ENGINEERING REPORT

RESERVOIR OPERATION AND MANAGEMENT PLAN

ALTOONA WATER AUTHORITY
900 CHESTNUT AVENUE
ALTOONA, PA

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EXECUTIVE SUMMARY

- The reservoir operation and management was prepared according to the requirements of the 2008 PADEP water allocation permit. The plan can be a useful tool for managing periods of normal supply and shortage while also serving as a rational basis for drought contingency planning.

- The plan utilized a reservoir simulation model developed by the US Army Corps of Engineers. Res-Sim (Version 3.0) models all input/output parameters affecting reservoir storage and depletion.

- Res-Sim 3.0 relied on a 65-year stream flow record from the USGS gaging station on Bald Eagle Creek (Tyrone) to simulate long term reservoir operations. Reservoir withdrawals were based on historical, current and projected demands from discrete service areas. Other input parameters included evaporation, storage capacity, conservation releases and diversions. Operating rules were established for both single and multiple reservoir operation.

- The total useable storage of the Authority water supply system is 2.76 billion gallons from the following reservoirs in descending order of capacity: Lake Altoona, Mill Run, Tipton, Bellwood, Cochran-Impounding, Kettle, Plane Nine, Muleshoe, Kittanning Point, Allegheny, Blair Gap and Homer Gap reservoirs. About 307 days of storage are provided at the current demand rate of 9.0 mgd. The average age of the Authority reservoirs is 94 years. Historically, the Authority has never imposed mandatory restrictions.

- Based on the Res-Sim 3.0 simulation model, the safe yield (or dependable flow) of the reservoir system is 12.8 mgd. This is the production that can be sustained during all drought conditions without draining the reservoirs. The Horseshoe Curve and Tipton are surplus reservoirs under all demand conditions. The remaining reservoirs are in various stages of deficiency during severe droughts. The system is about 2.0 mgd in deficit for the projected 2033 demand of 14.789 mgd during extreme drought periods.

- A reliability and deficiency analysis was performed using standard statistical and frequency analysis methods. Shortage Indices (per U.S. Corps of Engineer criteria) were also calculated, based on various demand conditions. The Horseshoe Curve and Tipton Reservoirs rank highest in reliability for all reservoirs. For current production, they are followed in descending order by: Bellwood, Plane Nine and Mill Run. For projected production, they are followed in descending order by: Kettle, Plane Nine, Bellwood, Mill Run and Homer Gap.

- A study of the Res-Sim 3.0 maximum drought durations and depletion volumes revealed the "drought of record" occurred in late 1965. Six major droughts occurred in the 1960's while four similar periods occurred from 1997 to 2004. However, all reservoirs recovered (refilled) in the late fall-to-early winter season.

- An economic evaluation shows that the "four reservoir" operating mode results in savings of $350,000 per year. Based on current demand, this justifies the decommissioning of Mill Run, Kettle and Homer Gap Reservoirs. These serve as "stand-by" reservoirs. The Horseshoe Curve Reservoir system is currently the most cost effective system followed in descending order by: Bellwood, Plane Nine and Tipton.

EXECUTIVE SUMMARY (Continued)…

- As a result of this study, the Authority can supply water up to 12.0 mgd as the safe yield of the system. Also, total reservoir storage should be used for drought planning triggers.
- For production less than 12.0 mgd, the Authority can safely deliver water during shortages within the parameters of state drought declarations while monitoring total shortage capacity.
- For production levels above 12.0 mgd and when drought storage levels dictate, voluntary and mandatory restrictions should be implemented according to the revised drought contingency plan outlined herein.
- Based on production levels under 11.0 mgd, the "four reservoir" operation plan is adequate. These include the Horseshoe Curve, Bellwood, Plane Nine and Tipton systems. The Mill Run plant could be run concurrently since it is a functional component of the Horseshoe Curve service area.
- From 11.0 to 13.5 mgd, Mill Run Reservoir will need to operate. At 13.5 mgd, Kettle Reservoir system comes on-line while at 14.25 mgd, all reservoir systems are operational with the addition of Homer Gap Reservoir.
- The Horseshoe Curve reservoir system is the most reliable and dependable source in the Authority inventory. It serves as the ultimate shortage buffer for the entire system. The ability to transfer Horseshoe Curve water throughout the service area provides great operational reliability.
- If production continues to decline to 8 mgd, further economies could be realized by operating Horseshoe Curve, Bellwood and Plane Nine and taking Tipton Reservoir temporarily off-line.
- If future demand increased above 14.5 mgd, expansion of Bellwood Reservoir with its large drainage area (18.2 sq. mi.) and favorable dam site is the most favorable storage option.
- For normal operating conditions, individual treatment plants should be operated at sustainable treatment rates to ensure 50% reserve capacity for peak demand conditions.
- Given the Authority's investment in its supply system and the area's economic conditions, the availability of surplus capacity for economic development is a priority. Production costs and revenues will continue to be major considerations in the future management of the reservoir system. This operating plan will provide a sound technical basis for insuring adequate capacity under all supply and demand conditions.
- With a fully integrated water distribution system, the Authority has considerable flexibility in the management of the reservoir system. We expect this flexibility will be maintained in the future and within the technical confines set forth in this plan.
- Continue to operate the reservoir system as a fully integrated whole. During severe droughts, supplement individual reservoirs in deficit with those reservoirs in surplus by distribution systems transfers (pump stations, tanks).
- Retain all reservoirs and treatment plants for use as supplemental supplies in the event of scheduled maintenance, severe drought shortages, increased demand and emergencies (dam safety, water quality, hydraulic, fire safety, system outages, etc.).

EXECUTIVE SUMMARY (Continued)…

- Reservoir water quality has taken on increased importance in system operations. The Authority has very good-to-exceptional quality sources. Despite increased regulation, the Authority treatment plants operate at a high level of efficiency and meet all regulatory guidelines. Accordingly, reservoir management and cost effectiveness must be taken into account.

- Generally, the highest yielding reservoirs also have the best water quality. The best quality reservoir systems are (in descending order): Tipton, Horseshoe Curve, Mill Run, Plane Nine, Bellwood, Kettle and Homer Gap.

- Tipton Reservoir can fully supplement or replace Bellwood Reservoir during periods of unstable water quality. This will result in lower operating costs for chemical consumption and waste solids production.

- Reservoir water quality will decline during severe droughts. Operating personnel will need to closely monitor raw water quality and make necessary process adjustments to maintain quality.

- Responses and protocols for non-drought emergencies (reservoir contamination, dam safety problems, treatment plant outages) are addressed by previous emergency response planning. Generally, the loss of an individual reservoir has a negligible effect. However, if the Horseshoe Curve reservoirs were removed from service, safe yield would be reduced to 7.72 mgd. Additional studies, beyond the scope of this study, are necessary to define drought measures and hydraulic restrictions for this condition.

PURPOSE

The Altoona Water Authority (AWA) authorized Gwin, Dobson & Foreman, Inc. to perform a reservoir operation and management plan. This plan is required by the PA Department of Environmental Resources (PADEP) Water Allocation Permit issued April 29, 2008.

The evaluation will review current procedures and related operating costs. Reservoir inflow, storage, demand and draft assumption will be routed using computer model simulations for individual and combined reservoir systems. Safe yield, depletion and shortage periods will be developed for various operational scenarios. The analysis will provide guidance on future reservoir management for both normal and contingency (droughts, shortages) operations.

SCOPE

The detailed scope of work for the AWA reservoir operation and management plan includes the following work elements:

a. Compile historical reservoir production records and service area characteristics including hydraulic gradients, system interconnections and diversions.
b. Review Water Allocation Permit provisions for allowable conservation release and maximum withdrawals at each reservoir.
c. Compile historical, current and projected water demands for individual and combined service areas.
d. Review PADEP drought contingency planning (DCP) guidelines and current AWA drought contingency plan. Update DCP resulting from reservoir management plan.
e. Compute physical properties of reservoirs including watershed area, storage-area-stage relationship, sediment storage zones and intake-withdrawal taking points.
f. Derive representative stream flow records with sufficient period of record. Apply monthly inflow data to specific reservoirs. Compute evaporation rates, diversions, minimum conservation releases, losses and contractual withdrawals (intermunicipal agreements). Prepare data for input to computer modeling program.
g. Perform reservoir routing using US Army Corps of Engineer's HEC Res-Sim 3.0 reservoir model simulation. Based on specified input data, generate storage scenarios for various demand conditions for individual and multi-reservoir watershed systems.
h. Perform economic analysis of reservoir production costs including treatment, pumping, conveyance and storage expenses. Compute unit operating costs for various operational scenarios.
i. Perform statistical and frequency analysis based on reservoir routing output. Predict storage limitations, demand reduction rules, shortage indices, dependable yields, drought durations and system interconnection restrictions.
j. Prepare a detailed report summarizing the findings of the evaluations. Provide all necessary narratives, graphs, mapping, simulation model/input, output, economic evaluation and recommendations.
k. If required, modify operating procedures to maximize system demand storage and minimize drought/shortage potential for the full range of hydrologic conditions.
l. If required, modify drought contingency plan to reflect the results of this reservoir management and operations plan.

