Drinking Water Operator Certification Training

Module 3:
Surface Water Sources

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:
The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
Dering Consulting Group
Penn State Harrisburg Environmental Training Center

Topical Outline

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Unit 1 – Introduction to Surface Water

Learning Objectives

- Define the five components of the Hydrologic Cycle and illustrate them.
- Define Safe Yield and explain why estimating it is important to surface water supply.
- Identify and describe the treatment common to all surface water sources of supply.
- Define when a water allocation permit is required and specify how permits are obtained.

The Hydrologic Cycle is the process of *evaporation* of water into the air and its return to earth by *condensation* and *precipitation* (rain or snow). The process also includes *transpiration* from plants, *infiltration* into the ground and groundwater movement, and *runoff* into rivers, streams, and, ultimately, the ocean.

Precipitation

Precipitation is the way that water returns to the earth from the air. All precipitation comes in the form of rain, snow, sleet, or hail.

- Precipitation amounts vary in the United States. Pennsylvania receives about 45 inches of precipitation per year.
- Factors for consideration in describing precipitation include total amount, intensity, and duration.
- After the initial "flush," precipitation quality is relatively free from pollutants.

Runoff

Runoff is the portion of precipitation that flows over the ground surface, without infiltrating into the ground.

- Runoff drains to rivers or streams, which can discharge into impoundments such as lakes or reservoirs, or to the ocean.
- The amount of runoff varies considerably between wet and dry years. It is dependent on the amount and intensity of precipitation, and the slope and imperviousness of the ground surface.

Infiltration

Infiltration is the portion of precipitation that infiltrates the soil, which replenishes the soil moisture or is used by vegetation.

- Water that infiltrates below the vegetative root zone replenishes groundwater and can maintain streamflow during periods of little or no precipitation.

Evaporation/Transpiration

Evaporation is the process in which water from surface bodies (lakes, reservoirs, streams, rivers, and oceans) and from shallow groundwater is transformed from a liquid into a gas.

- Temperature and humidity are key weather factors that affect the amount of evaporation to the atmosphere.

Transpiration is the process in which soil moisture taken up by growing vegetation is returned to the atmosphere in the form of a gas.

Condensation

Condensation is the process in which water vapor from evaporation and transpiration is initially carried by the winds as clouds.

- As the clouds are chilled, water particles condense into larger droplets.
- When water droplets become large enough, they fall as precipitation over land and water.
- Part of the precipitation that falls is immediately evaporated and returned to the atmosphere.

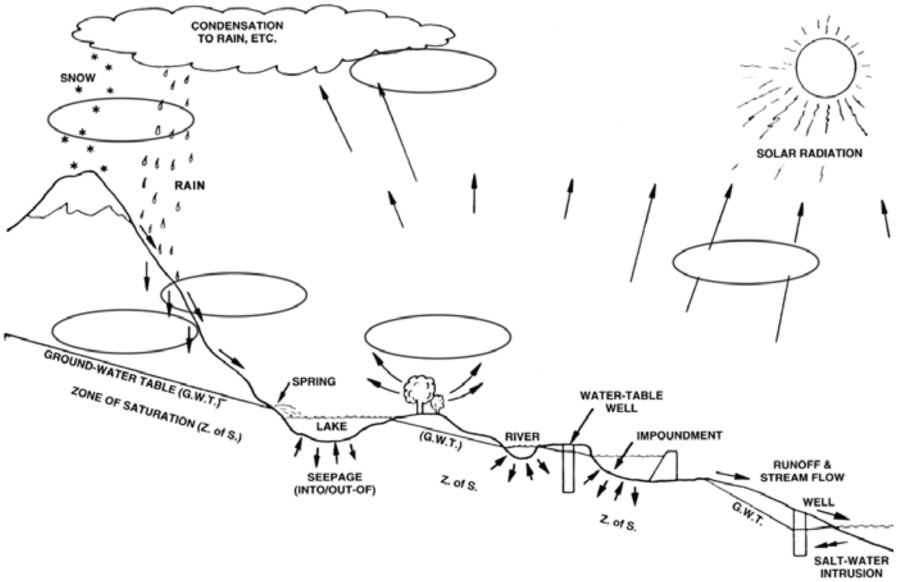


Figure 1.1 Hydrologic Cycle[1]

Surface water sources are defined as all water open to the atmosphere or subject to surface runoff, and are generally classified as a streamflow supply or an impoundment supply. A groundwater supply that exhibits surface water characteristics is also classified as surface water.

Streamflow

Streamflow results from runoff of precipitation that forms rivers and streams.

- Base streamflow can be fed by groundwater discharge.
- Streamflow quantity is generally related to the size of the drainage area of the contributing watershed.

Impoundment

Impoundments (reservoirs or lakes) typically result from a man-made dam constructed in a stream channel. Some lakes can be formed naturally such as Lake Erie.

- Impoundments can retain runoff from high flow periods for use during periods of lower flow.
- The expected yield from an impoundment is considered in the design capacity.

Groundwater Under Direct Influence (GUDI)

Groundwater Under Direct Influence (GUDI), as defined by the 1989 Surface Water Treatment Rule, is water directly influenced by surface water, which may include springs, infiltration galleries, cribs, or wells.

- Groundwater sources near streams or those subject to rapid recharge could be contaminated by pathogenic organisms like bacteria, viruses, or *Giardia Lamblia* cysts and pose a public health threat if not treated as a surface water source.
- GUDI is identified by rapid shifts in water quality characteristics due to precipitation, or by the presence of microscopic particles and organisms indicative of surface water.
- Certain groundwater sources are considered by DEP to be protected from surface water influence. Others are considered questionable because of their depth, geology, location, construction, and/or type, including springs and certain wells.

Questionable wells include those:

- Less than 200 feet from a surface water body or recharge boundary
- In a carbonate aquifer with a static water level less than 100 feet below ground level
- In an unconfined aquifer with a static water level less than 50 feet below ground level
- In a confined aquifer that is located less than 50 feet below ground level

Surface Water Influence Evaluation Plan


Ward Creek near Tahoe City.
Lake Tahoe, CA.

Questionable groundwater sources require special monitoring to determine if the source is influenced by surface water or by precipitation and rapid infiltration.

- A monitoring plan is submitted for approval to DEP by the water system based on source location, design, and construction.

Samples are collected from the source prior to treatment (raw water). Groundwater samples must be collected at production pumping rates and during an operating period.

- Monitoring shall be conducted for 6 months and include a high flow period (April-June or October-December) and a low flow period (July-September).
- Monitoring results must be submitted to DEP monthly.

Required sample analyses and measurements include:

- Daily turbidity, pH, specific conductance (or total dissolved solids), and temperature
- Daily flow and/or water level (static or pumping, but consistently one or the other)
- Weekly total coliform and, if positive, fecal coliform
- Daily precipitation
- Daily local surface water conditions (river or stream stage or flow)

If the monitoring results indicate a relationship between groundwater quality and surface water conditions, DEP will require a microscopic particulate evaluation to check for the presence of:

- Insects
- Microorganisms
- Algae
- Organic debris
- Large-diameter pathogens

If the microscopic particulate analyses indicate surface water characteristics, the source is considered to be surface water influenced, and treatment requirements of a surface water source will be applicable, unless deficiencies resulting in the surface water contamination are corrected or the source is abandoned.

There are five (5) common factors to all surface water sources: quantity/volume, safe yield, quality/treatment, required hydraulic and treatment facilities, and source protection.

Quantity/Volume

Quantity/Volume is to how much water is available for use as a source of supply.

- In determining the withdrawal amount that will be permitted, DEP will evaluate the amount of supply available from a source under all conditions, including "dry" periods.

The quantity of water at the source shall:

- Be adequate to meet the projected water demand
- Provide a reasonable surplus for anticipated growth
- Be adequate to compensate for all losses, such as silting, evaporation, and seepage
- Be adequate to provide ample water for other legal users of the source

Safe Yield

Safe Yield is the quantity of water that can be taken from a source of supply at a constant rate for a period of years without depleting the source permanently, i.e., beyond its ability to be replenished naturally in "wet years."

- Sufficient supply is considered to be available if the lowest flow or yield exceeds the maximum demand of all uses.

Safe yield is determined differently for rivers and streams (natural flow or regulated), reservoirs, and groundwater sources.

- For streams and rivers**,** statistical analysis of streamflow data is used to estimate safe yield.
- For lakes and reservoirs, computer models can be developed that consider inflow, precipitation, evaporation, and storage volume in estimating safe yield.
- For groundwater wells**,** pumping tests are used to estimate the aquifer yield under drought conditions.

Quality/Treatment

The potential for contamination of a surface water source of supply makes it necessary to regard such sources as unsafe for drinking unless properly treated. Agents that alter the quality of water may be classified as:

- Physical
- Chemical
- Biological
- Radiological

A sanitary survey is performed to determine whether there are any contaminants that do or could pose a health hazard. Components of a sanitary survey are:

- Collection of raw water samples to assess raw water characteristics
- Determination of future water uses and effects of impoundments or reservoirs
- Determination of the control over the watershed that can be exercised by the owner
- Assessment of the vulnerability of the supply to accidental or deliberate contamination

A number of factors must be considered to determine which filtration and disinfection technology is most appropriate for a surface water source.

Water quality analyses of source water are required to determine additional treatment needs.

Required Hydraulic & Treatment Facilities

All surface water sources require continuous filtration and disinfection. Actual or potential contamination determines the type of treatment processes used in the treatment plant, in addition to filtration and disinfection.

If sufficient hydraulic head is not available to deliver water to the treatment plant by gravity, water from a stream or reservoir source will need to be pumped.

Well pumps deliver groundwater under the direct influence of surface water from the aquifer to the treatment plant.

Source Protection

The Source Water Assessment and Protection (SWAP) Program is mandated by the 1996 Safe Drinking Water Act to assess drinking water sources serving public water systems for susceptibility to pollution.

- Initial assessments in Pennsylvania are performed by the Pennsylvania Department of Environmental Protection (DEP) staff or through DEP-contracted services.
- Assessments are enhanced by sanitary surveys conducted by the water supplier and DEP.
- A primary goal of the SWAP Program is to support the development of local, voluntary source water protection programs.

A more in depth look at the DEP SWAP program is included in the Appendix.

It is more cost effective to protect raw water quality at the source than it is to treat contaminated water at a treatment plant.

