# CE 3372 WATER SYSTEMS DESIGN

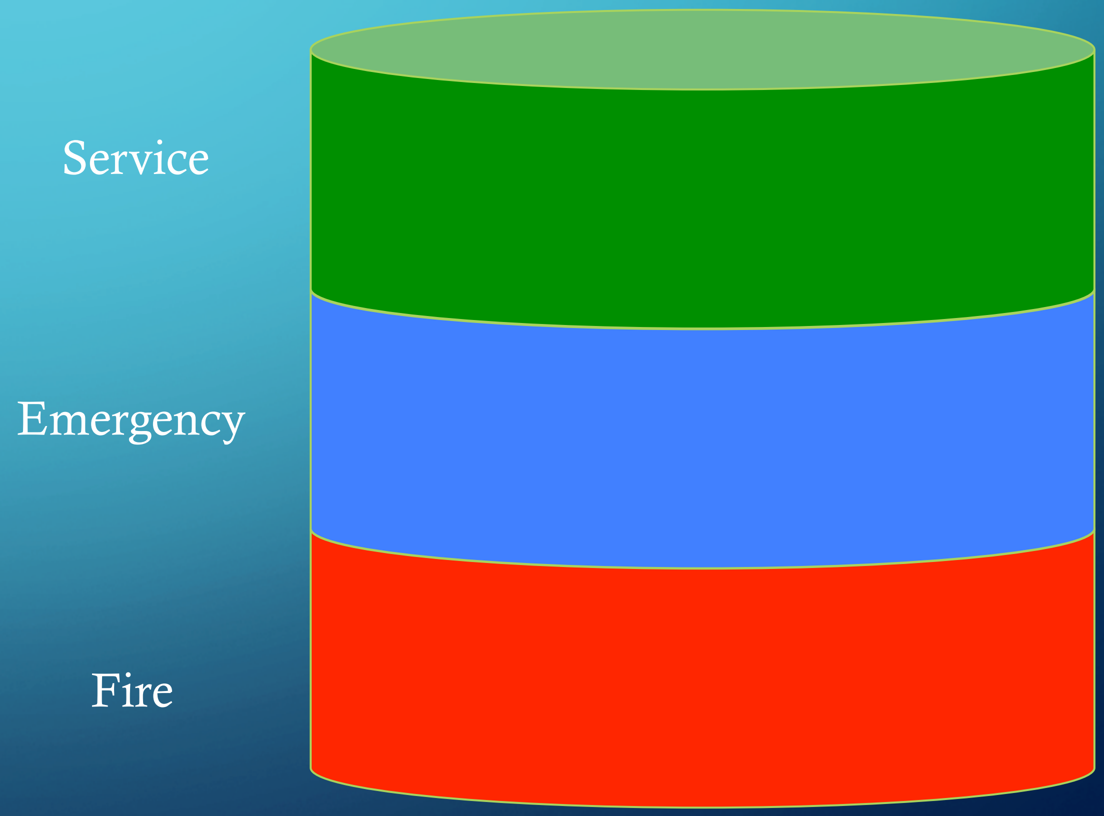
LESSON 07: DRINKING WATER STORAGE

# STORAGE

- Storage is used in water supply, storm water management, and wastewater systems for a variety of reasons.
  - SERVICE STORAGE
    - flow equalization — generally things are designed for a particular steady flow rate and storage can be used to accommodate variable flow rates in a system.
    - Pressure zone maintenance
  - EMERGENCY STORAGE
    - used to provide supply during repairs and other system interrupts
  - FIRE STORAGE
    - used to provide supply during fire fighting activities – could logically be considered as part of emergency
- Storage is either elevated (above grade), at grade (reservoir, tanks, ponds, etc.) or below grade (subsurface vaults — NOT AQUIFERS).

# STORAGE COMPARTMENTS

- Service storage
- Emergency storage
- Fire Storage



# FLOW-EQUALIZATION

- Flow-equalization storage is sufficient storage to account for peak demands in the system without having to exceed supply capacity.
  - A desirable volume is 1-2 days of average daily demand.

# FIRE STORAGE

- Fire storage is sufficient storage to allow the system to meet routine uses plus substantial fire flow.
  - The desirable volume is based on expected fire flow rates multiplied by the required fire flow duration.

# EMERGENCY STORAGE

- Emergency storage to allow the system to operate without external supply sources for a period of time to allow for repairs or other unusual circumstances.
  - Without emergency storage, every upset will lead to a ”boil-water” order or substantial interruption of service — these kinds of interruptions should be rare if the system is well engineered.
  - A desirable volume is 1-2 days of average daily demand.

# HOW MUCH?

- Engineering would tend to choose for the larger volumes
- Economics will argue for the smaller volumes
  - The engineer will have to balance these competing choices in a design.

# RESIDENCE TIME

- Additionally, residence times in any storage reservoir for TREATED water should not exceed a reasonable amount disinfection residual contact time.
  - For chlorine/chloramine disinfection time is on the order of 6-10 days
  - An hydraulic retention time of any such reservoir should be no longer than 8 days (as a reasonable rule of thumb).

# HYDRAULIC RETENTION TIME

- Hydraulic retention time is the ratio of storage volume to average discharge through the reservoir

$$HRT = \frac{V_{\text{tank}}}{Q_{\text{average-daily}}}$$

# HOW MUCH?
## FLOW EQUALIZATION

- Operating (flow-equalization) storage is determined as follows:
  1. Determine the hourly demand for a typical design day.
  2. Compute the cumulative draft (cumulative volume as a function of time)
  3. Compute the average constant draft rate (flow rate that if applied over the day end at the same accumulated value)
  4. The equalization storage is the sum of the two largest deviations from the average flow line to the cumulative draft line.

# SERVICE STORAGE

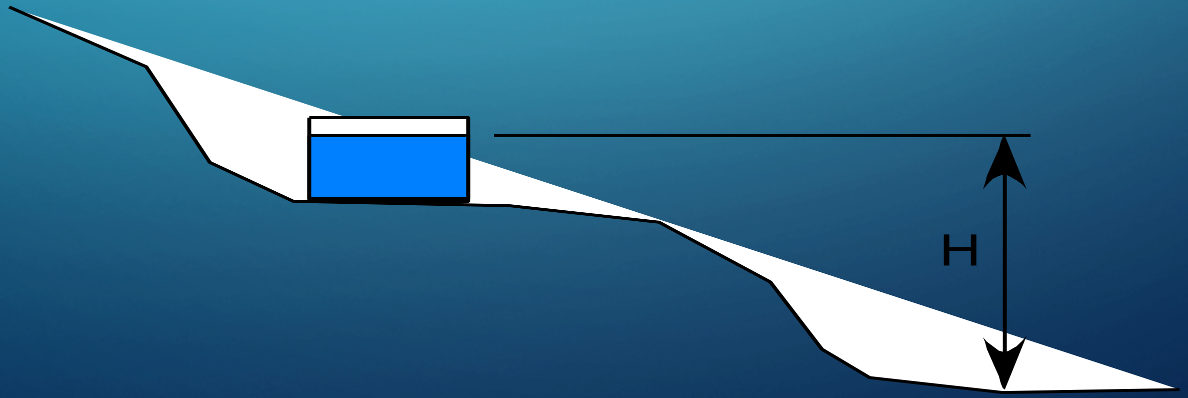
- Purpose of storage reservoirs
- Types of reservoirs
- Calculating storage requirements