RESERVOIR SYSTEM - HISTORY & DESCRIPTION

Overview of System - The Authority water system serves a population of 75,000 in Blair County, PA. The system extends from Tyrone Borough in the north to Hollidaysburg Borough in the south. The Authority owns the largest publicly-owned water system between Pittsburgh and Harrisburg.

The supply system serves sixty percent of Blair County residents with drinking water. Water is collected and stored in thirteen (13) reservoirs built on the eastern slope of the Allegheny Mountain range. The water supply and distribution system currently supplies water to all or a portion of the following municipalities: City of Altoona, Borough of Hollidaysburg, Borough of Bellwood, Allegheny Township, Antis Township, Blair Township, Frankstown Township, Freedom Township, Juniata Township, Logan Township and Snyder Township.

The Authority's water sources are comprised of seven reservoir systems and one well field. The reservoirs have a combined storage volume of 2.85 billion gallons and a net yield (Q_{7-10}) of 14.61 million gallons per day (mgd). The 31st Street well field, which is capable of producing 1-2 mgd, is reserved for emergency use only and is currently removed from service.

Water is treated at seven state-of-the-art water treatment facilities (WTF). Andronic Pappas WTF, with a capacity of 7.5 million gallons per day (MGD), treats raw water from the Horseshoe Curve reservoir system (Upper Kittanning Reservoir, William L. Cochran Impounding Reservoir and Lake Altoona). The other six plants are Plane Nine WTF (4.0 MGD), Tipton WTF (4.0 MGD), Bellwood WTF (5.0 MGD), Kettle WTF (2.0 MGD), Homer Gap WTF (1.0 MGD) and Mill Run WTF (5.0 MGD).

The present surface water sources were formerly two separate systems, known as the Blair Gap and the City of Altoona systems. Constructed for the Pennsylvania Railroad, reservoirs associated with the Blair Gap System included: Plane Nine, Kettle, Bellwood and Tipton. Water sources developed by the City of Altoona system consist of the Horseshoe Curve, Mill Run and Homer Gap Run reservoirs. All Authority dams are inspected annually. Please refer to the reservoir/watershed plan in the Appendix. These reservoirs are discussed as follows:

Blair Gap Reservoirs

- Plane Nine Reservoir System

  The Plane Nine Reservoir System consists of the Muleshoe dam (Hollidaysburg Borough), Plane Nine dam and the Blair Gap dam. They are located on Blair Gap Run about 6½ miles upstream from the confluence with the Beaverdam Branch of the Juniata River. These reservoirs have a storage volume of 217 million gallons with a tributary drainage area of 12.6 square miles. The yield, based upon the 50-year low flow criteria, was computed to be 1.3 mgd in the water allocation permit application.

  Blair Gap dam was constructed for the Pennsylvania Railroad in 1905 and has a capacity of 25 MG. The dam is a masonry gravity structure 316 feet long with a maximum height of 47 feet and water surface elevation of 1780 msl. Blair Gap Dam is the highest elevation reservoir in the Authority system.

Photo No. 1 - Blair Gap Reservoir

The dam serves as a storage reservoir and is not directly connected to the Plane Nine system. However, a 12" transmission main from Blair Gap dam traverses the Allegheny mountain ridge and connects to the Horseshoe Curve Reservoir system at the Cochran Impounding dam.

Due to the nature of its construction (masonry gravity type), no mandated improvements are required at Blair Gap dam. Siltation removal, sluice gate replacement and access road improvements were done in 1991. In 2005, the upstream face was waterproofed and the sluice gate intake valves and operators were refurbished.

Recent inspections appear to indicate that the structure is considered adequate and that existing seepage does not appear to threaten the integrity of the dam.

Plane Nine dam was constructed in 1907 for the Pennsylvania Railroad. The reservoir has a capacity of 120 MG with a spillway elevation of 1408 msl.

The dam is an earthen structure 735 feet in length with a maximum height of 51 feet. Recent improvements included an additional spillway, auxiliary flood wall, intake tower and access bridge. These improvements were implemented in 1991 at a cost of $3,700,000. Recent inspections appear to indicate that the embankment is in adequate condition.

Photo No. 2 - Plane Nine Reservoir

The Muleshoe dam is 66 feet high with a capacity of 72 million gallons and water surface elevation of 1576 msl. The earthen dam was constructed in 1956 and is owned and operated by Hollidaysburg. The Borough continues to retain ownership of the structure. However, the Borough relinquished watershed yield and reservoir capacity to the Authority in order to optimize the source for operational considerations. The Borough is planning to upgrade spillway capacity and make structural improvements in 2010 - 2011.

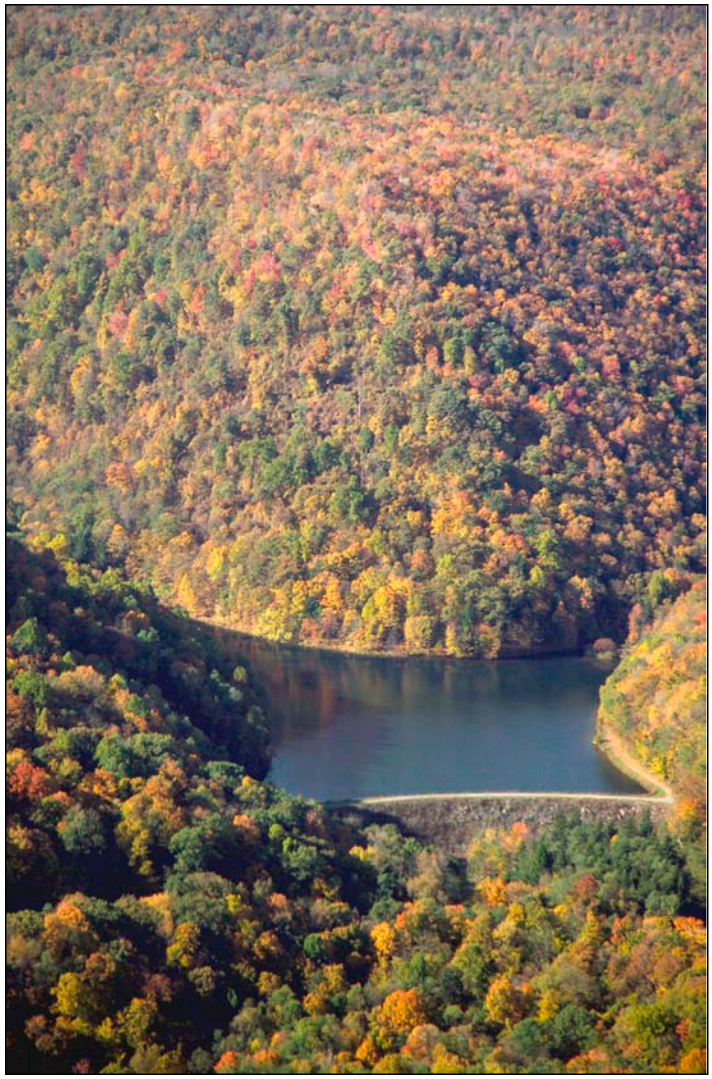


Photo No. 3 - Muleshoe Reservoir

With the inclusion of Hollidaysburg Borough in the regional treatment system, the Muleshoe Reservoir has been included in the Plane Nine operational plan. The Authority operates Muleshoe Reservoir as an integral system component. The computed safe yield of the Plane Nine Reservoir system was 1.30 mgd per the water allocation permit. The overflow from Muleshoe Reservoir discharges downstream into Plane Nine Reservoir. A 12" water transmission main from Muleshoe Reservoir traverses the left abutment of Plane Nine dam along old U.S. Route 22 to the Plane Nine treatment plant.

- Tipton Reservoir System

Tipton Reservoir is located on Tipton Run 4.5 miles upstream of its confluence with the Little Juniata River. This impoundment has a tributary drainage area of 8.57 square miles and a storage capacity of 320 million gallons. Tipton Reservoir also receives water from an intake on Loup Run, which is fed by a 3.0 square mile watershed.

Photo No. 4 - Tipton Reservoir

Tipton dam is a masonry gravity structure completed in 1924 for the Pennsylvania Railroad. The dam has a capacity of 320 million gallons at a spillway elevation of 1394 msl. The length is 555 feet with a maximum depth of 66 feet. Since the dam is a gravity masonry type, no mandated improvements have been required by PADEP.