Pennsylvania Department of Environmental Protection (DEP)

Allocation permits are required by DEP for using surface water sources and are issued for up to 25 years.

- Allocation permits within the Delaware and Susquehanna River basins are issued by DEP in conjunction with the respective river basin commission.

The allocation requested from DEP should be related to present and future (20-30 years) water demands.

Approved allocation allowances vary as follows:

- For stream intakes or small reservoirs, the allocation permit usually grants a maximum per day allocation
- For large reservoirs, the allocation permit is usually based on a 30-day average, with a maximum per day limitation

Delaware River Basin Commission (DRBC)

DRBC approval is required for:

- Any project that may have a substantial impact on the water resources of the Delaware River Basin.
- New impoundments with a storage capacity of 100 million gallons or more
- A groundwater withdrawal averaging 100,000 gallons per day or more based on a 30 consecutive day period
- A surface water withdrawal averaging 100,000 gallons per day or more based on a 30 consecutive day period

All project applications submitted to DRBC require the following descriptions of:

- Water-conserving practices and technology designed to minimize water use
- Source metering and service metering programs used by the water supplier
- Leak detection and repair program used by the water supplier

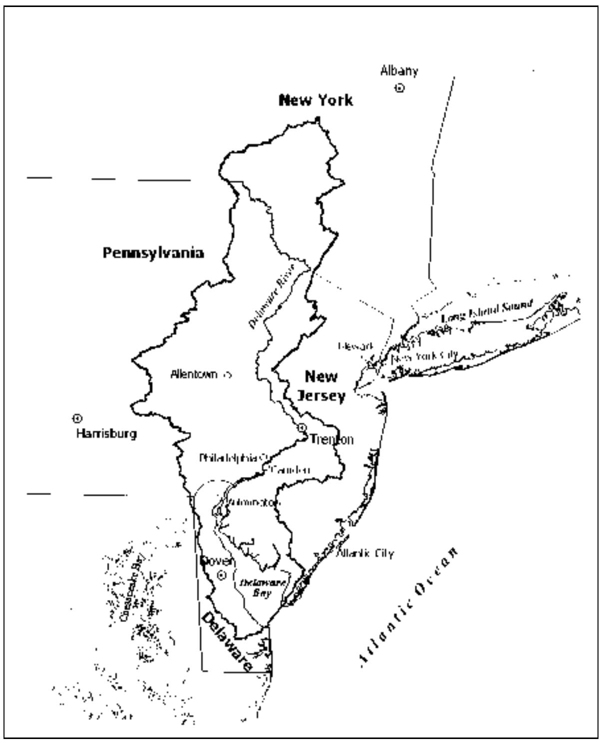


Figure 1.2 Delaware River Basin[2]

Susquehanna River Basin Commission (SRBC)

SRBC approval is required for projects:

- On or crossing the boundary between two signatory states
- Involving the diversion of water
- Resulting in consumptive use of water exceeding 20,000 gallons per day for any 30 consecutive day period
- Withdrawing in excess of 100,000 gallons per day for any 30 consecutive day period
- Already included in the SRBC Comprehensive Plan

All project applications submitted to SRBC require a description of the water supply system's plans to avoid consumptive use during low flow periods or provide compensation for such use.

SRBC allocation approval requires the water supplier to:

- Reduce distribution system losses to less than 20% of the withdrawal
- Install meters for all users
- Establish a water conservation program

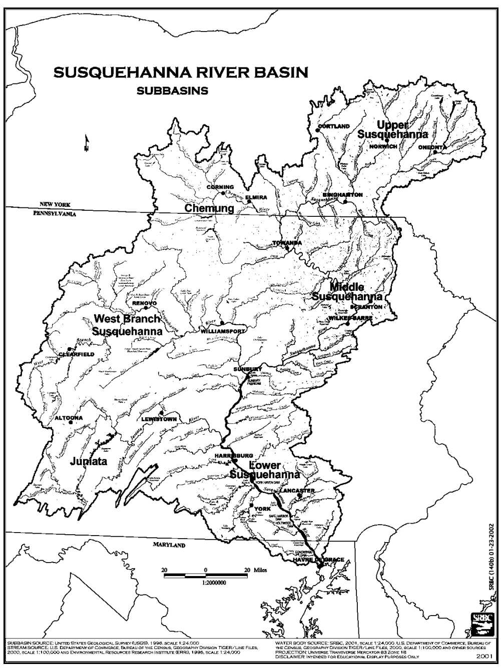


Figure 1.3 Susquehanna River Basin[3]

Key Points

Five components of the Hydrologic cycle are:

- Precipitation
- Infiltration
- Evaporation/ Transpiration
- Condensation
- Run Off

The three types of surface water are:

- Stream flow
- Groundwater under the direct influence of surface water
- Impoundments

Common factors in a surface water source include

- Quantity/Volume
- Safe Yield
- Quality/Treatment
- Required hydraulic and treatment facilities
- Source Protection

[1] California State University, Sacramento, Department of Civil Engineering, *Water Treatment Plant Operation, 4th ed., Volume I,* (Sacramento, CA: California State University, Sacramento Foundation, 2002), pp. 25 modified.

[2] Delaware River Basin Commission website. www.state.nj.us/drbc/drbc4.htm (June 3, 2003)

[3] Susquehanna River Basin Commission website. www.srbc.net/subbasin.htm (June 3, 2003)

Additional Resources Used

California State University, Sacramento, Department of Civil Engineering, *Water Treatment Plant Operation, 4th ed., Volume I, (*Sacramento, CA: California State University, Sacramento Foundation, 2002), Chapter 2.

Ray K. Linsley, Max A. Kohler, Joseph L.H. Paulhas, *Hydrology for Engineers, 2nd ed.*, (New York, NY: McGraw-Hill, 1975), Chapter 1.

Commonwealth of Pennsylvania, Department of Environmental Protection, *Fact Sheet: Surface Water Identification for Groundwater Sources, Community Water System*, 3800-FS-DEP2243, (August 2002).

Commonwealth of Pennsylvania, Department of Environmental Resources, Bureau of Water Supply & Community Health, Division of Drinking Water Management, "Community System Design Standards", *Public Water Supply Manual, Part II,* 383-2125-1081, (January 1, 1995), Chapter 2 and Chapter 3, Sections 3.2 and 3.3.

Commonwealth of Pennsylvania, DEP, *Fact Sheet: Pennsylvania's Source Water Assessment and Protection (SWAP) Program,* 3900-FS-DEP2417, (September 2001).

Commonwealth of Pennsylvania, Department of Environmental Protection, *Water Allocation Application and Instructions,* 3900-PM-WM0001, (Revised September 2001).

Delaware River Basin Commission, "Rules of Practice and Procedure," *DRBC Administrative Manual,* (Revised to include Amendments through May 31, 2002).

Susquehanna River Basin Commission, "Review and Approval of Projects," *SRBC Policies, Guidances Regulations and Planning, Omnibus Package of Regulatory Revisions, Part 803,* (Adopted May 11, 1995).

Unit 2 – Considerations for Use of Surface Water as a Source of Supply

Learning Objectives

- Name and describe three types of surface water supply.
- Estimate safe yield for the three types of surface water supply.
- Describe the facilities that could be associated with each type of surface water supply.
- Describe some common water quality problems associated with each type of surface water supply.

Streamflow (Quantity)

Streamflow quantity, expressed as "Q", must be adequate to meet the demands of all users in all conditions.

- Flow is recorded using a specific notation: $Q_{(\text{Consecutive-Day Average, Year Recurrence})}$.

In Pennsylvania, the most significant factor affecting streamflow quantity is the drainage area, which is the land surface area from which runoff drains to rivers or streams.

Deleted:

- Other contributing factors include geography, soil type, land use, and topography.

The United States Geological Survey (USGS) collects streamflow quantity data on many Pennsylvania streams.

Safe Yield

Safe yield, for a river or stream, is the minimum quantity of streamflow that can be expected to be available for water supply after accounting for other uses (e.g., boating, fishing, etc.).

- For an unregulated (natural flow) stream, it is desirable for the minimum consecutive 7-day average low flow having a 50-year recurrence interval (frequency), written as $Q_{7,\,50}$, to exceed the estimated maximum day water demand.
- Flow augmentation requirements, diversions, and instream flow needs must be accounted for consistent with minimum flow criteria.
- Where a specific low flow passby is required, the natural flow must be allowed to pass a water supply intake when the flow is less than the specified discharge. Passby flow is typically set at the 7-day, 10-year flow ($Q_{7,10}$).

Estimates of low-flow statistics are available for many Pennsylvania streams from DEP or USGS publications.

Quality & Treatment

In using a river or stream as a source of supply, upstream conditions and land use must be considered. Water quality could be affected by:

- Treated wastewater that has been discharged into a stream or river.
- Precipitation; for example, water quality can be degraded by increased turbidity from erosion, increased nitrates from agricultural runoff, or increased coliform levels from combined sewer overflow discharges.
- Upstream industry dumping of undesirable or harmful wastes into the river or stream.

Because of upstream pollution (wastewater, agricultural drainage, or industrial wastes), the proper identification and treatment of river and stream supplies is very important.

A comprehensive source water assessment (sanitary survey) should be conducted of the watershed to identify potential contaminant sources.

- Processes required to address existing or potential pollutants, in addition to filtration and disinfection, need to be considered in source of supply selection involving a river or stream.

Facilities

A raw water intake is required to withdraw water from a river or stream prior to transport to the treatment /filtration plant.

- The intake can be in the form of a pipe or culvert that diverts water directly from a stream or through an infiltration gallery in the streambed.
- Rivers and streams are susceptible to scouring of the channel bottom, channel changing, and siltration. Careful study of these conditions is required during design of the intake facility. Provisions must be made to withstand flood forces, ice conditions, heavy silting or scour, and other adverse conditions.
- Raw water pumping may be required to "lift" the water to the treatment plant. Adequate hydraulic head must be available to enable the water to move through the process equipment and associated piping as it passes through the treatment plant.
- Construction and annual operation and maintenance costs of facilities associated with a specific river or stream source also need to be considered in selecting facility locations.

Figure 2.1 Intake Facility

Capacity (Volume)

The volume of a lake or reservoir is dependent on the water level (elevation) and topography (ground surface) upstream from the dam.

- A lake or reservoir is also dependent on the river(s) or stream(s) flowing into it for replenishment and the upstream watershed drainage area.

A water level-capacity curve is used to determine the capacity of a lake or reservoir.