# STORAGE RESERVOIRS

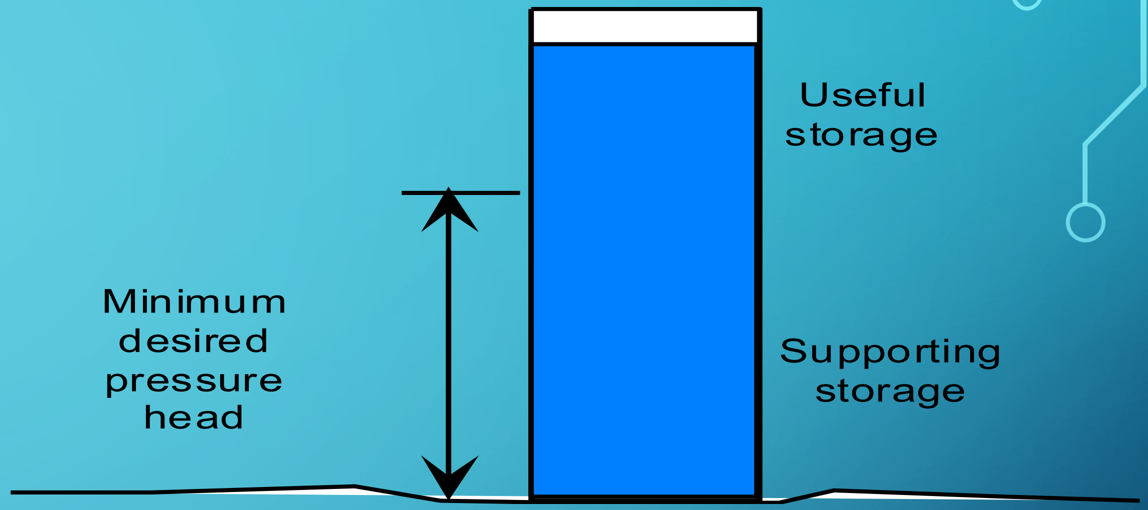
- Equalizing or Operating Storage
  - Equalize pumping rate into reservoirs
  - Provide storage for peak demand times
  - Provide system pressure without booster pumping
- Fire and emergency pressures
- Types
  - Surface reservoirs
  - Standpipes
  - Elevated tanks

# SURFACE RESERVOIRS

- Where natural elevation is high enough
- For inexpensive pumped storage
- Covered for protection (contamination, algae growth, evaporation)
- Good temperature control



# STANDPIPES




- Vertical cylindrical pipe
- Height > diameter
- Useful storage = volume above elevation needed for minimum pressure
- Low storage useful for emergencies
- Steel, reinforced concrete

# ELEVATED STORAGE

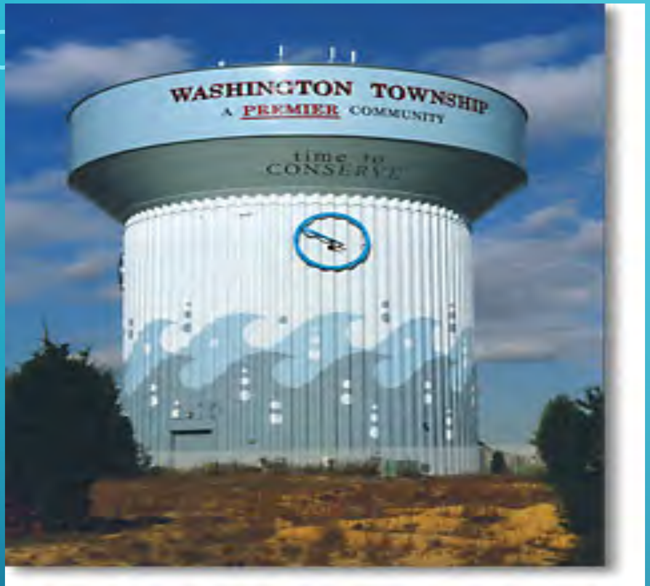
- Usually less $/volume of useful storage
- Foundation design important
  - Wind uplift
  - Earthquake stress
- General types
  - Hemispherical bottom (50-75000 gal)
  - Double ellipsoidal (< 1.5 MG)
  - Radial cone bottom (up to 3 MG)
  - Hydropillar (up to 3 MG)

