand is a function of price, Q = f(p,…)]

If we graph the two types of demands, they might look like:



A.



B.

3. Motivation to understand and forecast demands

Need to:

- (storage, treatment, delivery, waste-water treatment)
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- Forecast future needs
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4. Disaggregating demand

Water demand is an aggregation of

A. By users / uses

- Residential water use
    - Indoors ( )
    - (swimming pools)
- Agricultural water use
    - Tree crops
    -
    -
    - Rice
    - Potatoes
    - Livestock
    - Etc.
-
- Industrial water use
- Institutional water use
    -
    -
- Tourist
- Others:

i. Digging a bit deeper into residential water users and use

Figure 1 shows average water use in the U.S for different residential end uses.

ii. Factors that affect residential water use

- Demographics (number of occupants and their ages)
    - Does water use differ for children, adults, or the elderly?
- Current water infrastructure (technologies)
    - Toilet tank size
    - Flow rates of faucets and showers
    -
    - Dishwasher
    - Outdoor landscaping and irrigation
    -
- Water use practices (behaviors)
    -
    -
    -
    -
-
- Attitudes and behaviors towards water conservation
- Others?

Aggregate or Surrogate factors (often used in demand modeling)

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- Education
- Number of bathrooms
- Property value
-
- Season

iii. Average use vs. distribution of uses

Water use differs among different users (heterogeneity). Figure 2 shows some sample distributions of residential water use in the U.S. and Amman, Jordan.

What is the key implication of these distributions when implementing a water conservation program?

b. Spatial disaggregating

Figure 3 shows average water use in various US and international cities.

Why might use differ geographically?

Why does average residential water use differ in California and Boston?

In the U.K. and Jordan?

What is the likely water use in Logan?

c. Temporal disaggregating

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-
- Also, potentially by year type (wet / dry)

Figure 4 shows and fluctuations in demand. What causes these fluctuations?

Peak vs. average demand

Peak demand –

Average demand –

For which demand do we generally need to design / size systems?

5. Forecasting Demand

A. Population-based demand forecasting (Engineering method)

Use current population, per-capita water use estimates, and future population and per-capita water use projections to forecast future water use.

Simple version:

Q = P W

Q = [m^3 $year^{-1}$]
P = Population [ ]
W =

EXAMPLE 1: How much water will Logan use in 2050 if there are 65,000 people who use, on average, 285 gallons per person per day?

SOLUTION 1:

Q = P W = (65 000)(285) = 18.5 MGD (365) (3.07) = 20,800 ac-ft/year

Admittedly very crude and hard to predict. But often the best we can do. Can improve by disaggregating among types of uses:

$$Q = \sum_{i=1}^{I} P_i \cdot W_i$$

i = use category, e.g.:

B. End Use Estimation (Engineering Estimation)

Combine , , and demographic parameters to estimate and saved by a conservation action.

Method:

1. Identify which parameters directly influence water use
2. Specify the functional relation (use or effectiveness function)
3.

Examples:

1. Weekly shower water use:

   Q_{shower} [household^{-1} week^{-1}] = * 7
   A =
   B = Shower duration [ ]
   C = [capita]
   Conversion factor = 7 day week^{-1}

2. Water saved by installing a :

   $S_{low\text{-}flow\ shower}$ [gal household^{-1} week^{-1}] = [ ] B C * 7

   E =

3. Effectiveness (water saved) by reducing shower length:

   $S_{reduce\ shower\ length}$ [gal household^{-1} week^{-1}] = A (B – F) D * 7

F = Short shower length [min $person^{-1}$ day^{-1}]

EXAMPLE 2: Using the demographic and behavioral data for Salt Lake City, Utah (Table 1), how much water does the typical SLC household use to shower each week?

SOLUTION 2:

EXAMPLE 3: How much water will the typical SLC household save over a three month billing period by shortening their shower length to be the same length as the household that takes the shortest showers?

SOLUTION 3:

Similarly for , , laundry, outdoor water use.

Caution: Use and effectiveness estimates are precise for an individual household, but require more complex analysis to estimate average (or distribution) among a population.

$\overline{w} \neq \overline{a} \cdot \overline{b} \cdot \overline{c}$

C. Landscape water forecast (another engineering method)

For agricultural crops and residential landscaping, relate the water forecast to the plant water need (water the plant needs to transpire to stay healthy). Relate to a reference evapotranspiration value (measured by weather stations) and irrigation system efficiency.

$$Q_p = \begin{cases} c \cdot \dfrac{ET_o \cdot K_{c,p} \cdot \pi \cdot r_p^2}{e_p}, & p = \text{Trees, shrubs} \\ c \cdot \dfrac{ET_o \cdot K_{c,p} \cdot a_p}{e_p}, & p = \text{Turfgrasses, ground covers, perennials, annuals, vegetable gardens} \end{cases}$$

p = plant type (trees, shrubs, turfgrass, etc.)
c = a conversion factor,
ET_o = reference local evapotranspiration (inches),
$K_{c,p}$ = Water Needs Index for the plant *p* (fraction) [Table 2],
π = 3.1415
r_p = tree or shrub canopy radius (feet),
e_p = irrigation efficiency of the system component delivering water to the plant type *p* (fraction), and
a_p = planting area of the other plant types *p* (ft^2)

EXAMPLE 4: Compare the seasonal water needs of ¼ acre plots of drought-tolerant perennials and conventionally-maintained, cool season turfgrass irrigated with, respectively, 85% efficient drip and 60% efficient sprinkler systems. Assume seasonal reference evapotranspiration is 20.5 inches and the plants are in their 3rd year of growth.

SOLUTION 4:

Other Methods You Should Be Aware Of (but we won't use in this class)

D. Land-use based forecasts (another engineering method)

Method:
1. Gather land use parcels (polygons) for study area and assign a land use type to each parcel, c_j [1, 2, … K], j = parcel ID, K = number of land use types (see Table 3)
2. Estimate a water use factor for each land use type k, w_k [ac-ft/ac] (see Table 3)

3. In GIS multiply polygon area A_j [ac] of each parcel by water use factor for the parcel, $w_{c(j)}$ [ac-ft/ac], sum for all parcels

$$Q = \sum_j A_j w_{c_j}$$

4. **Repeat** with projected land-uses for different development scenarios

Table 2 shows sample water use factors for some land types in San Francisco, CA.

What types of land uses predominate in Logan, UT?

D. Econometric Regression (Economists method)

Regress measured water use among a population of customers (dependent variable) to numerous demographic, geographic, climatic, economic, and other factors (independent variables). Won't go into further detail here.

6. Wrap-up

- Engineers must understand, estimate, and forecast water demands to correctly size water supply systems.
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