Recent inspections indicate that the structure is in sound condition with nominal seepage. In 2005, the upstream face was waterproofed and the sluice gate intake valves and operators were refurbished.

Photo No. 5 - Loup Run Intake

Loup Run has an estimated capacity of 330,000 gallons and overflow elevation of 1448 msl.

The total drainage area is 11.57 square miles. The Tipton Reservoir system had computed a yield of 1.634 mgd (which did not include the yield of Loup Run) in the water allocation permit.

- Bellwood Reservoir System

Bellwood Reservoir, located on Bells Gap Run, has a tributary drainage area of 18.2 square miles and a storage capacity of 335 million gallons. The computed yield was 2.049 mgd, as reported in the water allocation permit application.

Photo No. 6 - Bellwood Reservoir

Bellwood dam is an earthen dam 1300 feet in length with a maximum height of 61 feet. The normal pool elevation is 1353 msl. The structure was constructed in 1902 for the Pennsylvania Railroad.

A significant enlargement of Bellwood dam was completed in 1946 for additional storage and spillway capacity. New PADEP criteria will necessitate a hydraulic/ hydrologic study to determine spillway adequacy. Recent inspections indicate that the embankment is structurally adequate and that existing seepage does not appear to affect the integrity of the dam.

- Kettle Reservoir System

Kettle Reservoir has watershed area of 2.5 square miles and a combined storage volume of 185 million gallons. A yield of 0.708 mgd was reported in the water allocation permit.

Photo No. 7 - Kettle Reservoir

The dam, with a normal water surface of 1717 msl, is 800 feet long and 54 feet high. The dam was constructed in 1888 for the Pennsylvania Railroad and is one of the oldest dams in the system. The structure was modified at a cost of $2,900,000 in 1990. The improvements included new spillway/floodwall, asphaltic concrete upstream deck, abutment drilling and grouting, intake tower and access bridge, toe drain, outlet valve control pit and access road. Elevationally, the dam is the second highest water reservoir in the system.

City Of Altoona Reservoirs

- Homer Gap Reservoir System

The Homer Gap reservoir has a drainage area of 2.47 square miles, a storage capacity of 26.7 million gallons and a computed yield of 0.202 mgd.

Homer Gap dam, with a normal water surface elevation of 1448.8 msl, is an earthfill embankment 1,250 feet in length with a maximum depth of 27 feet. The dam was originally constructed in 1914 for the Borough of Juniata. The property and water rights were acquired by the City of Altoona when the Borough was annexed in 1927. The dam was extensively modified in 1985 at a cost of $650,000. Dam improvements included new spillway, floodwall, silt removal and intake tower access bridge. Recent inspections indicate that the dam embankment is structurally adequate and has adequate hydraulic capacity for 50% of the probable maximum flood (PMF). Existing seepage does not appear to affect the integrity of the dam. A small settling basin, known as Homer Gap No. 1, is located upstream of the Homer Gap dam and has a negligible storage capacity of 75,000 gallons.

Photo No. 8 - Homer Gap Reservoir

- Mill Run Reservoir System

The Mill Run Reservoir system stores runoff from a 6.25 square mile drainage area in two impoundments, Mill Run Reservoir with a storage volume of 519 million gallons (with 6-foot inflatable rubber dam) and Allegheny Reservoir with a storage capacity of 46.8 million gallons. The yield is 2.4 mgd (with 6' high inflatable dam) as computed in the water allocation permit.

Mill Run dam was completed in 1958 as a new water source, principally to supplement City High Service. The dam has a water surface elevation of 1508 msl (with rubber dams) and an elevation of 1502 msl at the spillway. The dam is a zoned rockfill-earthfill embankment structure with a length of 1,200 feet and a height of 100 feet. This is the highest dam structure in the Authority system. However, the capacity places it second behind the Lake Altoona Reservoir.

A hydrologic and hydraulic evaluation of Mill Run dam was performed in 2010. The study revealed that the spillway and intake tower will eventually require replacement at a cost of about $9 million. Stabilization of the spillway slope is also to be performed.

Photo No. 9 - Mill Run Reservoir (1958)

Allegheny Reservoir, located downstream of Mill Run dam, is a sideline reservoir used to supplement Mill Run Reservoir from pumped storage. The earthen dam is 1,100 feet in length with a height of 31 feet. The reservoir has a water surface elevation of 1305.6 msl. Allegheny Reservoir is the lowest elevation impoundment in the Authority system.

The dam was constructed in 1905 by the Allegheny Water Company. The property and water rights were acquired by the City of Altoona in the 1920's and subsequently incorporated into the City system.

Due to the off-line nature of Allegheny Reservoir and capacity for the adjacent channel to pass 50% of the probable maximum flood, no mandated improvements have been required by DEP. The dam is considered to be in good condition based on recent inspections.

Photo No. 10 - Allegheny Reservoir

- Horseshoe Curve Reservoir System

The Horseshoe Curve reservoir system is comprised of three impoundments including Kittanning Point Reservoir, William L. Cochran Impounding Reservoir and Lake Altoona. This system has evolved over the years as an intricate hydraulic network of weirs, channels, spillways, tunnels and intakes.

Kittanning Point Reservoir has a total storage volume of 52.6 million gallons at a spillway elevation of 1496.0 msl. The earthen dam is 550 feet long and 45 feet deep. This reservoir is fed from intakes on Glen White Run and below the confluence with Kittanning Run. The total tributary drainage area is 8.99 square miles.

Kittanning Point Reservoir was constructed in 1884 for the City of Altoona water system by the Pennsylvania Railroad and is the oldest reservoir in the system. Coincident with construction of the Impounding Dam, a stone-masonry bypass channel/emergency spillway system was constructed in 1895-1898. This system was built for hydraulic and water quality purposes because of acid mine drainage formation in the watershed. During the WPA era, the diversion channel was extended to channelize Kittanning Run and Glen White Run upstream of the Horseshoe Curve. In 1985, dam improvements included three emergency spillways, floodwall, access road, access bridge, and intake valve house renovations. Recent inspections indicate that the embankment to be structurally sound with nominal seepage.

The downstream reservoir is the Cochran Impounding Reservoir. This structure has a storage capacity of 309 million gallons. The drainage area tributary to the Cochran-Impounding dam increases inflow only slightly (roughly 0.6 square miles) so that it's principal runoff source is overflow from Kittanning Point Reservoir.

The Cochran Impounding Reservoir was constructed in 1895-1898 by the City of Altoona as an additional water supply for Low Service. The dam is an earthfill structure, 1000 feet in length, depth of 54 feet and water surface elevation with inflatable rubber dam of 1434.6 msl. The dam currently serves as hydraulic control for the operation of the Andronic Pappas Water Treatment Plant. Dam modifications were completed in 1987 for $4,200,000. The improvements include an emergency spillway, primary spillway, bypass channel modifications, intake tower, inflatable rubber dam, rockfill upstream embankment, foundation drilling and grouting and PVC upstream slope membrane. Recent inspections indicate that the embankment is adequate and seepage normal.

The third impoundment is Lake Altoona with a capacity of 835 million gallons. This capacity includes the storage from a 4-foot inflatable rubber dam. The total drainage area above Lake Altoona is 12.4 square miles, which includes Scotch Gap Run. An intake on Scotch Gap Run can be piped directly to Lake Altoona. It is now silted-in.

Lake Altoona dam was completed in 1908 by the City of Altoona. The dam has a depth of 73 feet and a total crest length of 1650 feet. The water surface elevation with a four foot inflatable dam is 1359.1 msl. The earthfill embankment incorporates a concrete cutoff wall extending from the bottom of cutoff trench to the crest of the dam. The adjacent concrete bypass channel was constructed at that time in addition to Scotch Gap Reservoir (for settling purposes) and a bypass tunnel connecting the channel adjacent to the Cochran-Impounding Reservoir. The reservoir originally fed the Altoona Low Service system and supplemented the Altoona High Service system by pumping.

Photo No. 11 - Horseshoe Curve Reservoir Systems

Improvements to Lake Altoona were completed in 2000 at a cost of $8 million including bypass channel/spillway replacement, intake tower modifications, floodwall and discharge channel rehabilitation.

Flow from Burgoon Run normally discharges to a diversion channel, which bypasses all the reservoir as previously stated. This bypass channel also receives the discharge from Scotch Gap Run. Below Scotch Gap Run, the channel is provided with an intake structure for the option of diverting flow into Lake Altoona. The yield of this reservoir system was computed to be 6.32 mgd in the water allocation permit.

Together, Kittanning Reservoir, the Cochran-Impounding Reservoir and Lake Altoona comprise the Authority's largest water supply with over 1.2 billion gallons of available storage. The system comprises 42% of total system storage.