- For the existing lakes or reservoirs, a water level-capacity curve should already be available for use from design calculations.
- For proposed lake or reservoir sources, a water level-capacity curve should be developed during the project planning phase to ensure that sufficient storage capacity is available to meet the needs of all users.

Zorinsky Lake/Reservoir for Papio Dam #18. One of four dams on the Papio Creek protecting the Omaha metropolitian area. Omaha, Nebraska.

Safe Yield

The gross yield of impounding reservoirs should be based on a 50-year drought having a duration that is critical for the amount of active storage provided in the reservoir. The critical duration is that period of time from initial drawdown until active storage is depleted using a uniform withdrawal rate.

- If the required yield from a reservoir to meet water supply and other uses is known, the required volume (capacity) of a proposed reservoir can be estimated.
- Inflow, outflow, and evaporation must all be accounted for in determining reservoir yield.

Gross and net yields for water supply reservoirs can be estimated from DEP Water Resources Bulletin No. 7.

Conservation release rates for impoundments are dependent on the low-flow characteristics of the inflow stream, the proposed water supply withdrawal, and the size (capacity) of the reservoir relative to the size (drainage area) of the stream.

- The conservation release rate is typically set by DEP in consultation with the Pennsylvania Fish and Boat Commission (PFBC).

Detailed hydraulic models can be developed and applied to estimate the safe yield of a reservoir for water supply, considering system operational procedures, low flow release requirements, and long-term streamflow and evaporation data. Various "what if" scenarios can be tested using the model.

Quality & Treatment

The water quality of a reservoir source is directly related to the upstream land use in the watershed, and changes less rapidly than streamflow sources. Quality considerations include:

- Contaminants discharged into lakes, reservoirs, or their tributaries can be diluted due to the volume of water in the reservoir.
- Water quality near the bottom of a reservoir is typically of poor quality. This can be a problem when the reservoir "turns over" on a seasonal basis.
- Lakes and reservoirs are susceptible to algal blooms, especially after fall or spring turnovers. Algae can cause significant taste and odor problems in a source of supply.

Treatment can be enhanced through reservoir intake towers that typically have multiple intake ports at various levels or depths. This enables the delivery of raw water from the level with the best water quality.

Facilities

When demands cannot be met directly from surface water diversions from a river or stream, a dam is constructed to form an impoundment. An impoundment can provide carryover storage of excess runoff and a dependable water supply during periods of prolonged drought.

Intake structures and associated piping are used to withdraw water from the reservoir and deliver it to the water treatment plant. They may also be used to release a conservation flow to downstream rivers or streams if required by regulatory agencies. Depending on system hydraulics, a raw water pumping station may be required to deliver water to the water treatment plant.

- Single-level intake systems are most suitable in relatively shallow lakes or reservoirs that do not stratify significantly and that have fairly uniform water quality from the top to bottom throughout the year.

- Multi-level intakes, like that shown in Figure 2.3, are most suitable in deeper lakes or reservoirs. This type of intake system is commonly a vertical tower located in the deeper portion of the reservoir, extending above the water surface with intakes located at various levels equipped with individual gates/valves to allow for withdrawal of water from the depth with the best quality.

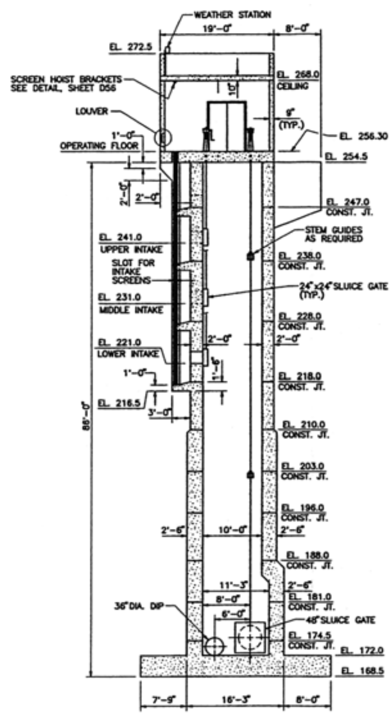


Figure 2.3 Multi-level Intake Facility

Proper dam design and construction are critical to ensure the safety of the downstream area. Well-designed operation and maintenance programs are essential to the performance of dams, intake structures, and related facilities.

- Dams should be inspected on at least an annual basis and after significant rainfall events to avoid catastrophic disaster.
- Dam maintenance should include removal of vegetation, filling of animal burrows, and replenishment of protective rip-rap (rock shell), especially at the water line.

Gavins Point Dam Spillway. View of spillway 29,000 CFS Release. Missouri River. Yankton, SD.

Groundwater Availability

Groundwater wells are typically located in areas identified by geologists as having favorable characteristics for development of a supply with sufficient yield.

- The quantity of groundwater supply depends on the underlying geologic formation.

Wells exhibiting surface water characteristics are called GUDI wells.

- Most shallow wells have the potential to be identified as GUDI wells because water levels in them are close to the ground surface.
- Wells finished in carbonate formations are capable of producing high yields, but are susceptible to surface contamination owing to the solubility of the rock.
- Wells in alluvium near a stream or river are typically connected hydraulically to the stream or river, and thus, are GUDI wells.

Safe Yield

After a well is drilled and developed, a pump test is required to determine the yield of the well. The test length is a minimum of 48 hours.

- During the pump test, water levels in the pumping well and nearby observation wells are monitored. From the data collected, estimates can be made of the available yield.
- DEP or other regulatory agency permits/allocations may reduce the approved withdrawal rate from the pump rate during the pump test to allow for drought conditions.
- The DEP permitted withdrawal rate, which may be 50% to 100% of the pump test rate, should be considered the safe yield for a GUDI well.

Quality & Treatment

As a surface water source, GUDI well water must be filtered and disinfected.

GUDI well water may contain other contaminants that will require additional treatment.

- GUDI wells constructed in carbonate aquifers may yield water with high hardness, which may require softening treatment.
- GUDI wells constructed in certain other formations yield water with high iron or manganese, which may require that it be sequestered, or oxidized and filtered.
- Well water may also contain Volatile Organic Chemicals (VOCs), Synthetic Organic Chemicals (SOCs), pesticides and herbicides, or radionuclides, all of which require special treatment, if the concentrations of the contaminants are above identified limits.

Facilities

GUDI wells construction is similar to "groundwater" well construction and must comply with DEP requirements. The depth and size is dependent on the geologic formation and the expected yield.

Filtration and disinfection are provided to the well water within the treatment facility. Additional treatment that is required will determine how the well water is pumped.

- A single pumping process uses the well pump to transmit water from the well through the treatment process and into the distribution system.
- A double pumping process uses the well pump to transmit the water through the treatment process, ending in a clearwell. From the clearwell, high service pumps pump treated water to the distribution system.

Key Points

Characteristics of Streams include:

- Stream flow quantity must be adequate to meet the demands of all users
- Safe yield is the minimum quantity of stream flow that can be expected to be available for water supply after accounting for other uses.
- Upstream conditions and land use must be considered when using a river or stream; streams are subject to rapid changes in quality.

Characteristics of a lake or reservoir

- The volume of a lake or reservoir is dependent on the water level and topography upstream from the dam.
- The gross yield of impounding reservoirs should be based on a 50-year drought
- The water quality of a reservoir is directly related to the upstream land use in the watershed, and changes less rapidly than stream flow sources.

Wells exhibiting surface water characteristics are defined as Groundwater under the direct influence of surface water (GUDI) and are regulated as a surface water source.

Characteristics of GUDI sources

- The quantity of groundwater supply depends on the underlying geologic formation.
- Safe yield for a GUDI well is determined by a pump test.
- As a surface water source, GUID well water must be filtered and disinfected.
- GUDI well construction is similar to groundwater well construction, and must comply with DEP standards.

Additional Resources Used

California State University, Sacramento, Department of Civil Engineering, *Water Treatment Plant Operation,* Volume 1, 4th ed., (Sacramento, CA: California State University, Sacramento Foundation, 1999), Chapters 2 and 3.

Commonwealth of Pennsylvania, Department of Environmental Protection, *Water Allocation Application and Instructions,* 3900-PM-WM0001, (Revised September 2001).

Unit 3 – Data Availability, Collection, and Analysis

Learning Objectives

- Name two agency sources of existing data for use in surface water supply analysis.
- Develop a rating curve to estimate streamflow.
- Develop a capacity curve to estimate the volume of a reservoir.
- Estimate the flow frequency of an ungaged stream location using U. S. Geological Survey (USGS) data.

Streamflow

Whenever possible, use streamflow data available from the U.S. Geological Survey (USGS), Water Resources Division to estimate flow characteristics at the withdrawal point. USGS maintains a network of streamflow gaging stations throughout Pennsylvania and some provide real-time data.

- The USGS records gage height (stage) data and uses a stage-discharge relationship developed from actual flow measurements to estimate daily streamflow. These records form the database from which flow statistical analysis is performed.
- If an intake is to be located on an ungaged stream or river, a reference gaging station must be identified that is of similar size, geologic, and climatic characteristics.
- Historic and current data for many USGS gaging stations in Pennsylvania are available from the USGS website, htttp://pa.water.usgs.gov/.

DEP's Water Resources Bulletin No. 12 (Low Flow Characteristics of Pennsylvania Streams) can also be used to obtain flow data, although this data is not always the most current.

Actual flow data may be collected at the site to supplement the use of a USGS reference gaging station. Flow data collected using a current meter, weir, or flume should include the date of measurement, weather conditions, and flow calculations.

Reservoir

Water level-capacity curves that relate water level to storage capacity at that level can be used to monitor the change in contents of a reservoir on a daily, weekly or monthly basis.

- The USGS maintains gages on a limited number of reservoirs in Pennsylvania to monitor water level.
- DEP has developed yield-storage-frequency relationships for 143 Pennsylvania streams, which are provided in Water Resources Bulletin No. 7 (Long Duration Low Flow of Pennsylvania Streams).
- Conservation release rates from impoundments will be required, and will be dependent on the low-flow characteristics of the stream, the proposed withdrawal amount, and the magnitude of the reservoir relative to the size of the stream.

Groundwater Under Direct Influence (GUDI)

Data for individual wells is obtained during extended 48-hour or longer pump tests. In order to determine potential yield from a well, pumping rate and corresponding drawdown (in feet below static level) are measured during the pump tests. Static water levels are measured on a weekly or monthly basis to determine long-term trends or to monitor the effects of hydrologic conditions.