# CB&I (FORMERLY CHICAGO BRIDGE & IRON) WATER TANKS

# COMPOSITE ELEVATED TANKS

# HYDROPILLAR™

# HYDROPILLAR





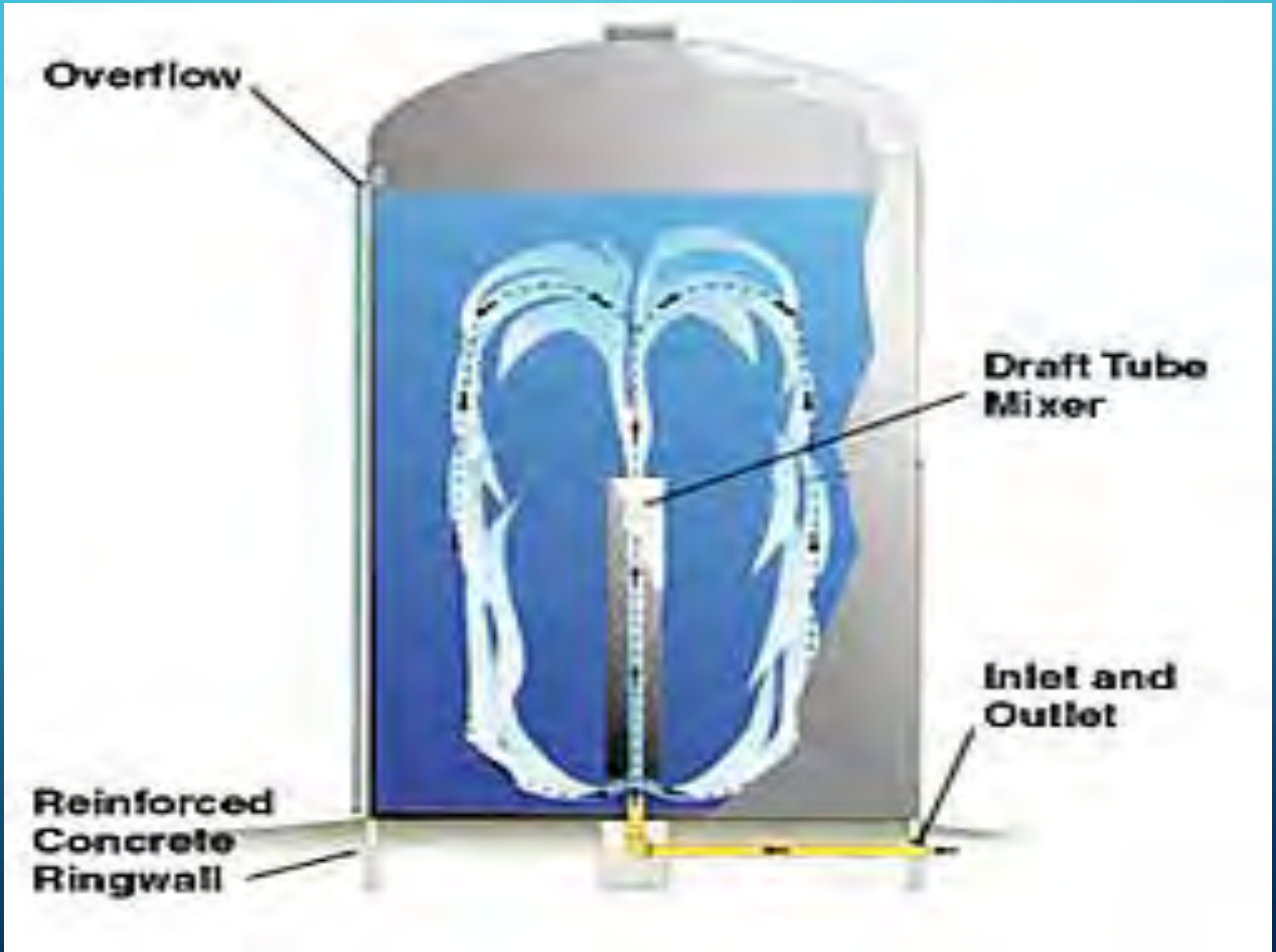
# WATER SPHEROIDS




# STANDPIPE GROUND LEVEL

# STANDPIPES AND RESERVOIRS


# FRESHMIX™ STANDPIPE MIXING



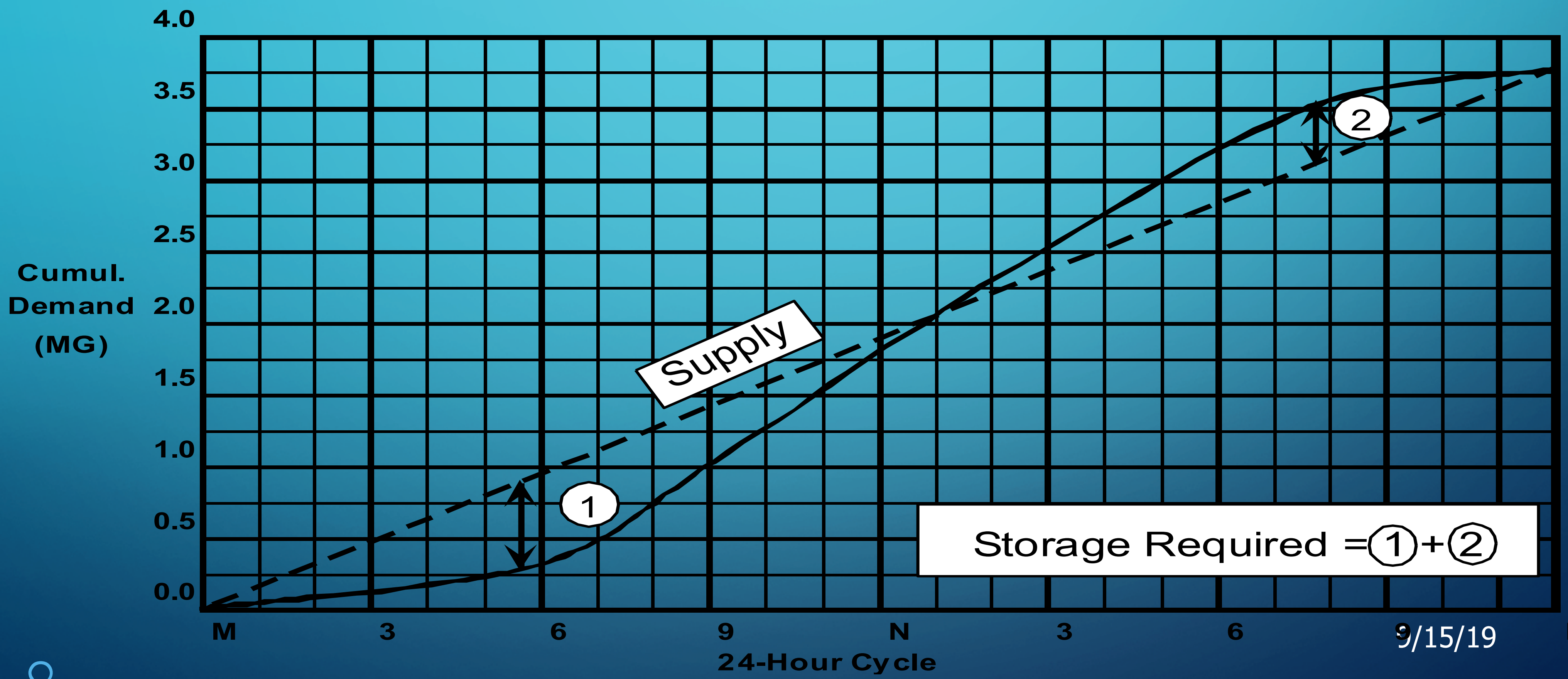
# COMPOSITE ELEVATED TANKS

| Standard CET Dimensions | | | |
|---|---|---|---|
| Capacity (in U.S. gallons) | Tank Diameter (in feet) | Head Range (in feet) | Pedestal Diameter (in feet) |
| 1,000,000 | 70 | 40 | 36 |
| 1,500,000 | 87 | 40 | 48 |
| 2,000,000 | 94 | 45 | 52 |
| 2,500,000 | 105 | 45 | 60 |
| 3,000,000 | 118 | 45 | 64 |

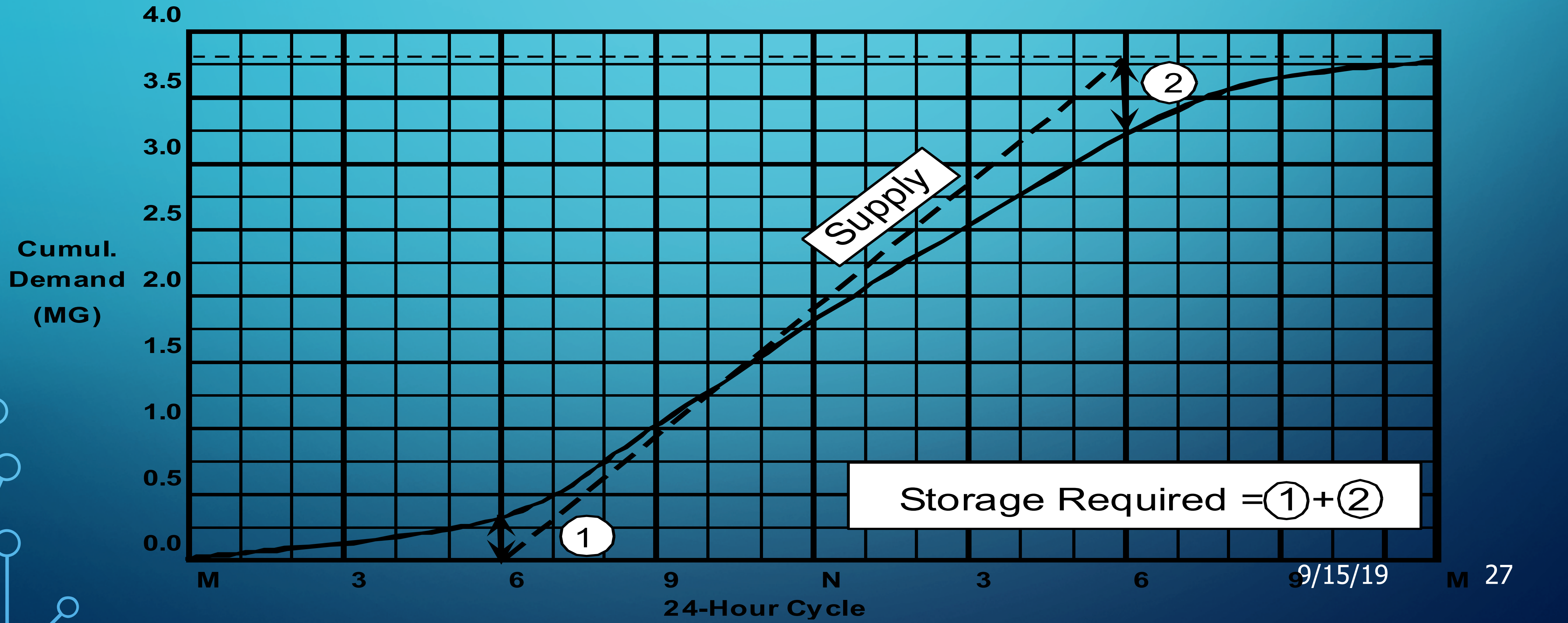
# OPERATING STORAGE

- Determine hourly demand for design day
- Calculate cumulative draft
- Plot cumulative draft vs. time (24 hr)
- Draw diagonal line representing constant pumping
- Read required storage as sum of two maximum ordinates