SERVICE AREA GRADIENTS AND DESCRIPTIONS

General - The hydraulic gradient of the Authority system is shown on the following diagram. The upper diagram shows the system as it existed in 1981 when the Authority assumed ownership of the system. The lower diagram shows the current configuration of the system along with all improvements made to the system in the last 30 years. Each reservoir system normally services a dedicated gradient with sub-gradients fed from pump stations and storage tanks. However, any reservoir system is capable of serving any major gradient through a network of interconnections and pump stations. A plan of the service area and reservoirs is shown in the Appendix.

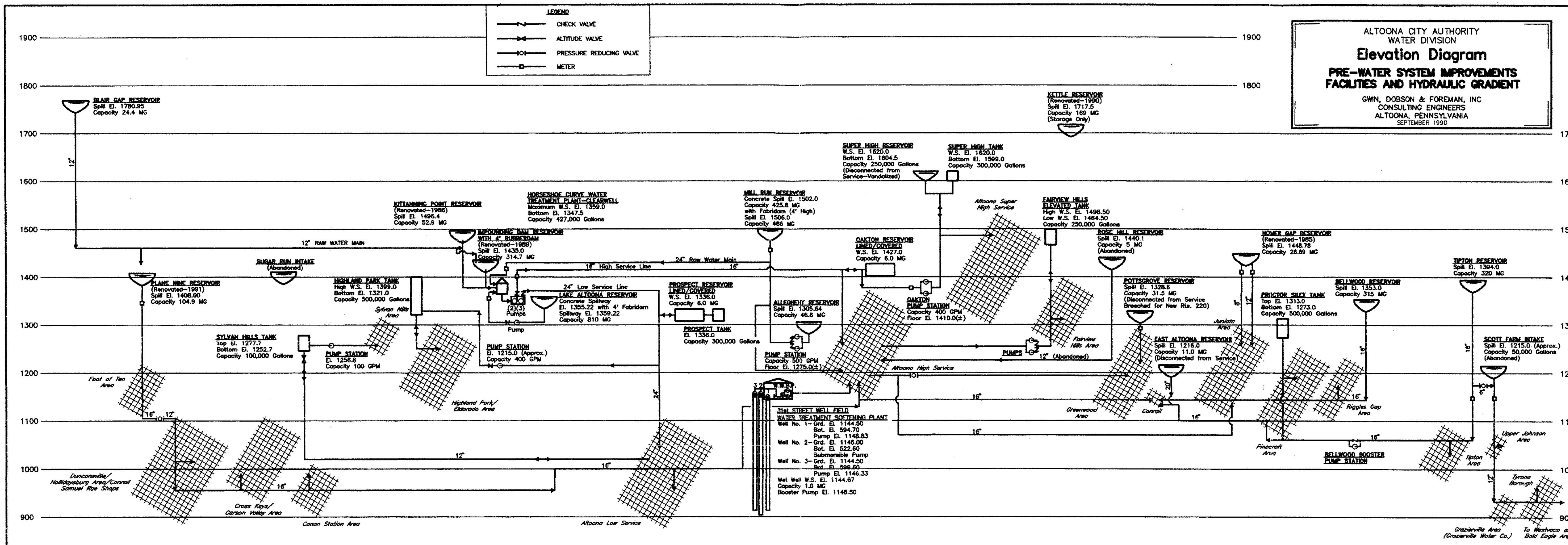
Blair Gap System

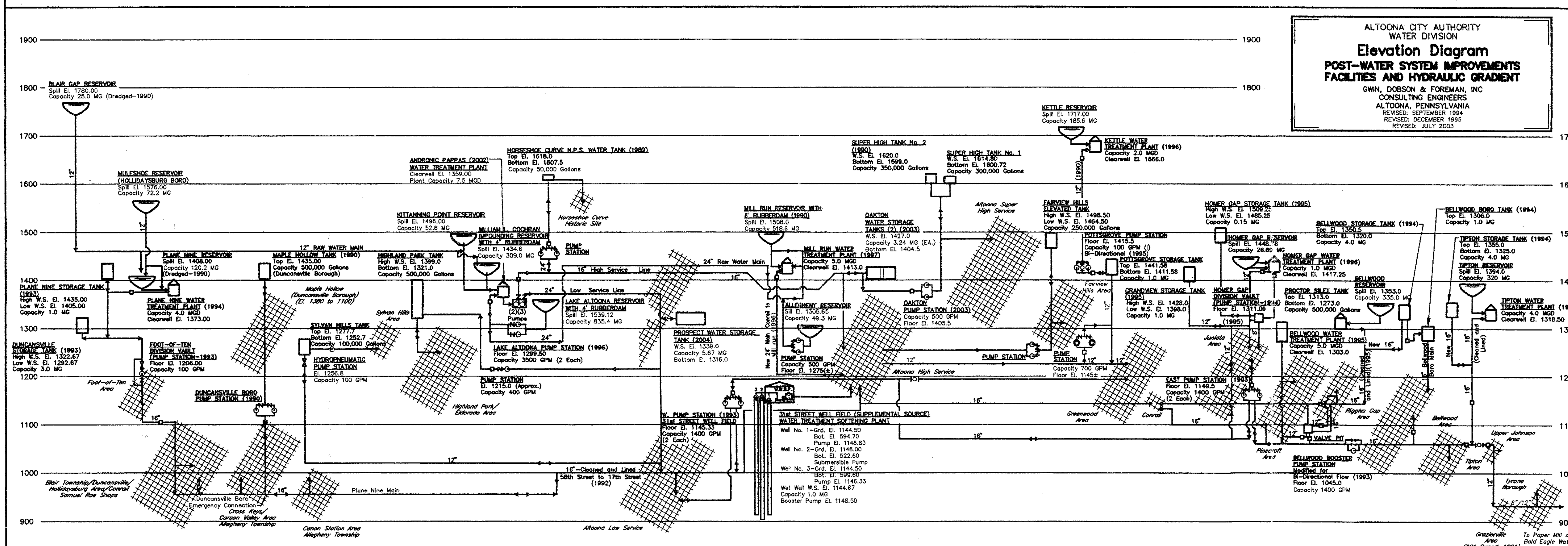
- **Plane Nine System** - The Plane Nine System and distribution system extends 12 miles from Blair Gap Reservoir to a division valve at 9th Avenue and 8th Street in the City of Altoona.

  A 16-inch transmission line follows U.S. Route 22 to the Foot of Ten Road (Old Route 22), along the Foot of Ten Road to the Duncansville intersection and through the Borough of Duncansville (Route 22) to the Wye Switches. There the line splits with a 16" line following the Hollidaysburg Branch railroad to 8th Street in Altoona while the 12" line follows Route 22 to the former Samuel Rea Shops in Hollidaysburg.

  The system has expanded through the years for intermunicipal service to Hollidaysburg Borough, Duncansville Borough, Blair Township and Freedom Township.

  As shown on the hydraulic gradient plan, a 1.0 mg tank serves the upper elevations while a 3.0 mg tank serves the lower areas. The Plane Nine system serves about 450 customers including four intermunicipal connections.





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As previously mentioned, Blair Gap Reservoir originally served the Horseshoe Curve with a 12" line. Its main function was to replenish water supplies of the stream locomotives operating on the Pennsylvania Railroad. However, with the development of diesel-electric locomotives and the phase out of steam engines, the operation of this system became unnecessary. In 1955, the transmission main from Blair Gap Dam to Kittanning Point Reservoir was operationally abandoned. It is interesting to note that this entire system remains intact to this day. It has been periodically reactivated to supply Cochran Impounding Dam or directly connected to the Pappas Water Treatment Plant.

- **Tipton System** - The Tipton System extends from Tipton Dam 3.5 miles along State Route 859 to the Village of Tipton and then via the 16-inch main west along the railroad mainline to the Norfolk Southern Shop Complex at 4th Avenue and 5th Street, Juniata. The entire length of the 16-inch main is 12.5 miles. Some portions of the main have been cleaned and lined recently.

  Tipton supplies water to several commercial customers (including DelGrosso's, I-99 Enterprise Campus and Peterson Industrial Park) and residential Villages of Tipton, Bellemead, Pinecroft and Grazierville and the Norfolk-Southern railroad complex in Juniata. A total of 750 customers are served by the Tipton system.

  A 4.0 mg water storage tank located above PA Route 859 between the water treatment plant and the Village of Tipton sets the hydraulic gradient for this system.

  A 12-inch branch main at Tipton follows the railroad north to Tyrone and then along Logan Avenue to the American Eagle paper mill on Pennsylvania Avenue. This was the line formerly supplied by Mulligan Run and Scott Farm intakes which have since been abandoned. The 12-inch line is 4.75 miles in length from Tipton to Tyrone.