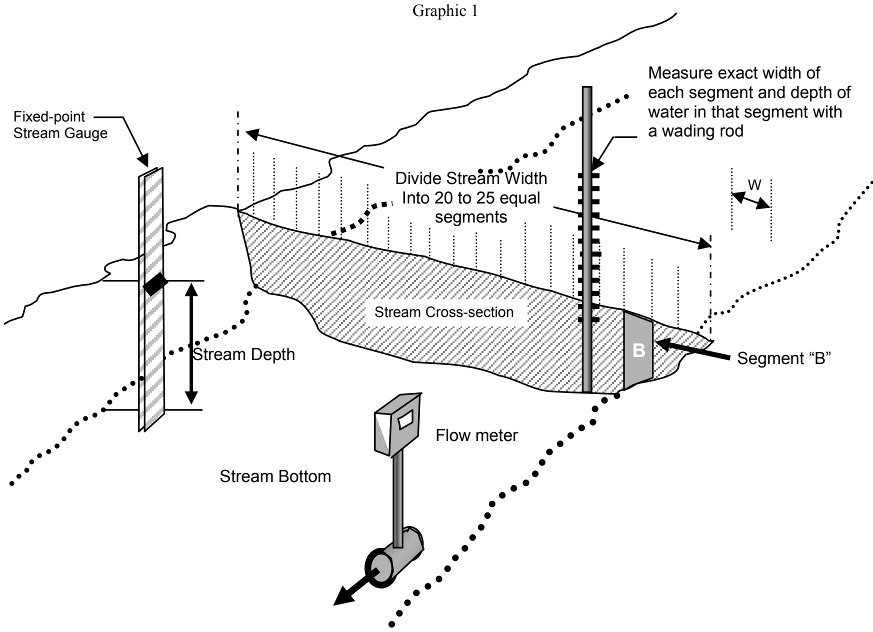
- The USGS maintains a limited number of groundwater monitoring wells throughout Pennsylvania at which water level is measured and recorded.
- Long-term records at such sites can be used to generally describe current hydrologic or groundwater level conditions.

Streamflow Measurement

The streamflow or discharge (sometimes expressed as "Q") of a river or a stream is most often measured using current-meter methodology. In order to make a current-meter measurement, the width of a river or stream is divided into subsections within which the area and velocity are measured and multiplied together to yield the flow for that subsection. The flow in all subsections is then added together to determine the flow for the entire river or stream.

- Streamflow measurements should be made over the full range of gage heights (wet and dry seasons).

Graphic 1



Listed below are the steps that should be taken to measure gage height and streamflow.

- Gage height should always be measured from a relative fixed point. The fixed point can be set arbitrarily; however, it is critical to always use the same fixed point when measuring gage height.
- Measure the stream width with a measuring tape. Divide the width into twenty (20) to twenty-five (25) relatively equal subsections.
- Within each subsection, use the measuring tape to determine width.
- Within each subsection, use a wading rod to measure depth.
- Subsection area is the product of width times depth.
- Use a current meter to measure velocity.

- To calculate the subsection flow, use this calculation:

  Subsection Flow in CFS = (Subsection Width x Subsection Depth) x Subsection Velocity

  = Subsection Area x Subsection Velocity

  Example: The subsection width is 1 foot.
  The subsection depth is 2.5 feet.
  The subsection area is 2.5 feet^2.
  The subsection velocity is 4 feet per second.
  Subsection Flow (CFS) = (1.0 Ft x 2.5 Ft) x 4 Ft/sec
  Subsection Flow (CFS) = 2.5 Ft^2 x 4 Ft/sec
  Subsection Flow = 10 CFS

- To calculate the entire streamflow, flow is calculated for each subsection and then all subsection flow measurements are added together to yield the total discharge in cubic feet per second.

Perform this calculation: The subsection width is 1.5 feet.
The subsection depth is 3 feet.
The subsection velocity is 2 feet per second.
What is the subsection flow?

Gage height and streamflow measurements made over time can be plotted on graph paper and used to develop a Streamflow Rating Curve that can be used to estimate streamflow at any gage height. Streamflow is plotted on the X-axis and gage height is plotted on the Y-axis. Points are plotted for each streamflow measurement, and a curve drawn to develop the Rating Curve for that stream location. The Rating Curve can then be used to estimate flow at that location for any gage height.

As a class, plot the measurement points provided in the table below on the graph paper provided in Figure 3.1. Draw a "best-fit" straight line based on the points. This is a Streamflow Rating Curve.

Table 3.1

Measurement #	Gage Height (Ft)	Streamflow (CFS)
#1	3.23	2.22
#2	3.20	1.87
#3	3.13	1.33
#4	3.28	2.60
#5	3.14	1.42
#6	3.32	3.03

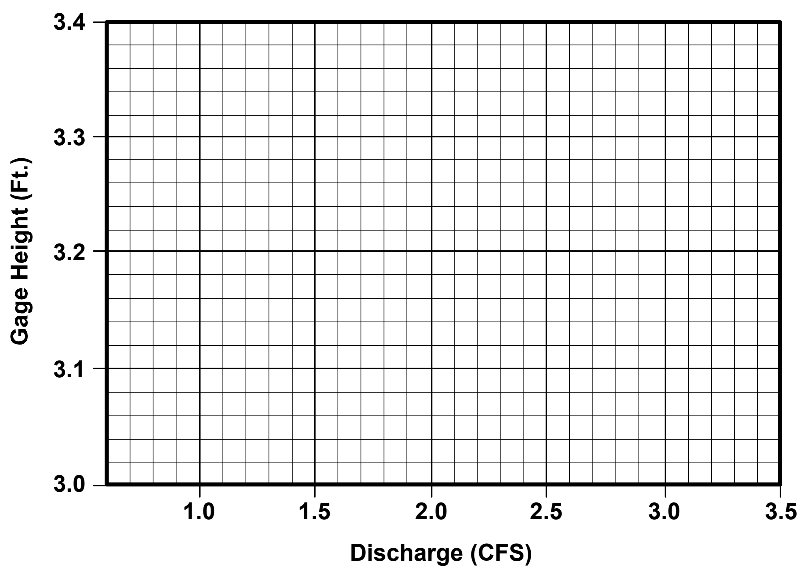


Figure 3.1 Graph Paper for Streamflow Rating Curve

Use the Streamflow Rating Curve shown in Figure 3.2 to estimate the streamflow at the gage heights shown in Table 3.2.

Table 3.2

Gage Height (Ft.)	Estimated Streamflow (CFS)
3.10	1.00
3.17	
3.22	

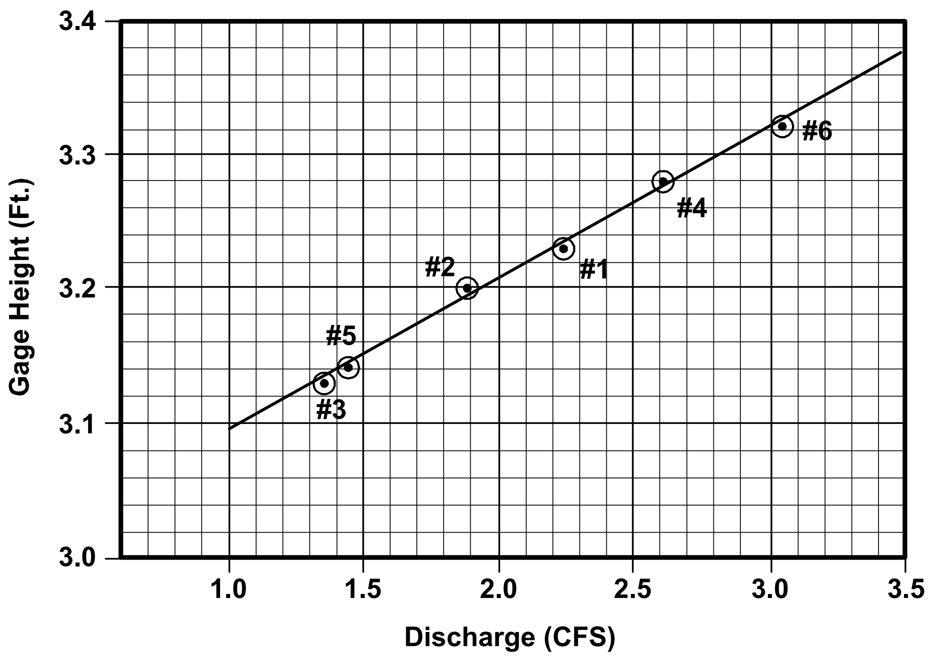


Figure 3.2 Streamflow Rating Curve

Reservoir Volume Measurement

Reservoir volume is estimated using a water level-capacity curve that is developed from topographic or other maps showing ground surface contours. A water level-capacity curve relates water level (or elevation) to capacity. If the water level is known, the volume can be estimated. Listed below are the six (6) steps that should be taken to estimate the volume of a reservoir.

Step 1: A plan view from a topographical map like that shown in Figure 3.3 to calculate the surface area at specific intervals. From the elevations shown on the map, a plenimeter is used to develop estimates of surface area at specified elevations.

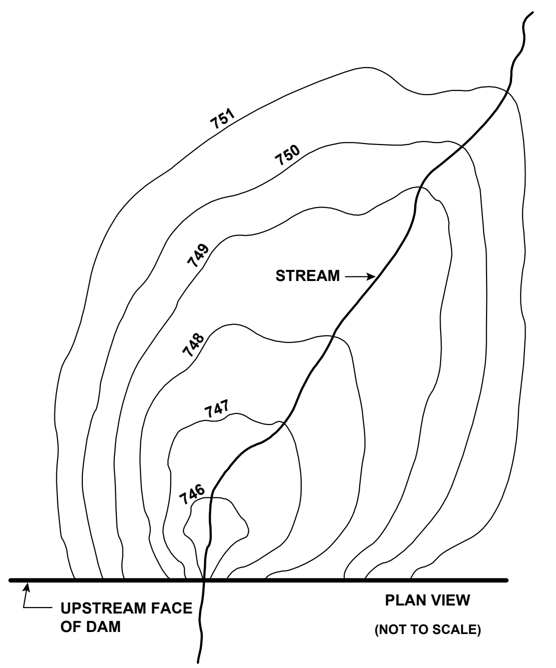


Figure 3.3 Plan View of a Hypothetical Reservoir

Step 2: Estimate the average surface area between elevations.