# MASS DIAGRAM (24-HR PUMPING)



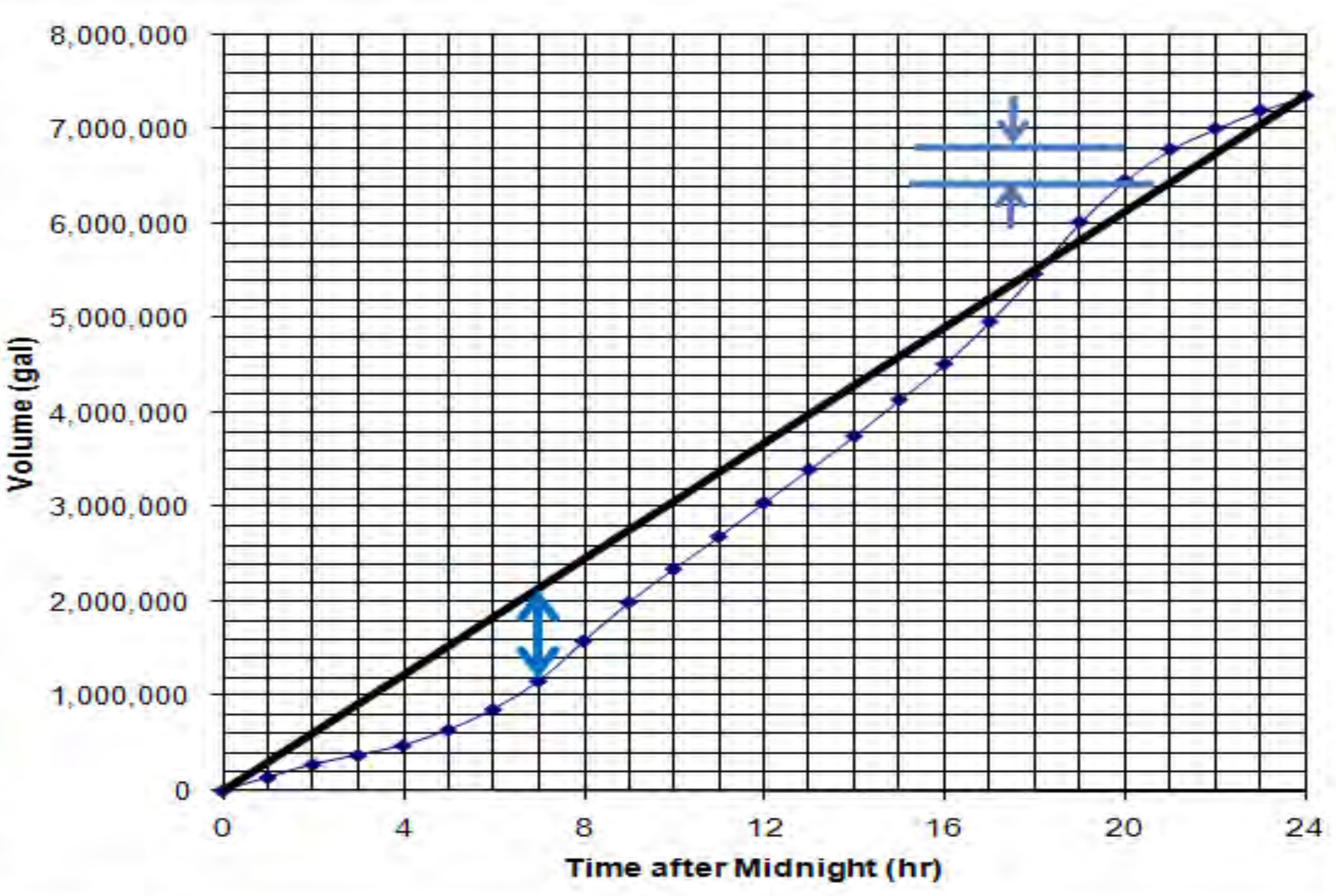
# MASS DIAGRAM (12-HR PUMPING)



Example Service Storage Problem

1. Given: Average hourly demands in the table below.
   Find: Uniform pumping rate (gpm) and required storage (gallons).

| Time (hr) | Time after midnight (hr) | Hourly Demand (gpm) | Cumulative Demand (gal) | Uniform Supply (gal) | Difference (gal) |
|---|---|---|---|---|---|
| 12:00 AM | 0 | 0 | 0 | 0 | 0 |
| 1:00 AM | 1 | 2370 | 142206 | 306627 | 164421 |
| 2:00 AM | 2 | 2252 | 277343 | 613253 | 335910 |
| 3:00 AM | 3 | 1644 | 375983 | 919880 | 543897 |
| 4:00 AM | 4 | 1740 | 480377 | 1226506 | 746129 |
| 5:00 AM | 5 | 2745 | 645106 | 1533133 | 888027 |
| 6:00 AM | 6 | 3644 | 863758 | 1839759 | 976002 |
| 7:00 AM | 7 | 5020 | 1164938 | 2146386 | 981447 |
| 8:00 AM | 8 | 7053 | 1588104 | 2453012 | 864908 |
| 9:00 AM | 9 | 6850 | 1999104 | 2759639 | 760535 |
| 10:00 AM | 10 | 5877 | 2351742 | 3066266 | 714524 |
| 11:00 AM | 11 | 5699 | 2693694 | 3372892 | 679198 |
| 12:00 PM | 12 | 5960 | 3051264 | 3679519 | 628255 |
| 1:00 PM | 13 | 5844 | 3401929 | 3986145 | 584216 |
| 2:00 PM | 14 | 5946 | 3758677 | 4292772 | 534095 |
| 3:00 PM | 15 | 6384 | 4141729 | 4599398 | 457669 |
| 4:00 PM | 16 | 6302 | 4519849 | 4906025 | 386176 |
| 5:00 PM | 17 | 7521 | 4971127 | 5212651 | 241524 |
| 6:00 PM | 18 | 8428 | 5476822 | 5519278 | 42456 |
| 7:00 PM | 19 | 9105 | 6023123 | 5825904 | -197218 |
| 8:00 PM | 20 | 7330 | 6462893 | 6132531 | -330362 |
| 9:00 PM | 21 | 5494 | 6792515 | 6439158 | -353357 |
| 10:00 PM | 22 | 3669 | 7012646 | 6745784 | -266862 |
| 11:00 PM | 23 | 3217 | 7205652 | 7052411 | -153241 |
| 12:00 AM | 24 | 2556 | 7359037 | 7359037 | 0 |




Uniform flow rate = 5110 gpm

Storage volume = 981447 + 353357 = 1334805 gal

2. Given: Same data

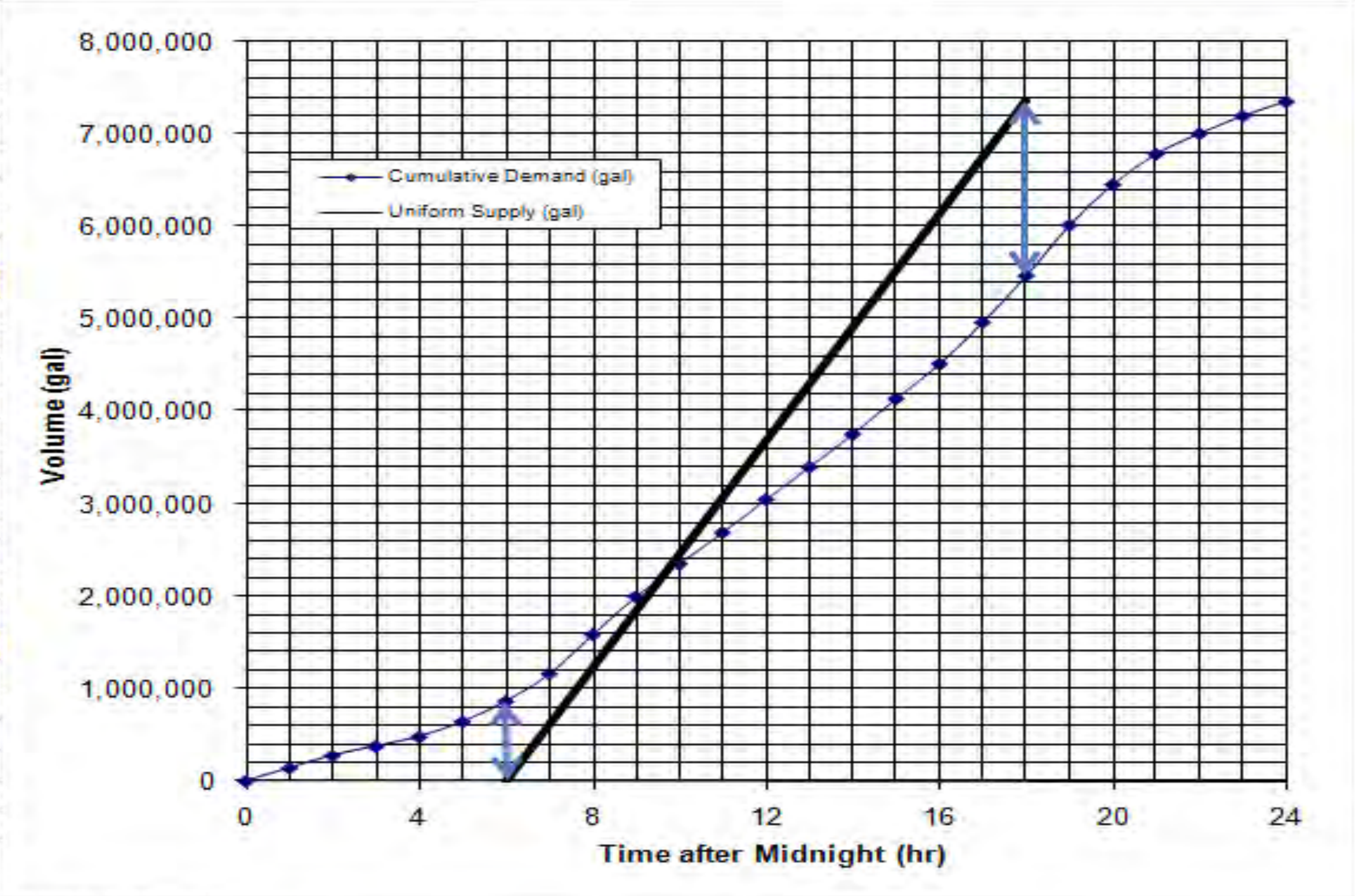
Find: Uniform pumping rate (gpm) and required storage (gallons) for the following:

[a] Pumping from 6 AM to 6 PM only

[b] Pumping from 6 PM to 6 AM only

[a]

| Time (hr) | Time after Midnight (hr) | Hourly Demand (gpm) | Cumulative Demand (gal) | Uniform Supply (gal) | Difference (gal) |
|---|---|---|---|---|---|
| 12:00 AM | 0 | 0 | 0 | | |
| 1:00 AM | 1 | 2370 | 142206 | | |
| 2:00 AM | 2 | 2252 | 277343 | | |
| 3:00 AM | 3 | 1644 | 375983 | | |
| 4:00 AM | 4 | 1740 | 480377 | | |
| 5:00 AM | 5 | 2745 | 645106 | | |
| 6:00 AM | 6 | 3644 | 863758 | 0 | -863758 |
| 7:00 AM | 7 | 5020 | 1164938 | 613253 | -551685 |
| 8:00 AM | 8 | 7053 | 1588104 | 1226506 | -361598 |
| 9:00 AM | 9 | 6850 | 1999104 | 1839759 | -159345 |
| 10:00 AM | 10 | 5877 | 2351742 | 2453012 | 101270 |
| 11:00 AM | 11 | 5699 | 2693694 | 3066266 | 372572 |
| 12:00 PM | 12 | 5960 | 3051264 | 3679519 | 628255 |
| 1:00 PM | 13 | 5844 | 3401929 | 4292772 | 890843 |
| 2:00 PM | 14 | 5946 | 3758677 | 4906025 | 1147348 |
| 3:00 PM | 15 | 6384 | 4141729 | 5519278 | 1377549 |
| 4:00 PM | 16 | 6302 | 4519849 | 6132531 | 1612682 |
| 5:00 PM | 17 | 7521 | 4971127 | 6745784 | 1774657 |
| 6:00 PM | 18 | 8428 | 5476822 | 7359037 | 1882216 |
| 7:00 PM | 19 | 9105 | 6023123 | | |
| 8:00 PM | 20 | 7330 | 6462893 | | |
| 9:00 PM | 21 | 5494 | 6792515 | | |
| 10:00 PM | 22 | 3669 | 7012646 | | |
| 11:00 PM | 23 | 3217 | 7205652 | | |
| 12:00 AM | 24 | 2556 | 7359037 | | |




Uniform flow rate = 10221 gpm in 12 hours

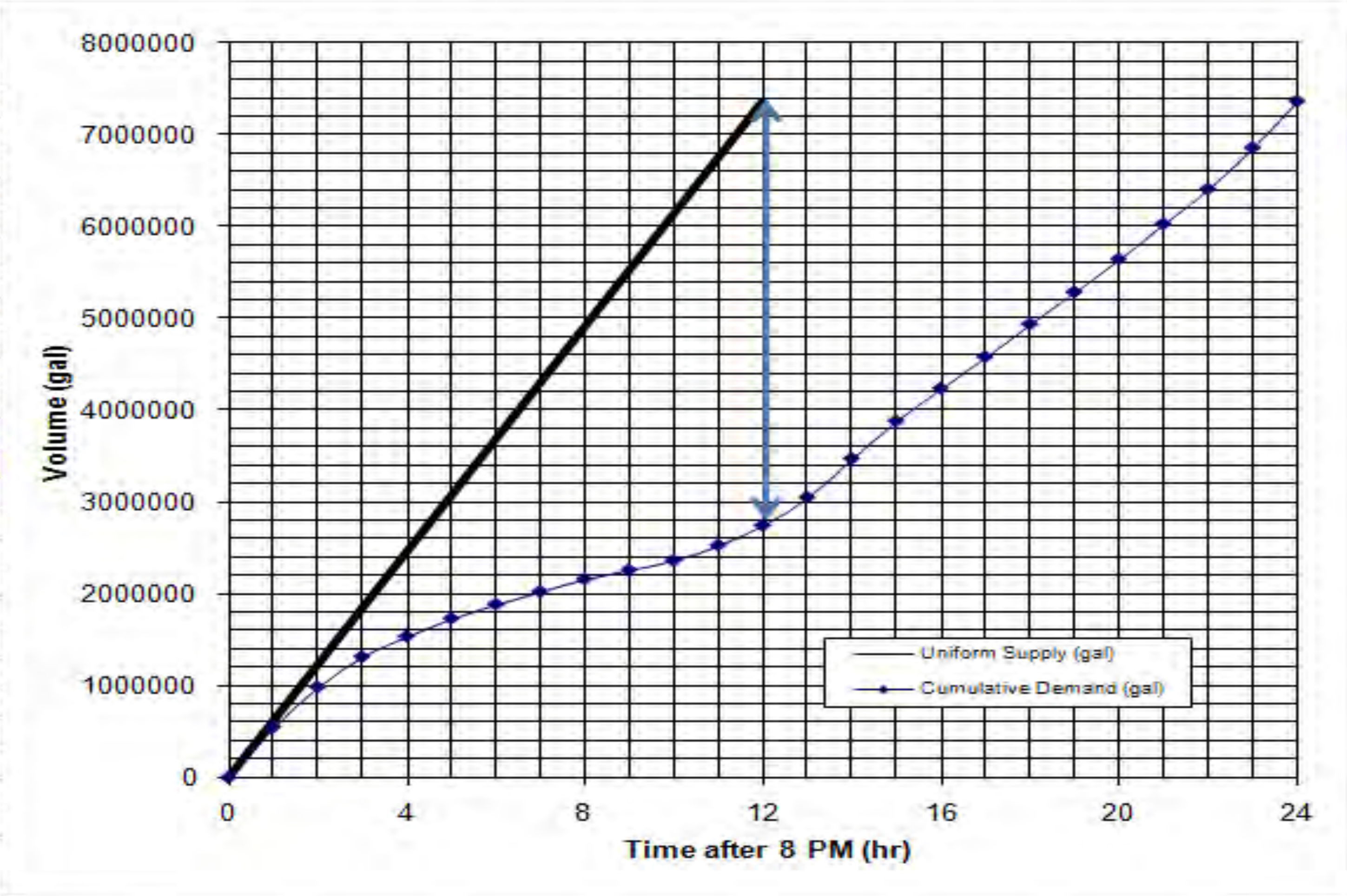
Storage volume = 863758 + 1882216 = 2745973 gal