- **Bellwood System** - The Bellwood system extends from Bellwood Dam (1.25 miles northwest of Roots Crossing); then along Bell's Run to Roots Crossing, then cross-country and paralleling L.R. 07026; then crossing Sugar Run and Township Road T-485 and then going cross-country until it meets the railroad mainline (0.6 miles east of Antis Tower). From Antis Tower, the line follows the mainline to the Norfolk Southern Railroad power plant at 4th Avenue and 2nd Street, Juniata where it enters the shop complex. The main transmission line is a 16-inch diameter pipe. A portion of this main was cleaned and lined in 1995. The total length of this 16-main is 8 miles.

  The primary function of the Bellwood system is to serve the Borough of Bellwood and the NS rail complex. About 150 customers are served. A 4.0 mg storage tank controls the gradient near the Roots Crossing area. A 2.0 mgd bi-directional pump station (Bellwood Booster station) is capable of feeding either the Bellwood or Tipton gradients from either reservoir source.

  The system has expanded to supply the Borough of Bellwood. The interconnection is made at the Bellwood water treatment facility which fills the adjacent Borough tank.

- **Kettle System** - A 12-inch transmission line extends 2 miles from Kettle Dam through Greenwood and the East End areas of Altoona to the 4th Street and 9th Avenue area of Altoona. There, it cross-connects with the Bellwood system and continues to a division valve at 9th Avenue and 8th Street. The 12-inch main (formerly known as the "Fire Line") was cleaned and lined recently. A 1.0 mg storage tank serves as the hydraulic gradient near the former location of the Rose Hill intake. The Kettle system serves over 500 customers.

  The Kettle system is now a subsystem of the City High Service area. A pump station near 9th Avenue and Bellwood Avenue (at the Easterly CSO facility) has a capacity of 1.0 mgd which can transfer flow to-and-from the Kettle and City High Service gradients. The 1.0 mg tank ("Pottsgrove" tank) is capable of feeding High Service by gravity.

City Systems

- **Altoona Low Service** - The Altoona Low Service system is supplied by high capacity pumps at the Pappas water treatment facility. These pumps are connected to the Prospect distribution reservoir (5.67 mg) via a 24-inch transmission line. The service area consists of City customers below elevation 1250 feet. Satellite storage is provided by a 0.1 mg storage tank in the Sylvan Hills area. Another subsystem of Altoona Low Service is located in the Highland Park area, with associated pumps and 0.5 mg storage tank. A portion of the 24-inch main was recently cleaned and lined. Prospect storage reservoir was replaced with a 5.67 mg capacity prestressed concrete storage tank at overflow elevation 1337 msl.

  The Horseshoe Curve and Mill Run watersheds provide the water supply to Altoona Low Service. The total length of transmission main is 5 miles from the Pappas treatment plant to the Prospect storage tank. This system supplies about 12,000 customers.

- **Altoona High Service** - The Altoona High Service system is supplied by pumps at the Pappas water treatment facility. These pumps are connected to the Oakton storage tanks by a 16" transmission main and serve the higher areas of the city below elevation 1340. Sub-gradients include Fairview Hills and Super High (above Beverly Hills and the PSU Altoona Campus) each with a pump/storage tank system. The system currently supplies about 10,000 customers including about 2,000 customers in the Homer Gap system (Juniata) and 500 customers in the Kettle system.

  The Horseshoe Curve and Mill Run watersheds provide water supply to Altoona High Service. The total length of the transmission main from the Horseshoe Curve water treatment to the Oakton storage tanks is 4 miles. Sections of this line were recently cleaned and lined or replaced. The Oakton reservoir was replaced with two prestressed concrete 3.24 mg capacity storage tanks in 2003.

- **Juniata** - The Juniata system is supplied with water from Homer Gap reservoir through two transmission mains, 8" and 12" in diameter. The customer area is the Juniata section of the City. The system has approximately 2000 customers. A 1 mg capacity storage tank provides pressure control for the system near the Grandview area. The total distance from Homer Gap to the Juniata area is 3.5 miles. As noted, the Juniata area is now fed directly by Altoona High Service.

CURRENT RESERVOIR MANAGEMENT PLAN

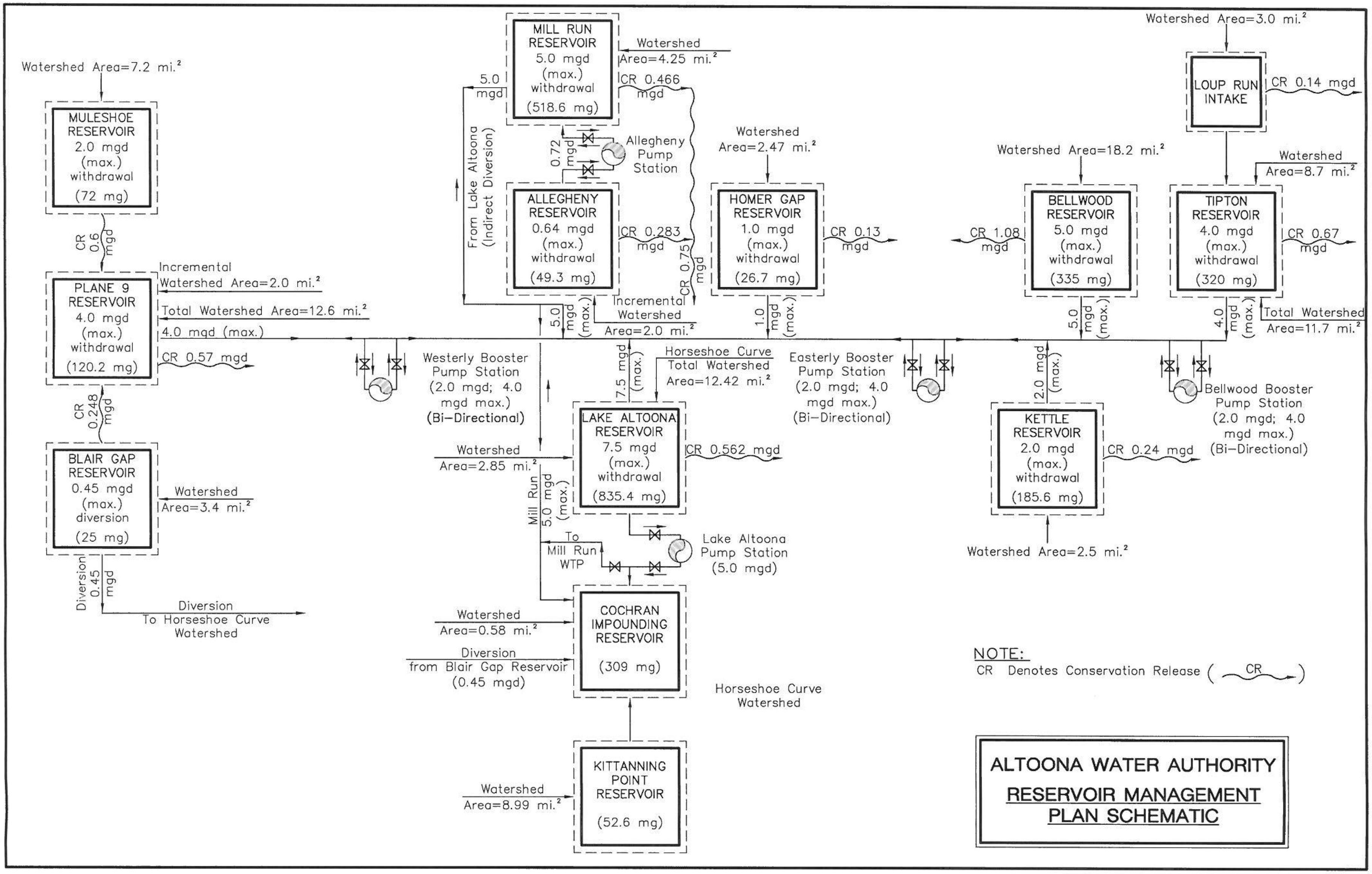
The Altoona City Authority has multi-source conveyance capabilities. Water can be transmitted to any part of the system from virtually any source by a network of pump stations, storage tanks and transmission mains. This capability ensures continuous service, without interruption, for virtually any contingency. Therefore, the current watershed and reservoir management plan reflects typical daily operations, given average consumption conditions and reservoirs at-or-slightly-below normal pool elevations. Please refer to the reservoir management schematic on the following page.

- **Horseshoe Curve Reservoir System, Upper Kittanning/William L. Cochran Impounding and Lake Altoona Reservoirs** - The Andronic Pappas water treatment facility treats water supplied from the Upper Kittanning, Cochran Impounding and Lake Altoona Reservoirs on Burgoon Run. The Horseshoe Curve reservoirs are located in-series.