As a class, calculate the average surface area between the remaining elevations shown in Table 3.3 below.

Table 3.3

Elevation (Ft)	Area (Ft²)	Average Area Between Two Elevations (Ft²)
746	200	500
747	800	________
748	2,100	________
749	4,800	________
750	8,500	________
751	14,500	

Step 3: Estimate the volume at a specific level. To calculate the volume, use this calculation:

Estimated Volume at Specific Elevation (Ft^3) = Volume at the Previous Elevation (Ft^3) +
[(Average Area Between the Two Elevations, Ft^2) x (Difference Between the Two Elevations, Ft)]

As a class, estimate the volume of water at the specified elevations as shown in Table 3.4 below.

Table 3.4

Specific Elevation (Ft)	Volume at Previous Level (Ft^3)	Average Area Between Two Elevations (Ft^2)	Difference Between Two Elevations (Ft)	Estimated Volume at Level (Ft^3)
Volume @ 746 ft =				0 Ft^3
Volume @ 747 Ft =	0 Ft^3 +	[500 Ft^2 x	1 Ft] =	500 Ft^3
Volume @ 748 Ft =	500 Ft^3 +	[1,450 Ft^2 x	1 Ft] =	1,950 Ft^3
Volume @ 749 Ft =	______ Ft^3 +	[____________ Ft^2 x	____ Ft] =	________ Ft^3
Volume @ 750 Ft =	______ Ft^3 +	[____________ Ft^2 x	____ Ft] =	________ Ft^3
Volume @ 751 Ft =	______ Ft^3 +	[____________ Ft^2 x	____ Ft] =	________ Ft^3

Step 4: Surface area and volume at specific elevations are plotted on a graph as shown in the example provided in Figure 3.4. This is a water level-capacity curve, which can be used to estimate volume at any water level.

- Volume, in cubic feet, is plotted along the bottom X-axis, from left to right. Area, in square feet, is plotted along the top X-axis, from right to left. Elevation, in feet, is plotted along the Y-axis.

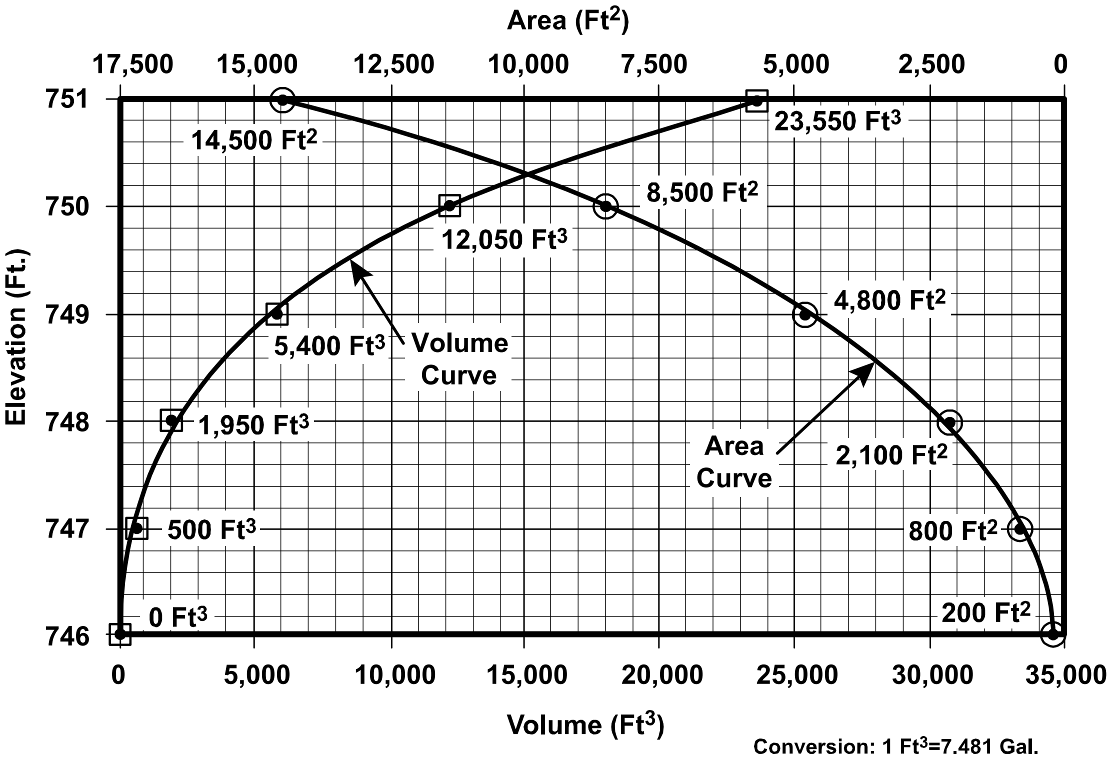


Figure 3.4 Water Level-Capacity Curve

Step 5: The Water Level-Capacity Curve is used to develop a Water Level-Capacity Table, as shown in Table 3.4 below, which allows volume to be estimated at any elevation. Storage volume (in Ft^3) is estimated at each elevation from the curve and converted from cubic feet to gallons (1 Ft^3 = 7.481 gallons). The difference in volume from one elevation to another, expressed in gallons, can then be calculated.

As a class, calculate the difference in volume between two elevations and complete the table below.

Table 3.4-Water Level-Capacity Table

Elevation (Ft)	Volume in Ft^3	Volume in Gallons	Difference in Volume Between Elevations (Gal)
746	0	0	
747	400	2,990	2,990
748	2,000	14,960	11,970
749	5,600	41,890	26,930
750	12,000	89,770	____________
751	23,500	175,800	____________

Step 6: To estimate the volume, in gallons, for any elevation, use data from the Water Level-Capacity Table. Interpolate between elevations as needed following the example below.

- Example: Estimated Volume at 750.85 Ft = 89,770 Gal + (0.85 x 86,030 Gal)
  = 89,770 Gal + 73,130 Gal
  = 162,900 Gal

As a class, use the Water Level-Capacity Table to estimate volume at the specified levels.

Estimated Volume at 749.50 Ft =
=
=

Estimated Volume at 746.75 Ft =
=
=

Groundwater Level Measurement

Groundwater level measurements relate the current water level in a well to an established point, such as top of well casing. Groundwater level measurements can be made using several different types of equipment; however, in all cases it is the current water level that is being measured.

- Battery-powered devices use a probe and small current to indicate when the water surface is reached as the probe is lowered into the well. The probe provides an automatic reading.
- The simplest measurement device is a steel tape that is lowered into the water at depth. A known point on the tape is held at a fixed measuring point, and the "wetted" surface is observed after tape retrieval. The water level below the measuring point is the difference between the held and wetted tape readings.

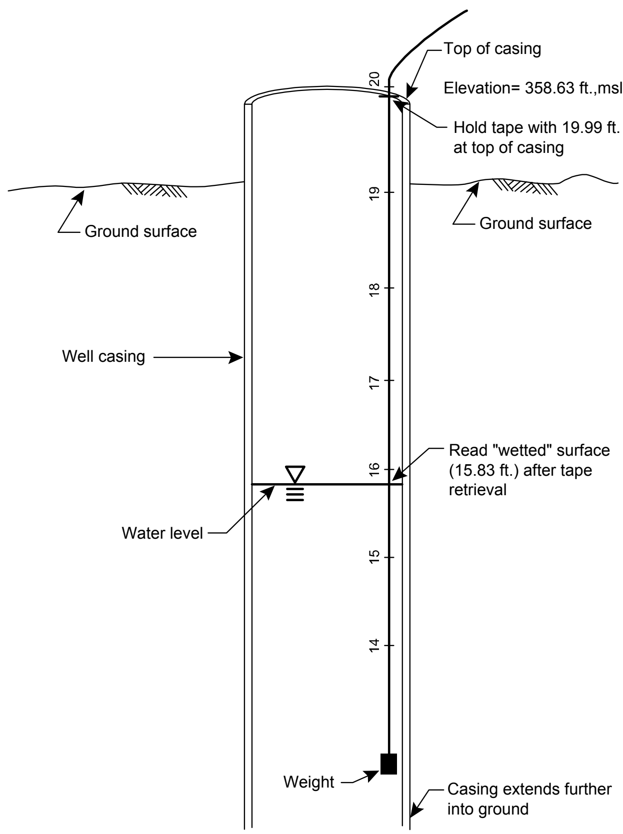


Figure 3.5 Well Cross-Section

Comparison with Long-Term Records

The USGS has the largest streamflow and well monitoring network available for use in data analysis. Many USGS gaging stations and well monitoring sites have long-term data records, and may include records from significant drought periods. Long-term data records are useful in establishing flow frequency estimates.

- Statistical analysis of long-term USGS daily discharge records yields flow-duration-frequency estimates used by DEP and other regulatory agencies in permitting new sources of supply.
- Conservation release requirements are also typically based on specified discharges identified from statistical analysis of long-term records from representative USGS gaging stations.
- Use of USGS gages and estimates to compare streamflow duration and frequency may preclude the need to collect data for analysis.

Flow Frequency Estimate

The USGS has developed low-flow statistics for approximately 2,800 ungaged stream locations in Pennsylvania using statistics from 312 gaging stations and drainage-area ratios. All gaging stations used in the USGS computations were active or discontinued with at least 10 years of record and are representative of hydrologic conditions throughout Pennsylvania. Regulation of streamflow during a period of record was taken into consideration.

- Statistics are available online at "http://pc13pahrb.er.usgs.gov//flowstats/", and can be located for streams by County Name, USGS Quad Name, or Stream/Basin Name.
- Available information includes: stream name; USGS reference gage number; drainage area; flow duration table; $Q_{1,10}$, $Q_{7,10}$, $Q_{30,10}$, and mean flows; and other statistics.
- Low-flow characteristics of Pennsylvania streams are also available in several DEP publications, although the data are dated and the analyses do not include recent droughts.