[b]

| Time (hr) | Time after 6 PM (hr) | Hourly Demand (gpm) | Cumulative Demand (gal) | Uniform Supply (gal) | Difference (gal) |
|---|---|---|---|---|---|
| 6:00 PM | 0 | 0 | 0 | 0 | 0 |
| 7:00 PM | 1 | 9105 | 546301 | 613253 | 66952 |
| 8:00 PM | 2 | 7330 | 986071 | 1226506 | 240435 |
| 9:00 PM | 3 | 5494 | 1315693 | 1839759 | 524066 |
| 10:00 PM | 4 | 3669 | 1535825 | 2453012 | 917188 |
| 11:00 PM | 5 | 3217 | 1728830 | 3066266 | 1337435 |
| 12:00 AM | 6 | 2556 | 1882216 | 3679519 | 1797303 |
| 1:00 AM | 7 | 2370 | 2024422 | 4292772 | 2268350 |
| 2:00 AM | 8 | 2252 | 2159558 | 4906025 | 2746466 |
| 3:00 AM | 9 | 1644 | 2258198 | 5519278 | 3261080 |
| 4:00 AM | 10 | 1740 | 2362592 | 6132531 | 3769939 |
| 5:00 AM | 11 | 2745 | 2527321 | 6745784 | 4218463 |
| 6:00 AM | 12 | 3644 | 2745973 | 7359037 | 4613064 |
| 7:00 AM | 13 | 5020 | 3047154 | | |
| 8:00 AM | 14 | 7053 | 3470320 | | |
| 9:00 AM | 15 | 6850 | 3881320 | | |
| 10:00 AM | 16 | 5877 | 4233958 | | |
| 11:00 AM | 17 | 5699 | 4575910 | | |
| 12:00 PM | 18 | 5960 | 4933480 | | |
| 1:00 PM | 19 | 5844 | 5284145 | | |
| 2:00 PM | 20 | 5946 | 5640893 | | |
| 3:00 PM | 21 | 6384 | 6023945 | | |
| 4:00 PM | 22 | 6302 | 6402065 | | |
| 5:00 PM | 23 | 7521 | 6853343 | | |
| 6:00 PM | 24 | 8428 | 7359037 | | |

Uniform flow rate = 10221 gpm in 12 hours

Storage volume = 4613064 gal



# FLOW EQUALIZATION STORAGE

- Demand pattern from historical data appropriate to the service area.

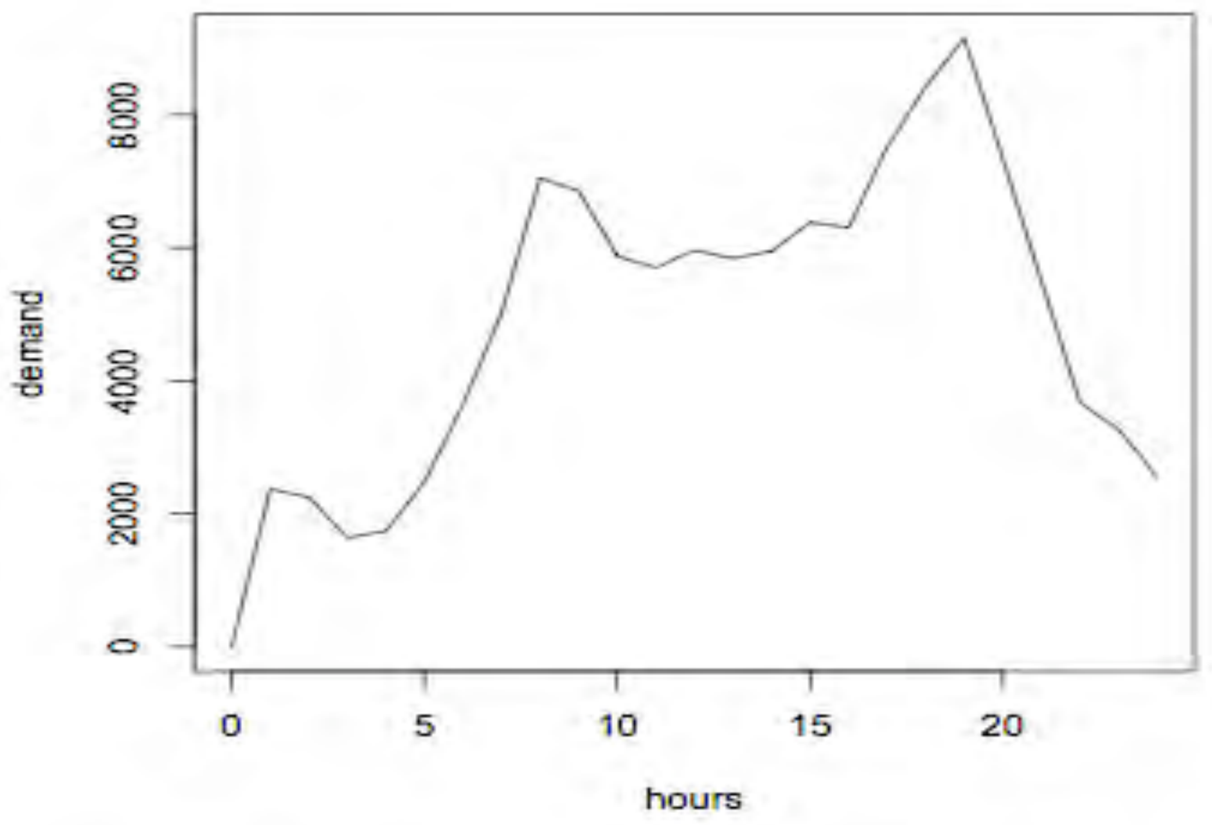


Figure 1: Hourly Demand Pattern for Storage Example

# FLOW EQUALIZATION STORAGE

- Accumulate the demand

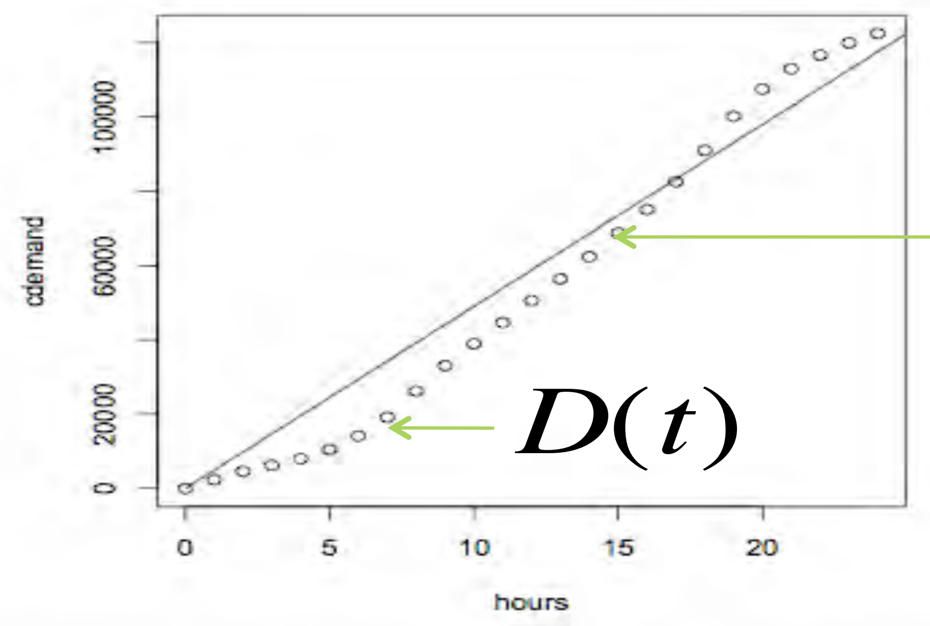



Figure 2: Cumulative Demand Pattern with Constant Supply Rate for Storage Example