  The Upper Kittanning reservoir overflows into the Cochran Impounding Reservoir. Under normal conditions, the Cochran-Impounding Reservoir is used every day, year round to supply water to the City of Altoona. When required, the Lake Altoona Reservoir is drawn from 3-4 months out of the year and is conveyed to the Pappas treatment plant by the Lake Altoona pump station. The City has two major service areas, City High service and City Low service. The High Service district receives about 1.5 million gallons per day from the Horseshoe Curve system. The Low Service district receives about 1.75 million gallons per day from the Horseshoe Curve system. Water from the Blair Gap watershed can be conveyed to the Cochran-Impounding Reservoir by a gravity 12" transmission main (about 1.0 MGD).

  The Oakton (High Service) and Prospect (Low Service) storage tanks maintain the hydraulic gradient or pressure control on each system. The tanks are supplied from both the Andronic Pappas and Mill Run treatment facilities via a system of pumps, controlled manually or automatically in response to reservoir level. Also, a pump station located at the Oakton site supplies water to the City Super High service district. The Horseshoe Curve system can receive water supply from the Mill Run system in special situations and during drought conditions.

- **Mill Run and Allegheny Reservoirs** - Mill Run WTF treats water supplied from the Mill Run and Allegheny Reservoirs. Under normal conditions the Mill Run reservoir is used every day, year round to supply water to the Altoona's Low and High Service districts. The Allegheny Reservoir is occasionally used (via pump station) in conjunction with Mill Run Reservoir when Mill Run Reservoir storage declines, normally in the fall. Currently, the Mill Run System are treated at the Andronic Pappas WTF via a gravity 24" transmission main. Conversely, Lake Altoona (and, in general, the Horseshoe Curve reservoir system) can, in rare occurrences, be treated at the Mill Run WTF via the Lake Altoona pump station and the same 24" main.


ALTOONA WATER AUTHORITY
RESERVOIR MANAGEMENT PLAN SCHEMATIC
MULESHOE RESERVOIR 2.0 mgd (max.) withdrawal (72 mg)
Watershed Area=7.2 mi.²
CR 0.6 mgd
PLANE 9 RESERVOIR 4.0 mgd (max.) withdrawal (120.2 mg)
Incremental Watershed Area=2.0 mi.²
Total Watershed Area=12.6 mi.²
4.0 mgd (max.)
CR 0.57 mgd
CR 0.248 mgd
BLAIR GAP RESERVOIR 0.45 mgd (max.) diversion (25 mg)
Watershed Area=3.4 mi.²
Diversion 0.45 mgd
Diversion To Horseshoe Curve Watershed
MILL RUN RESERVOIR 5.0 mgd (max.) withdrawal (518.6 mg)
Watershed Area=4.25 mi.²
CR 0.466 mgd
5.0 mgd
From Lake Altoona (Indirect Diversion)
0.72 mgd
Allegheny Pump Station
ALLEGHENY RESERVOIR 0.64 mgd (max.) withdrawal (49.3 mg)
CR 0.283 mgd
CR 0.75 mgd
Incremental Watershed Area=2.0 mi.²
5.0 mgd (max.)
Westerly Booster Pump Station (2.0 mgd; 4.0 mgd max.) (Bi-Directional)
HOMER GAP RESERVOIR 1.0 mgd (max.) withdrawal (26.7 mg)
Watershed Area=2.47 mi.²
CR 0.13 mgd
1.0 mgd (max.)
7.5 mgd (max.)
Horseshoe Curve Total Watershed Area=12.42 mi.²
LAKE ALTOONA RESERVOIR 7.5 mgd (max.) withdrawal (835.4 mg)
Watershed Area=2.85 mi.²
CR 0.562 mgd
Mill Run 5.0 mgd (max.)
To Mill Run WTP
Lake Altoona Pump Station (5.0 mgd)
COCHRAN IMPOUNDING RESERVOIR (309 mg)
Watershed Area=0.58 mi.²
Diversion from Blair Gap Reservoir (0.45 mgd)
Horseshoe Curve Watershed
KITTANNING POINT RESERVOIR (52.6 mg)
Watershed Area=8.99 mi.²
Easterly Booster Pump Station (2.0 mgd; 4.0 mgd max.) (Bi-Directional)
BELLWOOD RESERVOIR 5.0 mgd (max.) withdrawal (335 mg)
Watershed Area=18.2 mi.²
CR 1.08 mgd
5.0 mgd (max.)
2.0 mgd (max.)
KETTLE RESERVOIR 2.0 mgd (max.) withdrawal (185.6 mg)
CR 0.24 mgd
Watershed Area=2.5 mi.²
LOUP RUN INTAKE
Watershed Area=3.0 mi.²
CR 0.14 mgd
TIPTON RESERVOIR 4.0 mgd (max.) withdrawal (320 mg)
Watershed Area=8.7 mi.²
CR 0.67 mgd
4.0 mgd (max.)
Total Watershed Area=11.7 mi.²
Bellwood Booster Pump Station (2.0 mgd; 4.0 mgd max.) (Bi-Directional)
NOTE:
CR Denotes Conservation Release (CR)

- **Plane Nine, Muleshoe and Blair Gap Reservoirs** - Plane Nine WTF treats water supplied by the Blair Gap, Plane Nine and Muleshoe reservoirs on Blair Gap Run. Under normal conditions, the Plane Nine and Muleshoe reservoirs are used every day, year round to supply water to Hollidaysburg Borough, Blair Township, Duncansville Borough (emergency), Allegheny Township and Freedom Township. The Plane Nine system can be supplied with water from Altoona's Low and High Service districts by utilizing the Westerly pump station. Conversely, Plane Nine can supply water to the City from this pump station. The Blair Gap Reservoir is not drawn from, except during drought situations, to help service the areas mentioned above. Also, the Blair Gap Reservoir has the capability to divert raw water to the Cochran Impounding Reservoir by a 12" gravity transmission main when stream flow conditions allow.

- **Tipton Reservoir -** The Tipton WTF treats water supplied by the Tipton Reservoir. Under normal conditions the Tipton reservoir is used every other day, year round to supply water to the Norfolk Southern Railroad (Juniata) Tipton, East Altoona and Grazierville. The Tipton service area can supplemented by Altoona Low and High Service District's via the Easterly booster pump station and a system of 16" transmission mains. Conversely, Tipton can supply water to the Altoona service districts from this pump station.

- **Bellwood Reservoir** - The Bellwood WTF treats water supplied by the Bellwood Reservoir on Bells Gap Run. Under normal conditions the Bellwood Reservoir is used every day, year round to supply water to Bellwood Borough and other customers. The Bellwood system can be supplemented with water from Altoona's Low and High Service districts by the Easterly booster pump station. The Bellwood service area can be served from the Tipton system, when needed, via the Bellwood booster pump station. Conversely, this system can be supplied from Bellwood through these pump stations.

- **Kettle Reservoir** - Kettle WTF treats water from the Kettle Run Reservoir. Before 2006, Kettle Reservoir was used every day, year round to supply water to Altoona's East End, Greenwood and Bellmeade areas. The Kettle service area is currently served from Altoona High Service via a booster pump station, located at East 6th Avenue and Kettle Street, when needed.

- **Homer Gap Reservoir** - The Homer Gap WTF treats water supplied from Homer Gap Reservoir. Before 2006, the Homer Gap Reservoir was used every day, year round to supply water to the Juniata by the Grandview tank. The Homer Gap service area is currently served from Altoona High Service. The Upper Homer Gap area can be served from High Service via a booster pump station, located near the Homer Gap Reservoir, when needed. Also, Homer Gap water can supplement Altoona High Service by the Grandview tank.

RESERVOIR OPERATION CONCEPTS

The operation of a reservoir system may be summarized by the following excerpt from a leading text:

- Operations during "normal" hydrologic conditions from the standpoint of optimizing daily, seasonal and annual use of the reservoir system.

- Operations from the perspective of maintaining capabilities for responding to future hydrologic extremes. This would include provision for maintaining reliable supplies of water at all times.

- Operations during hydrologic extremes including flood events and low flow or drought conditions.

An operating plan or release policy is a set of rules for determining the amount of water to be stored and withdrawn from a reservoir system. Operating rules and decisions include the allocation of storage capacity for multiple water users, minimizing the risks of water shortages, optimizing beneficial water use and managing environmental resources.

Reservoir Operation Simulation Modeling

The US Army Corps of Engineers developed "HEC-5-Simulation of Flood Control and Conservation Systems" to perform detailed reservoir system analysis. This model has been supplanted by HEC Res-Sim 3.0 which will be discussed in greater detail in the following section.