Low-Flow Statistics for Pennsylvania Streams

Developed by the U.S. Geological Survey for the
Pennsylvania Department of Environmental Protection

Pennsylvania Low-Flow Statistics - Query Results

LOW-FLOW STATISTICS

[All flow statistics in cubic feet per second (ft^3/s)]

Mouse over or click on table headings to view definition of statistic

STREAM NAME: Jordan Creek
GAGE OR BRIDGE SITE: gage
REFERENCE GAGE:[1] 01451800

COUNTY: Lehigh
USGS QUAD: Slatedale
STATION NAME: Jordan Creek near Schnecksville, PA

LATITUDE: 403942
LONGITUDE: 753738
DRAINAGE AREA (sq. mi.): 53.0

Entire Period of Record [2]	$Q_{1,10}$	$Q_{7,10}$	$Q_{30,10}$	MEAN	MEDIAN	HARMONIC MEAN
1967-94	1.84	2.58	4.17	92.7	49.2	26.7

FLOW DURATION TABLE (Probability of Exceedance)

P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
323	209	126	87.0	64.5	49.2	37.0	27.5	19.3	11.2	7.60

1 Reference Gage indicates which USGS gage was used in the computation of lowflow statistics for the specified locations
2 Period of Record for climatic year, April 1 through March 31
3 Period of record refers to pre-regulation conditions
4 Period of record refers to post-regulation conditions
** Statistic not computed due to insufficient data

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Figure 3.6 Low-Flow Statistics for a Gaging Station Used for Estimating Flow at an Ungaged Site – Jordan Creek @ 53.0 mi^2 [1]

Low-Flow Statistics for Pennsylvania Streams

Developed by the U.S. Geological Survey for the Pennsylvania Department of Environmental Protection

Pennsylvania Low-Flow Statistics - Query Results

LOW-FLOW STATISTICS

[All flow statistics in cubic feet per second (ft³/s)]

Mouse over or click on table headings to view definition of statistic

STREAM NAME: Jordan Creek
GAGE OR BRIDGE SITE: bridge
REFERENCE GAGE:[1] 01451800

COUNTY: Lehigh
USGS QUAD: Slatedale

LATITUDE: 403832
LONGITUDE: 753912
DRAINAGE AREA (sq. mi.): 26.9

Entire Period of Record [2]	$Q_{1,10}$	$Q_{7,10}$	$Q_{30,10}$	MEAN	MEDIAN	HARMONIC MEAN
1967-94	0.93	1.31	2.11	47.0	25.0	13.5

FLOW DURATION TABLE (Probability of Exceedance)

P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
164	106	63.9	44.1	32.7	25.0	18.8	13.9	9.79	5.68	3.85

1 Reference Gage indicates which USGS gage was used in the computation of lowflow statistics for the specified locations
2 Period of Record for climatic year, April 1 through March 31
3 Period of record refers to pre-regulation conditions
4 Period of record refers to post-regulation conditions
** Statistic not computed due to insufficient data

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Figure 3.7 Low-Flow Statistics for an Ungaged Site on a Gaged Stream – Jordan Creek @ 26.9 mi^2 2

USGS

Low-Flow Statistics for Pennsylvania Streams

Developed by the U.S. Geological Survey for the Pennsylvania Department of Environmental Protection

Pennsylvania Low-Flow Statistics - Query Results

LOW-FLOW STATISTICS

[All flow statistics in cubic feet per second (ft^3/s)]

Mouse over or click on table headings to view definition of statistic

STREAM NAME: Kishacoquillas Creek
GAGE OR BRIDGE SITE: gage
REFERENCE GAGE:[1] 01565000

COUNTY: Mifflin
USGS QUAD: Burnham
STATION NAME: Kishacoquillas Creek at Reedsville, PA

LATITUDE: 403917
LONGITUDE: 773500
DRAINAGE AREA (sq. mi.): 164

Entire Period of Record [2]	$Q_{1,10}$	$Q_{7,10}$	$Q_{30,10}$	MEAN	MEDIAN	HARMONIC MEAN
1941-70;84-85	17.4	18.5	20.1	206	118	74.1

FLOW DURATION TABLE (Probability of Exceedance)

P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
642	476	322	232	165	118	83.9	59.8	42.8	30.9	25.3

1 Reference Gage indicates which USGS gage was used in the computation of lowflow statistics for the specified locations
2 Period of Record for climatic year, April 1 through March 31
3 Period of record refers to pre-regulation conditions
4 Period of record refers to post-regulation conditions
** Statistic not computed due to insufficient data

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This system designed and developed by the U.S. Geological Survey, Water Resources Division, New Cumberland, Pa. © 2002.

Figure 3.8 Low-Flow Statistics for a Gaging Station Used for Estimating Flow at an Ungaged Site on an Ungaged Stream – Kishacoquillas Creek @ 164 mi^2 [3]

Low-Flow Statistics for Pennsylvania Streams

Developed by the U.S. Geological Survey for the Pennsylvania Department of Environmental Protection

Pennsylvania Low-Flow Statistics - Query Results

LOW-FLOW STATISTICS

[All flow statistics in cubic feet per second (ft^3/s)]

Mouse over or click on table headings to view definition of statistic

STREAM NAME: Honey Creek
GAGE OR BRIDGE SITE: bridge
REFERENCE GAGE:[1] 01565000

COUNTY: Mifflin
USGS QUAD: Burnham

LATITUDE: 403956
LONGITUDE: 773533
DRAINAGE AREA (sq. mi.): 93.1

Entire Period of Record [2]	$Q_{1,10}$	$Q_{7,10}$	$Q_{30,10}$	MEAN	MEDIAN	HARMONIC MEAN
1941-70;84-85	9.89	10.5	11.4	117	67.0	42.1

FLOW DURATION TABLE (Probability of Exceedance)

P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95
364	270	183	132	93.7	67.0	47.6	33.9	24.3	17.5	14.4

1 Reference Gage indicates which USGS gage was used in the computation of lowflow statistics for the specified locations
2 Period of Record for climatic year, April 1 through March 31
3 Period of record refers to pre-regulation conditions
4 Period of record refers to post-regulation conditions
** Statistic not computed due to insufficient data

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Figure 3.9 Low-Flow Statistics for an Ungaged Site on an Ungaged Stream – Honey Creek @ 93.1 mi^2 [4]

Water Level Comparison

The USGS monitors groundwater levels on a real time basis at 68 sites in Pennsylvania, and on a less frequent basis at other locations. Water levels measured during the period of record at an observation well are used to establish the range (low to high levels), mean, and other statistics, including indicators for drought watch, warning, and emergency conditions.

- Records from a nearby USGS observation well can be used to indicate the hydrogeologic conditions at a GUDI well.

Key Points

- USGS has the largest stream flow and well monitoring network available for use in data analysis.

- Water level-capacity curves that relate water level to storage capacity at that level can be used to monitor the change in contents of a reservoir on a daily, weekly or monthly basis.

- Data collected to obtain a permit varies. For rivers and streams, stream flow is measured, for lakes and reservoirs, volume is measured, and for GUDI wells the groundwater level is measured.

[1] USGS website. http://pc13dpahrb.er.usgs.gov/flowstats/lowflow.ASP?WCI=stats&WCU;ID=27 (June 3,2003).

[2] USGS website. http://pc13dpahrb.er.usgs.gov/flowstats/lowflow.ASP?WCI=stats&WCU;ID=1126 (June 3,2003).

[3] USGS website. http://pc13dpahrb.er.usgs.gov/flowstats/lowflow.ASP?WCI=stats&WCU;ID=153 (June 3, 2003).

[4] USGS website. http://pc13dpahrb.er.usgs.gov/flowstats/lowflow.ASP?WCI=stats&WCU;ID=1085 (June 3, 2003).

Additional Resources Used

Commonwealth of Pennsylvania, Department of Environmental Protection, *Water Allocation Application and Instructions,* 3900-PM-WM0001, (Revised September 2001).

S.E. Rantz and others, U.S. Geological Survey, “Water Supply Paper 2175”, *Measurement and Computation of Streamflow, Measurement of Stage and Discharge,* Vol I, (Washington, DC: U.S. Government Printing Office, 1982), Chapters 4 and 5.

Unit 4 – Source Water Assessment and Protection

Learning Objectives

- List the three key components of the Source Water Assessment and Protection (SWAP) program.
- Identify the information that should be collected during a wellhead protection sanitary survey.
- Explain why public participation is important to the success of a Source Water Protection (SWP) program.
- Describe the additional benefits of a Source Water Protection program.

Required by 1996 Safe Drinking Water Act (SDWA) Program

The 1996 SDWA requires states to develop a Source Water Assessment and Protection (SWAP) program to assess drinking water sources that serve public water systems for their susceptibility to pollution.

- States were required to assess all sources serving public water systems within two (2) years of program approval by the U.S. Environmental Protection Agency (EPA).
- Pennsylvania contains approximately 14,000 drinking water sources.
- DEP is responsible for completing the assessment, with input from water systems and the general public.
- This information will be used as a basis for building voluntary, community-based barriers to drinking water contamination.

Directed at Raw Water Quality

SWAP assessments are of raw water quality, not finished (treated) water quality.

- Assessments are not intended to measure water supplier compliance with SDWA requirements.
- DEP and its contractors use existing information, such as Geographic Information System (GIS) databases available from townships, cities or local municipalities, to complete the SWAP assessments.

Delineate Source Boundaries

One of the objectives of the SWAP program is to delineate the boundaries of the areas providing source waters for all public water systems.

- A variety of delineation methods have been used considering the limited resources and time available to complete the assessment.
- DEP has delineated the watershed areas for all surface water intakes serving public water systems.
- Large watersheds (i.e., those larger than 100 mi^2) have been divided into smaller areas so specific inventories of significant potential contaminant sources can be conducted.
- The delineated wellhead protection areas for GUDI wells that serve public water systems have been defined in state regulations and the Wellhead Protection Program (WHPP).
- Initial statewide assessments will identify at-risk drinking water sources.

Identify Origins of Potential Contaminants

The types of potential contaminants for a community water system using surface water as a source of supply are listed below. Certain contaminants are a more common cause of pollution than others. The potential contaminants are ranked from those that are more common and pose a greater health risk, to those that are less common and pose less of a health risk.

- Microbiological Pathogens: Total/Fecal Coliform, Viruses, Protozoa
- Turbidity
- Nitrate/Nitrite
- Disinfection By-Product Precursors
- Synthetic Organic Compounds (SOCs)
- Volatile Organic Compounds (VOCs)
- Taste and Odor Precursors
- Radionuclides

Potential contaminants are linked to particular activities and land use categories, although the potential contaminant is dependent on the specific chemicals and processes being used in the activity.

- Potential contaminant source inventories include activities that use, store, transport, or dispose of specific types of contaminants.
- Activities associated with potential contamination located within the delineated source boundaries will be identified by DEP.