$D(t)$

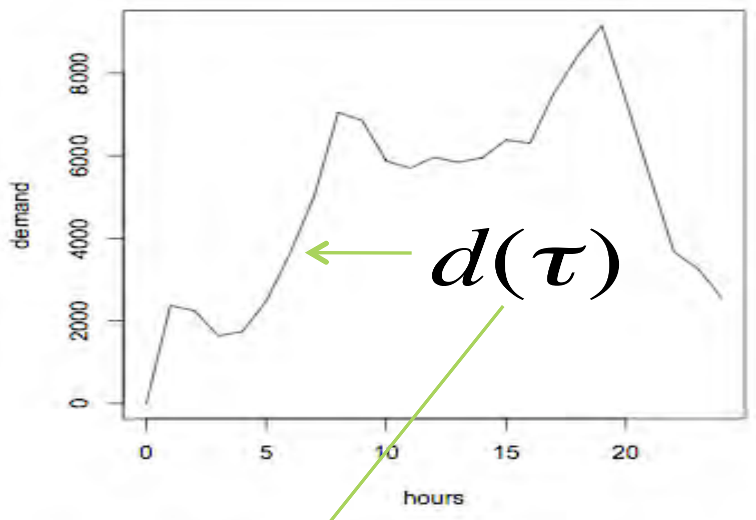



Figure 1: Hourly Demand Pattern for Storage Example

$d(\tau)$

$$D(t) = \int_0^t d(\tau)\,d\tau$$

# FLOW EQUALIZATION STORAGE

- Average constant draft

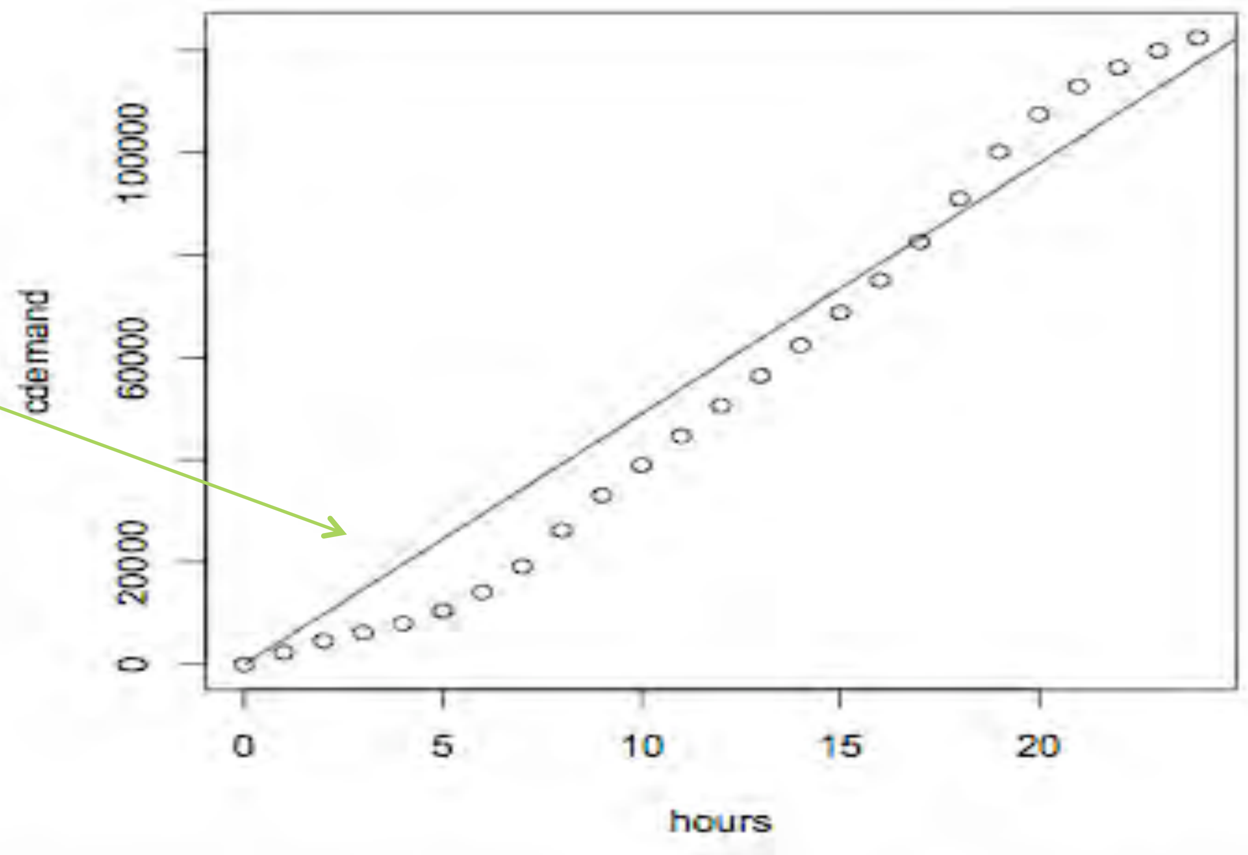



Figure 2: Cumulative Demand Pattern with Constant Supply Rate for Storage Example

# FLOW EQUALIZATION STORAGE

- Sum the 2 largest deviatio
- Storage required V1+V2
- In this chart, about 25000 volume units.

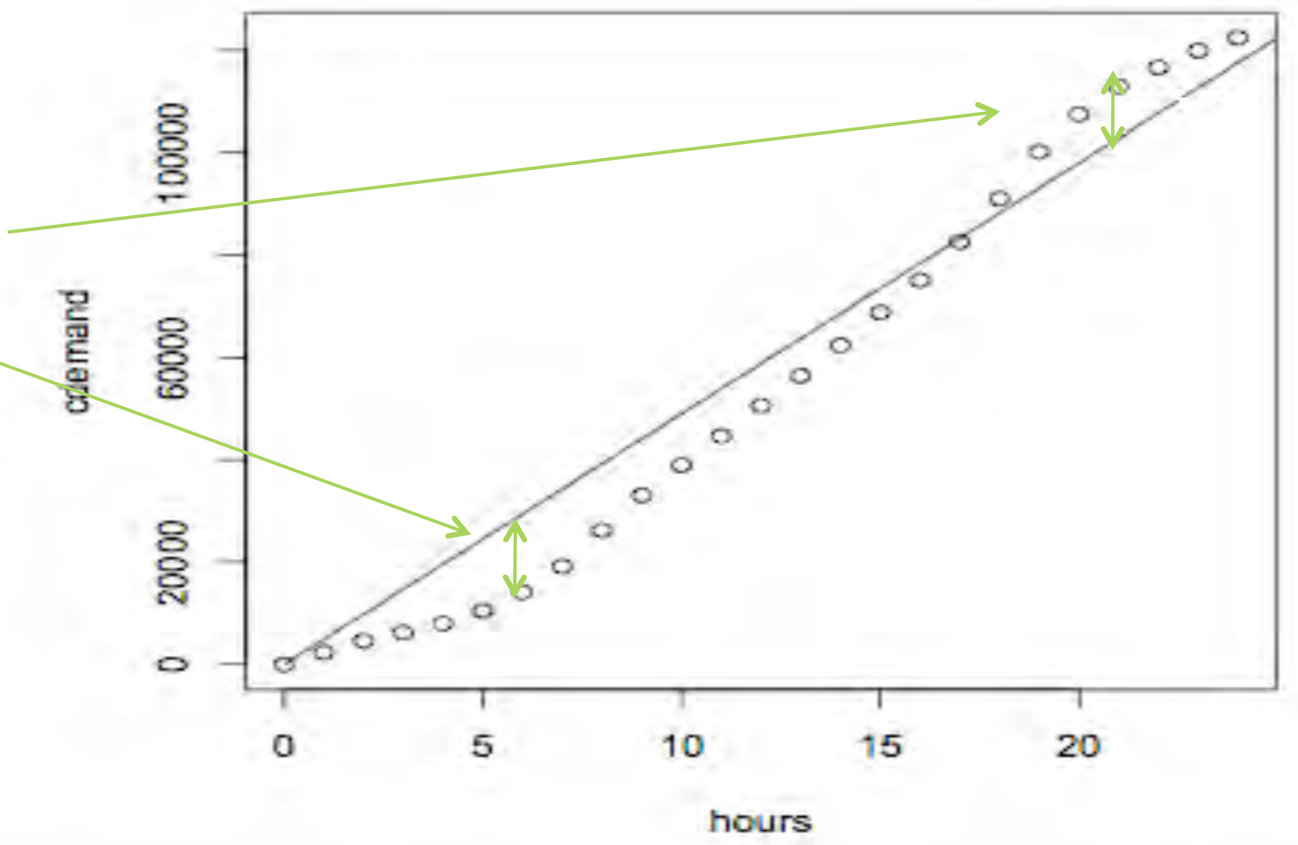



Figure 2: Cumulative Demand Pattern with Constant Supply Rate for Storage Example

# FLOW EQUALIZATION

- The engineer needs to decide which demand to use:
  - Daily
  - Peak
- These volumes are added to that needed for emergency and fire flow.
- Determines the tank volume required
- Tank type (elevated, at-grade, buried) determines shape – elevation, diameter, min-level, max-level.
  - Elevated tanks have substantial structural considerations

# TYPICAL INSTALLATION

**Notice of Public Hearing**
**City of Pharr**
**DWSRF Program Clean Water Tier II Program**
**City of Pharr WTP Expansion Project**

## Date/Time/Place of Hearing

The City of Pharr will hold a public hearing on **Tuesday, January 21, 2014 at 5:00 PM** in the Council Chambers (118 S. Cage Blvd, Pharr, TX 78577) as part of the regularly scheduled City Council Meeting.