We utilized the Res-Sim 3.0 simulation model in our operational evaluation of the AWA reservoir system. It simulates the sequential period-by-period operation of a reservoir system for input sequences of unregulated streamflows and evaporation rates. The program uses a variable time interval. In our case, monthly data is used during periods of normal or low flow. User specified operating rules include inputting reservoir storage zones, withdrawals/diversions and minimum instream flow targets. The model makes release decisions to meet user-specified withdrawals/ diversions and instream flow targets based on storage levels. Model output includes yield and storage determination along with reservoir depletion volumes and indices.

Basic input parameters of Res-Sim 3.0 are as follows:

- Each reservoir must be physically described in terms of storage volume, surface area and reservoir elevation. Hydrographic surveys provide basic information for computation of storage-area-elevation relationships. The average end-area method is generally used for computation purposes, although the conic method is also employed.

- The minimum pool elevation at the bottom of active conservation storage establishes lower limit of normal reservoir drawdown. This inactive zone can be used for sediment storage and often contains poor water quality which is unsuitable for instream aquatic releases or potable water use.

  This zone can also be defined as the hydraulic limit of gravity flow to a downstream water treatment facility or the lowest outlet of a dam. It is generally specific to the individual reservoir.

The Corps of Engineers has summarized the operation of reservoir systems in EM 1110-2-1420, "Hydrologic Engineering Requirements for Reservoirs." Their experience in managing their extensive system of multi-purpose reservoirs has led to development of simulation software and engineering manuals. Excerpts from EM 1110-2-1420, "Hydrologic Engineering Requirements for Reservoirs" are relevant to our current study. Water resource system operation is typically modeled mathematically. It is necessary to simulate the detailed sequential operation of a system representing the manner in which each element will function under realistic conditions of inputs and system requirements.

For public water supplies, shortages are the overwhelming concern and principal object to be avoided. Therefore, operating rules are developed that specify quantities of water to be released and reservoir storage to be maintained. These quantities will vary seasonally along with the amount of storage in the system. "Rule curves" are developed for each parameter and tested on the basis of synthetic or historical stream flows (inputs) and system requirements (outputs). The reservoir system must be completely described in terms of the location and functional characteristics. A simulation model must include all components that affect project operation and the required outputs.

The two principal operating needs are "flood control" and "conservation" storage. The AWA reservoirs provide conservation storage for public water supply and to maintain in-stream flow for aquatic life. This storage is occupied from the top of spillway to the top of the sediment deposition/unusable storage zone. The zone above the conservation zone from the top of spillway to the top of dam is known as the "surcharge" zone used to convey floods through the reservoir. The "unusable" storage zone is reserved for sediment (both current and future) and/or poor water quality unsuitable for drinking water purposes or aquatic life.

- Losses must be specified for evaporation or known leakage through the reservoir basin. Typically, evaporation factors are applied to reservoir surface areas. Reservoir losses into groundwater are generally not accounted for. Over time, accumulated silt tends to "seal" the reservoir bottom.

- Withdrawals and diversions are releases from the reservoir to satisfy public water supply needs. Such needs are based on an analysis of historical water use. Projections are based on anticipated growth in the service area or a statistical analysis using regression techniques.

- For stream flow, historical period-of-record streamflows adjusted to represent the specified locations must be developed. Typically, long term gaged streamflow records from USGS stations are utilized.

- Rule curves for the top and bottom of the conservation zone has been previously discussed. When the bottom of conservation storage (on top of sediment storage), inflow must equal outflow. Outflow, in this case, satisfying some degree of water demand or acting as in-stream-releases. However, operating rules may include triggering mechanisms by which certain demands are curtailed when storage falls below pre-specified levels. Public water supplies require a high degree of reliability. Specifying the withdrawal as a function of storage is called a "hedging rule." The rule curves used a triggering mechanism are called "buffer zones" or "ration storage zone."

RES-SIM 3.0 MODEL INPUT PARAMETERS

The following input parameters to the Res-Dim 3.0 simulation model are discussed in the following section. Each parameter will be discussed in detail along with regulatory requirements as they affect model operation.

Water Allocation Permit

The PADEP issued a Water Allocation Permit on April 29, 2008. The key permit provisions pertaining to this study include:

- Maximum combined withdrawal allowance of 14.5 million gallons per day (mgd) from 13 reservoir sources with a combined storage of 2,850 million gallons (mg) (or 2.85 billion gallons)

- Conservation releases are specified for each reservoir

- Permit duration is 25 years, expiring April 29, 2033

- Maximum withdrawals from individual reservoir systems are generally based on maximum treatment plant capacities

- Update drought contingency plan

- Unaccounted-for-usage shall be reduced to a level of 30% within 5 years (2013) and to 20% within 10 years (2018)

- Develop an unaccounted-for-water (UAW) use reduction program within six months or October 26, 2008

- Develop a reservoir operations plan within 3 years or April 29, 2011

The AWA has made progress in meeting specified permit goals. Measurement and data recording devices have been installed at all reservoirs and are continuously maintained. A UAW reduction program was submitted to and approved by PADEP. UAW has recently averaged 12%, a reduction from 40% in 2002. A provisional drought contingency plan was approved by PADEP in February 2010.

Table 1 provides a summary of allowable withdrawals and conservation releases.

Table 1 - Summary of Allowable Reservoir Withdrawals and Conservation Releases

Service Area[(1)]	Reservoir	Maximum Withdrawal/ Diversion (mgd)	Conservation Release (mgd)
Bellwood	Bellwood	5.0	1.080
Juniata	Homer Gap	1.0	0.130
Greenwood	Kettle	2.0	0.240
Plane Nine	Blair Gap Muleshoe Plane Nine	0.45 2.0 4.0	0.248 0.600 0.570
Tipton	Loup Run Intake Tipton	- 4.0	0.140 0.670
Mill Run[(2)]	Allegheny Mill Run	- 5.0	0.283 0.466
Horseshoe Curve[(2)]	Kittanning Point Cochran Impounding Lake Altoona	- - 7.5	- - 0.562

Notes:

(1) Service areas represent normal operating gradients supplied by the reservoir sources. However, the reservoirs can be water sources to multiple service areas/gradients because of the fully integrated and interconnected AWA transmission system.

(2) These service areas are considered City of Altoona service areas including Low Service and High Service.

Drought Contingency Planning - The AWA Drought Contingency Plan (DCP) was first developed in response to a previous May 21, 1984 PADEP water allocation permit and was included in the AWA's March 23, 1992 WAP application. The plan was based on certain assumptions concerning system demand/available storage and the DEP drought stages existing at the time. It is summarized as follows:

Table 2 - 1984 Drought Contingency Plan

Stage	Trigger	Corresponding Total System Storage (mg)	Storage Days @ 9 mgd	Demand Measures
I	75% Storage	2,138	238	Voluntary Conservation
II	50% Storage	1,425	158	Mandatory Restrictions
III	40% Storage	1,140	127	Water Rationing
IV	30% Storage	855	95	Shedding Customers
V	26% Storage	741	82	Priority Uses

A revised drought contingency plan was approved by PADEP on February 4, 2011 as set forth in Table 3.

Table 3 - 2011 Drought Contingency Plan

Stage	Trigger	Corresponding Total System Storage (mg)	Storage Days @ 9 mgd	Drought Stage
I	75%	2,150	240	Drought Watch
II	50%	1,425	158	Drought Warning
III	35%	1,000	111	Drought Emergency

The approved DCP is considered provisional until the reservoir operation plan is complete. A revised DCP will then be resubmitted to PADEP with any changes resulting from the reservoir plan.

PADEP technical criteria is provided in "Drought Management Guidelines for Public Water Suppliers, 2007." The document includes demand and supply measures to be implemented during periods of drought and shortages. These are supplemented by regional drought response measures designated by the Governor and Pennsylvania Emergency Management Council. The trigger points, demand measures and supply measures have been formalized in a Drought Contingency Plan Summary (Form 3920-FM-WM0023, Rev. 10/2007).

To quantify drought shortages, PADEP has suggested the following guidelines for public water supply reservoir sources:

- Reservoir storage levels should be monitored and used for triggering the various stages of a drought contingency plan. A trigger is a device used to indicate the severity or stage of a localized drought.

- Drought stages must correspond to Stage I (drought watch), Stage II (drought warning) and Stage III (drought emergency).

- Technical analysis generally follows the traditional mass inflow technique and the hydrologic book-keeping formula, i.e., Final Storage = Initial Storage + Inflow - Demand - Losses (evaporation, conservation releases). This procedure is essentially a reservoir routing equation.

- The number of days remaining in a reservoir is an important parameter for use in triggering the various stages of a DCP. This is computed by dividing total storage by average daily demand, assuming stream inflow equals losses (evaporation, conservation releases).