Determine Source Susceptibility to Contamination

The susceptibility of a drinking water source serving a public water system is the potential for that source to draw water contaminated by inventoried sources of contamination at concentrations that would pose a concern. Susceptibility is determined at the point of withdrawal.

- Surface water sources offer limited protection to contamination.
- Large reservoirs can offer some protection to upstream or distant contamination.

A susceptibility analysis attempts to identify the potential contaminant sources of concern. The susceptibility analysis is a qualitative measure of relative priority for concern of the potential and existing sources of contamination based on the following:

- Drinking water source sensitivity;
- Potential impacts posed by sources of contamination to the water supply source; or
- Potential for release of contaminants of concern.

Assessment is made of the potential for contamination of the water supply source if the contaminant is released from the potential contaminant source without consideration of any source protection.

- Factors controlling the potential for contamination from a release are the fate and transport of the contaminant, the amount of the contaminant that might be released, and the time of travel (or distance) to the source of supply.

A drinking water source is considered to be highly sensitive to contamination if at the point of withdrawal:

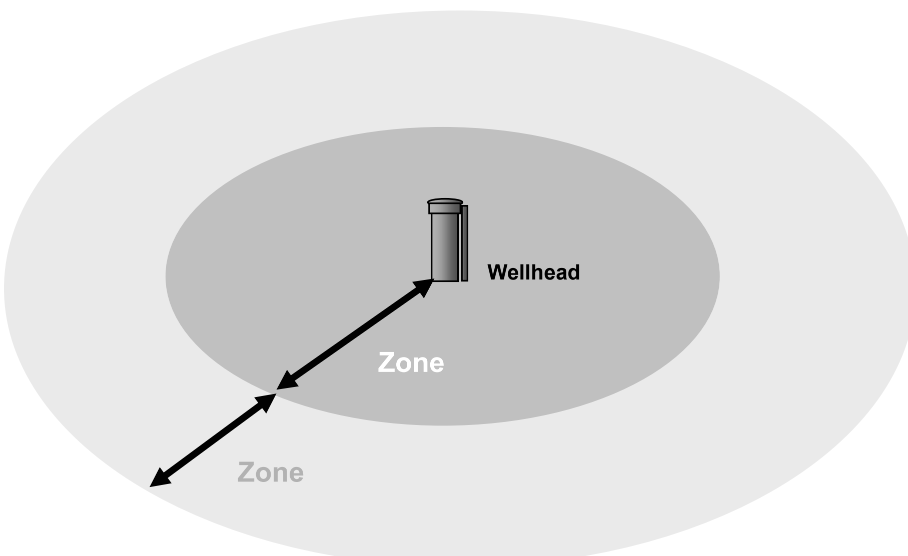
- A Maximum Contaminant Level (MCL) has been exceeded for a regulated contaminant.
- 50% of an MCL has been reached for nutrients or heavy metals; or
- VOCs or SOCs have been detected above the detection limit.

Enhanced by Sanitary Surveys

Water suppliers are the best source of information regarding their source of supply, through local knowledge and community interaction. In addition, sanitary surveys are regularly conducted and documented by DEP of all surface water and groundwater supply sources. DEP Sanitary Survey Reports contain information beneficial to the source water assessment. As additional sanitary surveys are performed in the future, pertinent new data should be included in the SWAP Plan for that source.

Sanitary surveys conducted for the selection of a location for a new well include collection of the following information:

- Character of local geology, size and topography of catchment area, slope of ground surface, and groundwater table;
- Nature and distance of local sources of pollution (i.e., animal feed lots, landfills, privies, sink holes, sewer lines, and industrial lagoons);
- Extent of drainage area likely to effect or contribute water to the supply, population density, land use, and waste disposal methods in the drainage area;
- Proximity to flood plain or impoundments that may cause flooding; and
- Proximity of other existing wells.



Additional Benefits of the SWAP Program

Other benefits associated to the SWAP Program are listed below. See Appendix for more information on each of the following.

- Facilitate Emergency Responses
- Improve Land Use Planning
- Prioritize Regulatory Agencies Action
- Educate the General Public

Prioritize Regulatory Agencies Action

Most susceptible water sources will be identified under the SWAP program. For non-point source and microbiological contaminants of concern, a critical area analysis will be conducted for each surface water intake based on existing water quality data on the physical characteristics of the watershed.

- Analyses will focus on nitrates, pathogens, sediment loading, and metals, and critical areas identified as being a high potential source of contamination.
- DEP and other regulatory agencies will link the results of the assessments with watershed management of Total Maximum Daily Load (TMDL) development activities.
- The SWAP program will provide a basis for implementing projects to support federal, state, and local programs for watershed remediation and source water protection.

Educate the General Public

Public meetings will be held at the initiation and at the completion of a source water assessment to obtain input and to discuss the results and recommendations of the assessment and ways to develop or enhance existing source water protection plans. The goal is to make everyone aware of the need to protect the water supply source from contamination.

- Copies of the assessment will be available to the general public for review at various locations, such as the water supplier offices, local library, local planning agency, and other public access locations.
- A summary of the assessment is to be included in the Consumer Confidence Report distributed annually to water system customers and users.

General

SWP Programs are intended to be locally designed, voluntary efforts to protect drinking water sources used by community water systems.

- Local programs will be supported with public education, program promotions, local grants for plan development and implementation, federal and state agency coordination, and technical assistance.
- DEP staff will present the relationship of the source water assessment results to the local SWP program and identify approaches for managing existing and potential sources of contamination.

Requirements

Recipients of SWP grant funding must establish a SWP program that includes a source water protection steering committee that will develop a plan that meets DEP's minimum requirements.

The minimum requirements of a SWP program include:

- Local steering committee;
- Public participation;
- Source water protection area delineation;
- Contaminant source inventory;
- Source water protection area management methods;
- Contingency planning; and
- New source planning.

SWP Funding and Promotion

SWP grants, offered through the DEP Growing Greener Grant application process, are available to help establish and develop local SWP programs. SWP grants of up to $200,000 for 5 years are available for public education and watershed management activities. Proposals will be reviewed by DEP and selected for approval on the basis of specific criteria.

- Applicants eligible for SWP grants include individual municipalities, a group of adjacent municipalities, or a community water system.
- Several other organizations are being funded to provide support for local SWP program development and promotion.
- The League of Women Voters will provide training and mini-grants to promote local education on the issues of source water protection. Various other groups and projects will be funded to develop educational materials, provide forums for education, and promote identified source water protection needs.

Key Points

- The 1996 SDWA requires states to develop a Source Water Assessment and Protection Program (SWAP) to assess drinking water sources that serve public water systems for their susceptibility to pollution.

- The objectives of the SWAP program are to delineate source boundaries, identify origins of potential contaminants, and determine source susceptibility to contamination.

- Additional benefits of the SWAP program include: facilitating emergency response, improving land use planning, prioritizing regulatory agency action, and educating the public about protecting source water.

Additional Resources Used

Commonwealth of Pennsylvania, Department of Environmental Protection, *Source Water Assessment and Protection Program,* Document 383-5000-001 (March 24, 2000).

Commonwealth of Pennsylvania, DEP, *Fact Sheet: Pennsylvania's Source Water Assessment and Protection (SWAP) Program,* 3900-FS-DEP2417, (September 2001).

Commonwealth of Pennsylvania, DEP, *Fact Sheet*: *Source Water Protection Grants,* 3900-FS-DEP2525 (September 2001).

Unit 5 – Drought Contingency Planning

Learning Objectives

- Name the five hydrologic conditions used by DEP to assess drought status.
- Name the three drought stages and describe the major actions required by each.
- Describe the major components of a Drought Contingency Plan.
- Define the triggers for each type of surface water supply that are used in a local drought contingency plan.

Pennsylvania DEP uses five (5) parameters to monitor water supply drought conditions: 1) Precipitation, 2) Streamflow, 3) Groundwater Levels, 4) Palmer Drought Severity Index (Soil Moisture), and 5) Reservoir Storage. Each parameter is used only as an indicator of **drought stage**.

- Declaration of a drought stage in a given county is based on review of the individual parameters, in combination with other considerations. Information on each parameter is collected and reported by various government agencies.

Precipitation

Earliest indicators of a potential drought are **precipitation deficits**.

"Normal" precipitation is the most recent 30-year average precipitation for a specific month.

- "Normal" precipitation is tracked by the National Weather Service (NWS). The NWS maintains long-term monthly averages of precipitation for each Pennsylvania county.

Total cumulative precipitation is the sum of precipitation, by county, for 3- to 12-month periods.

Precipitation deficit is the difference (in percent) between "normal" precipitation and total cumulative precipitation for a specific time period.

Table 5.1 Actual Precipitation Deficits and Drought Stage Conditions

Drought Stage Condition	**Actual Precipitation Deficit** (deficit as percent of normal precipitation)
Drought Watch	15% (12 month period) to 25% (3 month period)
Drought Warning	25% (12 month period) to 35% (3 month period)
Drought Emergency	35% (12 month period) to 45% (3 month period)

Streamflow

After precipitation, streamflow data provide the next earliest indication of a developing drought.

- The U.S. Geological Survey (USGS) maintains a network of streamgages across Pennsylvania. DEP uses 73 of these gages as its drought-monitoring network.
- Each gage provides data used to determine the preceding 30-day average flow for the entire period of record.
- Each county in Pennsylvania does not have a streamgage with an adequate period of record—as a result, surrogate streamgages can be used to represent streamflow for a neighboring county.

Exceedance Flow Value is the percentage of time the current 30-day average flow was exceeded for the same period in the past.

Table 5.2 Exceedance Flow Values and Drought Stage Conditions

Drought Stage Condition	**Exceedance Flow Value**
Drought Watch	75% (the current 30-day average flow was exceeded 75% of the time for same period in the past)
Drought Warning	90% (the current 30-day average flow was exceeded 90% of the time for same period in the past)
Drought Emergency	95% (the current 30-day average flow was exceeded 95% of the time for same period in the past)

Groundwater Levels

Groundwater levels are usually the third indicator of a developing drought.

- The USGS maintains a network of groundwater monitoring wells, recently upgraded to include at least one well in each county.
- Surrogate monitoring wells are used for monitoring drought conditions in some counties.
- Groundwater typically lags about 2 to 3 months behind precipitation, largely due to storage effects.

Groundwater Level Exceedance is a comparison of the current groundwater level to the long-term 30-day average level, based on the period of record for each drought-monitoring well.