The hearing is to discuss the proposed City of Pharr Water Transmission Main and Elevated Storage Tank Project, alternatives to the proposed project, and their associated costs. One purpose of the hearing is to discuss the potential environmental impacts of the project and the alternatives to it.

## Project Description

The City of Pharr (City) is making improvements to the water distribution system to address low pressures in the City's North Region and adding elevated storage to accommodate growth. The improvements include the installation of a water transmission main from the High Service Pump Station (HSPS) to the existing Expressway 83 and LBJ Elevated Storage Tanks. The transmission mains range from 12, 16, to 20-inch and extend approximately 4-miles. A 1-MG elevated storage tank is also being added (Eldora Elevated Storage Tank) at the intersection of Eldora and Dahlia St.

## Project Cost and Estimated Monthly Bill to a Typical Residential Customer

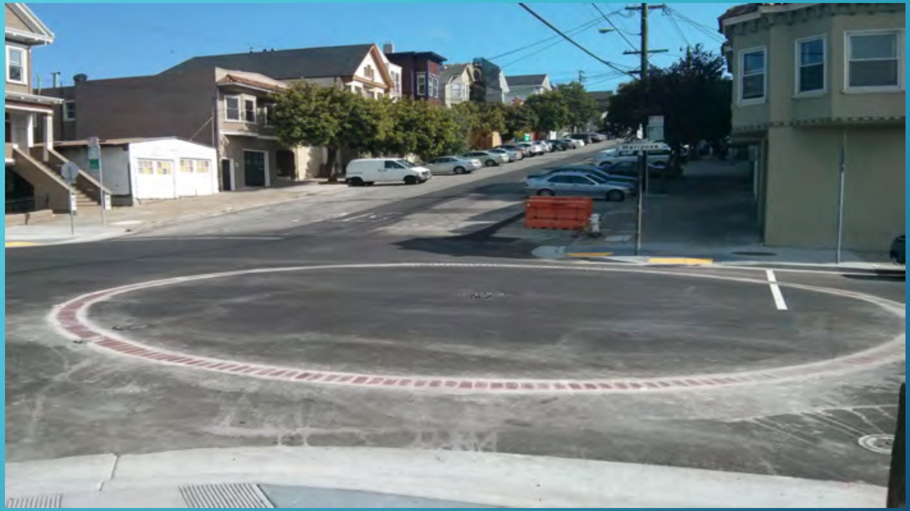
The estimated construction cost of the proposed project is approximately $9.1-Million. The City of Pharr has carefully studied the economic impact of not only this project but

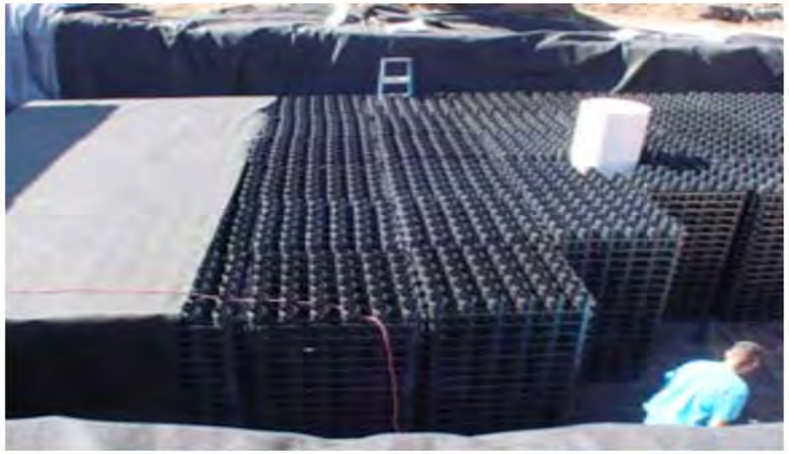
# STORM WATER STORAGE

- Used to mitigate peak flows from development.
- Provide water quality benefit.
- Develop a water resource (rainwater harvesting)

# UNDERGROUND "TANK"

- More than a hole in the ground
  - Needs structure to support surface loads
  - Needs a way to drain completely (usually a pump)





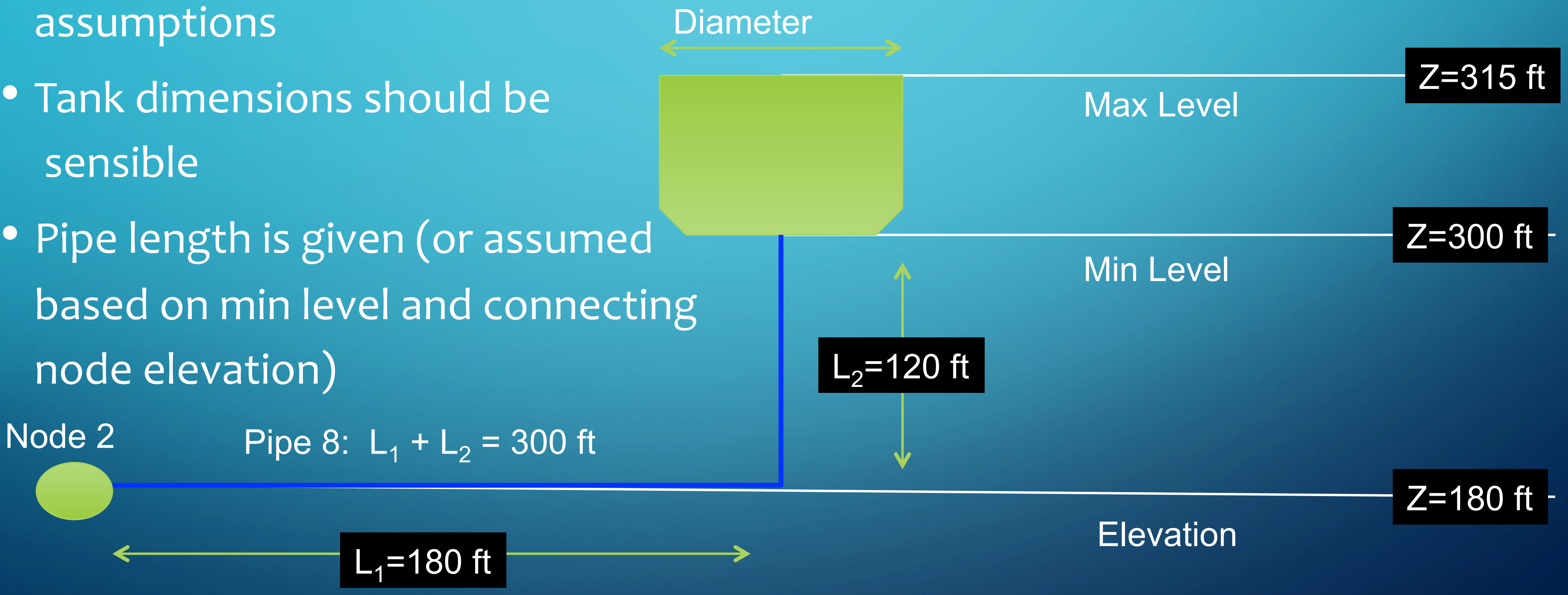
*Rainstore[3] is perfect for water harvesting. two layers of geotextile fabric encase an impermeable liner. A maintenance/access port is shown.*

# STORAGE IN COMPUTER MODELS

- Storage elements in computer models are tanks or reservoirs (EPANET),
  or storage junctions (SWMM)
- Have similar minimal data requirements that include:
  - Invert (bottom) elevation
  - Min Pool elevation (above the invert)
  - Begin Pool elevation (above the invert)
  - Max Pool elevation (above the invert)
  - Tank dimensions (or depth-storage curve)

# TANK DESCRIPTIONS

- Supply reservoir (or tank); identify reservoir pool elevation
  - May need to make configuration assumptions
  - Tank dimensions should be sensible
  - Pipe length is given (or assumed based on min level and connecting node elevation)



# TANK DESCRIPTIONS

- Supply reservoir (or tank); identify reservoir pool elevation
  - Can also use a volume vs. depth table to convey tank storage capabilities -- quite similar to reservoir routing in hydrology