Table 5.3 Groundwater Level Exceedance and Drought Stage Conditions

Drought Stage Condition	**Groundwater Level Exceedance**
Drought Watch	75% (the current 30-day average groundwater level was exceeded 75% of the time for same period in the past)
Drought Warning	90% (the current 30-day average groundwater level was exceeded 90% of the time for same period in the past)
Drought Emergency	95% (the current 30-day average groundwater level was exceeded 95% of the time for same period in the past)

Palmer Drought Severity Index (Soil Moisture)

The **Palmer Index** is the fourth drought stage indicator used by Pennsylvania DEP.

The **Palmer Index** is a computed value based on a number of meteorological and hydrological factors used to measure soil moisture conditions.

- The National Oceanic and Atmospheric Administration (NOAA) provides soil moisture information in the form of the Palmer Drought Severity Index.
- The Palmer Index is most effective in determining long-term drought (months) and is not as effective with short-term forecasts (weeks).

Table 5.4 Palmer Index Values and Drought Stage Conditions

Drought Stage Condition	**Palmer Index Values**
Drought Watch	-2.00 to -2.99
Drought Warning	-3.00 to -3.99
Drought Emergency	-4.00 and less

Reservoir Storage

Storage in several large public water supply reservoirs is the fifth indicator used by DEP for drought monitoring.

- The primary reservoir storage indicators are three New York City reservoirs located in the upper Delaware River basin.
  - Total quantity of storage and the length of the refill period are monitored at each reservoir.
  - Available storage capacity (i.e., how much water is left) is used to indicate the drought stage for each of the reservoirs, but time of year also needs to be considered.

Pennsylvania Emergency Management Agency (PEMA) manages Pennsylvania's water resources during droughts, with direct support from DEP and the Commonwealth Drought Coordinator. Activities are coordinated at the county level and include:

- Review drought indicators monthly to provide timely identification of developing drought conditions.
- Identify drought stages following a three-stage process, to indicate overall water supply conditions.

Drought Watch

When three (3) or more drought indicators signal a drought watch condition, DEP takes the following actions:

- Notifies PEMA of the developing conditions,
- Requests that PEMA convene a meeting of the Commonwealth Drought Task Force (Task Force), and
- Based on Task Force recommendations, issues a drought watch for the affected area(s).

Purpose

- Alert government agencies, public water suppliers, water users, and the general public regarding the onset of conditions indicating the potential for future drought.
- Notify public water suppliers of the need to monitor their water supplies and to initiate their respective drought contingency plans.
- Request voluntary water conservation.
  - Objective: Reduce water use by 5% in the affected area.

During a drought watch, DEP increases its monitoring frequency of drought indicators from monthly to weekly, and the Task Force schedules regular meetings to review developing conditions.

How many drought indicators are required for DEP to take action regarding a potential drought status condition? What are the five (5) drought indicators, or parameters?

Drought Warning

When drought indicators signal a warning condition, a process similar to that followed for a drought watch is followed—resulting in a drought-warning announcement issued by DEP for the affected area(s).

Purpose

- Prepare for a coordinated response to imminent drought conditions and potential water supply shortages,
- Initiate a concerted conservation effort to avoid or reduce water shortages,
- Relieve stressed sources,
- Develop new sources,
- If possible, forestall the need to impose water use restrictions, and
- Further reduce overall water usage through voluntary conservation measures.
  - Objective: Reduce water use by 10 to 15% in the affected area.

During a drought warning, DEP continues its weekly monitoring frequency of drought indicators, and the Task Force continues meeting regularly to review developing conditions.

Drought Emergency

When drought indicators signal an emergency condition:

- The Task Force may recommend that PEMA convenes a meeting of the Emergency Management Council to consider input from affected county commissioners and emergency management staff, and
- The Governor may issue a drought emergency proclamation, based on Emergency Management Council recommendations.
    - The Governor may also order mandatory restrictions on nonessential water use.

Purpose

- Respond to actual emergency conditions,
- Avoid depletion of water sources,
- Ensure at least minimum water supplies are maintained to protect public health and safety,
- Support essential and high priority water uses,
- Avoid unnecessary economic dislocations, and.
- Further reduce overall water usage through mandatory or voluntary conservation measures.

Objectives:

- Reduce consumptive water use by at least 15% in the affected area,
- Preserve public water supplies,
- Avoid or mitigate local or area shortages, and
- Ensure equitable sharing of limited supplies.

During a drought emergency:

- DEP increases its monitoring activities from weekly to daily, with drought reports prepared and posted daily on the DEP website.
- PEMA's county drought task forces meet regularly and the Task Force meets weekly to ensure continued coordination among agencies.

What are some ways you could conserve water—and, in turn, decrease water demand?

Water Rationing

Water rationing may be implemented when an individual water supplier's sources are so depleted as to threaten health and safety. Rationing ensures that these limited sources are protected for essential uses.

Only the Governor can ration Pennsylvania resources, including water resources. Therefore, approval of the Commonwealth Drought Coordinator, acting on behalf of the Emergency Management Council and the Governor, is required for a public water supplier or municipality to ration water within a designated service area.

Water Rationing Plans

- Require specific limits on individual water consumption to achieve significant reductions in use, and
- Allot a specific amount of water to each customer, generally based on a percentage of previous use or on a specific daily quantity per household.

A **Drought Contingency Plan** ensures that sufficient water is available at all times to preserve public health, sanitation, and safety. The Plan outlines:

- Actions to be taken by a water supplier during drought to stretch existing water supplies and reduce unnecessary water use,
- Indicator criteria (triggers) that will identify the onset of drought occurrences, and
- Public education and awareness strategies.

Plan Contents

A Drought Contingency Plan for a public water supply should, at a minimum, contain:

- Water supplier information,
- Source information,
- Withdrawals for previous year,
- System water demands for previous year,
- System criteria to identify water shortage,
- Plan of action, and
- Procedure for granting variances or exemptions.

Plan Implementation

Implementation of a Drought Contingency Plan should:

- Be based on applicable local drought indicator triggers, and
- Consider DEP or regional drought indicators.

Water suppliers should use reservoir storage levels, groundwater levels, and streamflow to monitor source of supply availability and trigger drought stages. In addition, water suppliers should use drought condition indicators applicable to their key source(s) of supply.

Local Drought Indicator Triggers

- Reservoir storage for a reservoir-supplied system,
- Groundwater level or yield of key wells for a groundwater-supplied system, and
- Streamflow quantity for a river- or stream-supplied system.

Regional Drought Indicators

- Accumulated precipitation deficiencies, and
- Soil moisture indices.

Table 5.5 Type of Drought Response Measure Implemented

Drought Stage Condition	Type of Drought Response Measure Implemented
Drought Watch	Water supplier measures should be triggered.
Drought Warning	Water supplier measures should be triggered.
Drought Emergency	The Governor or PEMA measures should be followed.

Voluntary to Mandatory to Rationing

Demand reduction measures followed by a water system generally follow a logical progression. Additionally, water use reduction goals are established for each drought stage.

- Voluntary water use restrictions (for drought watch and drought warning).
- A mandatory nonessential water use ban (for drought emergency).
- Rationing may be implemented, in addition to the ban on nonessential water use, under severe water shortage conditions.

Large User Alternative Supplies

Large users typically have the greatest impact on water system demands. As a result, water systems should meet with major commercial and industrial users to plan strategies for demand reduction at the respective facilities.

What are some examples of large users in this area?

During drought emergency situations, large users can be encouraged to use available alternative supplies.

- Alternative supplies should be 1) identified and evaluated as part of the user's operations plan, and 2) included in the water supplier's drought contingency plan.
- Alternative sources can include on-site wells, river or stream withdrawals, or interconnection with other water suppliers.

Public Education

Efforts to educate water customers about water conservation practices should be increased during the early stages of a drought. Customers should be:

- Alerted to drought conditions, and
- Informed of actions required to respond to water shortages.

What are some ways to reach customers in order to provide public education?

Leakage and Loss Reduction Program

System-wide leakage detection and repair is the first supply extension measure normally implemented by a water supplier at the onset of drought conditions.

- All water systems should, however, strive to keep unaccounted-for water to the lowest level possible during all conditions. Leak identification and repair in the transmission and distribution system reduces source depletion by minimizing avoidable water loss.

Bulk Purchase from Interconnected System

If a neighboring water system has surplus water available, it may be possible for a water supplier to secure a supply quantity to supplement their self-supply sources.

Many water systems in close proximity have existing interconnection points (normally closed valves) for use during emergencies.

A water supplier, located in a county experiencing a drought condition, is considering using water from an interconnected or neighboring system. What should the supplier consider?

Emergency Source of Supply

Emergency sources of supply could be used to supplement existing sources, including:

- A groundwater well reserved for emergency use only,
- Development of a temporary new source, such as springs, lakes, ponds, or quarries, and
- Trucking treated water from another water supplier, though it is an expensive alternative.

Water supply or allocation permits must be obtained prior to the use of a new emergency source of supply.

Reduction of Conservation Releases

As a last resort measure for drought emergency conditions only, supplies can be extended by reducing downstream conservation releases below water supply reservoirs, or passby flows downstream from stream intakes.

A water supplier must gain approval from DEP, in consultation with the Pennsylvania Fish and Boat Commission (PFBC), prior to reducing conservation flows.

Key Points

The five parameters used to monitor water supply drought conditions are:

- Precipitation
- Stream flow
- Groundwater levels
- Palmer drought severity index
- Reservoir storage

The three stages of drought are:

- Warning
- Watch
- Emergency

The Drought Contingency Plan ensures that sufficient water is available at all times to preserve public health, sanitation and safety.

Supply extensions include:

- Leak and loss detection
- Bulk purchase
- Emergency source
- Reduction of conservation releases

Additional Resources Used

Pennsylvania DEP Drought Information Center website. www.dep.state.pa.us/dep/subject/hotopics/drought/default.htm (15 May 2003). (This website is a portal to information on Drought Management in Pennsylvania, General Guidelines for an Individual Public Water Supply Drought Contingency Plan, and Drought Triggers for Public Water Suppliers.)

Pennsylvania Drought Condition Monitoring Maps. http://pa.water.usgs.gov/monitor (15 May 2003).

The Pennsylvania Code, Chapter 118.4 - Contingency Plans for Public Water Supply Agencies, www.pacode.com/secure/data/004/chapter118/s118.4.html (15 May 2003).