- Severe droughts are defined as having a frequency of 50 years or greater. If during this time, a drawdown/recovery period exceeds 12 months, the impounding is classified as a "large" reservoir. If the periods are less than 12 months, the reservoir is considered "small."

- For "small" reservoirs with 90 days or less of storage, a no-spill condition is considered for first trigger for voluntary restrictions (Stage I). For 60-days or less of storage, mandatory non-essential use restrictions are considered the second trigger (Stage II). The final trigger corresponds to 30-40 days of water supply or water rationing (Stage III).

- For "small reservoirs," PADEP considers that reservoir refill and recovery occurs between September 12 to February 28 (169 days). The time of storage and drought triggers are predicated on this refill/recovery period. The response measures are triggered if insufficient storage time exists until February 28.

- "Large" reservoirs (exceeding 12-month recovery/refill periods for extreme drought) are subject to intensive reservoir routing using long-term stream flow records (greater than 50 years), operating rules for various storage levels and demand conditions are generated from the hydrologic study, using flow simulation over the period of record and the routing equation.

The City had experienced restrictions particularly in the 1960's as its supplies were limited to the Mill Run, Homer Gap and Horseshoe Curve reservoirs. Ever since the "Blair Gap" system was acquired, no storage or supply deficiencies have occurred. The AWA system has never instituted mandatory restrictions or water rationing since the 1981 acquisition of the Blair Gap water system. The Blair Gap systm added one billion gallons from five reservoirs or a 50% increase in storage. Sufficient storage and supply have been maintained during all drought conditions. Obviously, this 30-year period or record may not be of a sufficient duration for an extreme drought event. Nevertheless, system storage would have to be reduced to 28% (at current 9 MGD demand) to even trigger DEP Stage II voluntary restrictions.

Contracted Water Supply - AWA maintains agreements with several municipalities for water supply. These are considered contractual obligations during all but the most extreme periods of shortage. Relevant agreement provisions are set forth in Table 4.

Table 4 - Intermunicipal Supply Obligations

Municipality	Date	Term	Primary Source	Average Allocation	Maximum Allocation	O&M/Capital Cost Recovery
Hollidaysburg Boro	04/27/92	Perpetuity	Plane 9	1.45 MGD	1.82 MGD	Proportional Use
Bellwood Boro	05/12/92	Perpetuity	Bellwood	0.85 MGD	1.25 MGD	Proportional Use
Duncansville Boro	05/05/92	Perpetuity	Plane 9	Supplemental	N/A	AWA Rate Schedule
Freedom Twp.	04/25/03	Perpetuity	Plane 9	0.073	0.1095	AWA Rate Schedule
Blair Twp.	12/08/92	Perpetuity	Plane 9	0.30	0.45	AWA Rate Schedule

Features of these municipal agreements include:

- Municipalities must adhere to AWA drought contingency plan in the event of drought conditions, emergencies or shortages.
- Municipalities are to monitor, identify and correct leakage and excessive lost water. Experience over the last 20 years has shown that all municipalities have effectively controlled lost water.
- AWA can supply municipalities from sources other than the primary source listed above. The AWA has not exercised this flexibility over the last 20 years.

Several private systems purchase AWA water based on the AWA rate schedule. These systems are the Mill Road Water Association, Grandview Trailer Park and Willowbrook Mobile Home Park. The total estimated usage is insignificant (0.044 MGD) compared to total demand.

For purposes of this study, these contractual water supply needs have a priority in terms of allocating total system supply. The PADEP water allocation permit recognizes these "contract" obligations with language that states, in part, *"…the permittee (AWA) shall not interrupt or terminate service of water..."* Further, *"…except pursuant to the terms of the contract, that emergency reductions in sale and delivery of water may be implemented commensurate with emergency water use restrictions imposed throughout the permittee's service area..."*

Insofar as possible, these municipalities will be allocated water up to their contracted flow in the reservoir routing model. A more detailed discussion about reservoir operating rules and conditions will be discussed in the simulation model section.

Streamflow Simulation - Traditionally, the USGS gaging station on Bald Eagle Creek at Tyrone (No. 1557500) has been used for correlation and development of low flow data for AWA reservoirs (Reference: Bulletin No. 7 - Long Duration Low Flow of PA streams, PADEP State Water Plan Division). This station has significance since it largely drains the eastern flank of the Allegheny Front. The AWA watersheds also drain this mountain flank and have similar characteristics including forested topography, bedrock and surficial geology, soil morphology, stream channel characteristics and relative size of drainage areas. Hydrologically, the watersheds experience similar temperature, humidity and precipitation conditions. A summary of streamflow statistics for this station is provided in the Appendix.

The gaging station has a watershed area of 44.1 sq. mi. By comparison, the AWA watersheds total 64.5 square miles. About 85% of the entire eastern flank of the Allegheny Front between Tyrone and Plane Nine is devoted to public water supply. Only Sugar Run, Riggles Gap Run and Spring Run watersheds (9 sq. mi., total) are not impounded for water supply.

The gaging station has a continuous 65-year record of streamflow data. This makes the data base suitable for simulation modeling and meaningful statistical analysis.

Time Interval - Selection of a computational time interval is a key consideration for model simulation. Planning studies involving water supplies and other conservation purposes are typically based on a monthly streamflow recorded over a period of many decades. USGS data from the Bald Eagle Creek Station is, therefore, ideal for the Res-Sim 3.0 model. Data can be downloaded from the station website (see Appendix) to obtain monthly mean streamflow from 1944 to 2009. This data is applied proportionally to the watershed area above each reservoir to obtain monthly "inflow" and entered as a time-series in the model.

Reservoir Characteristics - The storage-area-elevation function is a key input parameter for reservoir simulation. Considerable information has been developed through the years based on hydrographic surveys for each reservoir. Each reservoir's storage-area-elevation data is found in the Appendix. Input data to the Res-Sim 3.0 Model was entered as "paired data" for storage-stage elevation and area-stage elevation. The source of this data is found in the following table:

Table 5 - Sources of Reservoir Basin Survey Data

Reservoir	Date of Basin Survey	Source	Type of Survey	Remarks
Allegheny	June 1979	GD&F	Hydrographic	Surveyed for H/H Study
Bellwood	1946	Gannett Fleming	Topographic	Original Basin Survey
Blair Gap	Sept. 1991	GD&F	Topographic	Surveyed After Silt Removal
Homer Gap	July 1979	GD&F	Hydrographic	Surveyed for H/H Study
Impounding	May 1979	GD&F	Hydrographic	Surveyed for H/H Study
Kettle	1985	GD&F	Photogrammetric	Surveyed for Dam Design
Kittanning Point	May 1979	GD&F	Topographic	Surveyed for H/H Study
Lake Altoona	Sept. 1998	GD&F	Topographic	Surveyed After Reconstruction
Loup Run	1924	Tipton Water Co.	Topographic	Surveyed for Intake Construction
Mill Run	1955	Lewis L. Gwin	Topographic	Original Basin Survey
Muleshoe	1955	EADS Group	Topographic	Original Basin Survey (Assumed 7.8% Siltation)
Plane Nine	Oct. 1991	GD&F	Topographic	Surveyed After Silt Removal
Tipton	Feb. 1923	Tipton Water Co.	Topographic	Original Basin Survey

Notes: "H/H Study" refers to Hydrologic & Hydraulic Evaluation in response to USCOE Phase I Dam Inspection evaluations.

Tables 6 through 9 summarize the total storage capacity (million gallons and acre-feet), total reservoir surface area (acres), operating levels, depth of effective storage and total effective storage for each reservoir used in the Res-Sim 3.0 model.

Table 6 - Summary of Reservoir Storage-Area Values and Watershed Areas

Reservoir	Watershed Areas (sq. mi.)	Normal Pool Elevation	Storage Capacity (mg)	Storage Capacity (ac. ft.)	Surface Area (ac.)
Mill Run	4.25	1508.0 msl	519.0	1,593.0	50.3
Allegheny	2.00	1305.6 msl	49.3	151.3	11.4
Sub-Total	6.25		568.3	1,744.3	61.7
Kittanning Pt.	8.89	1496.0 msl	52.6	161.4	12.6
Impounding	0.68	1434.6 msl	309.0	948.4	42.8
Lake Altoona	2.85	1361.1 msl	835.0	2,563.0	89.1
Sub-Total	12.42		1,196.6	3,672.8	144.5
Homer Gap	2.47	1448.8 msl	26.7	81.9	7.1
Blair Gap	3.40	1780.0 msl	25.0	76.7	4.0
Muleshoe	7.20	1576.0 msl	72.0	221.0	13.0
Plane Nine	2.00	1408.0 msl	120.0	368.3	30.0
Sub-Total	12.60		217.0	666.0	47.0
Kettle	2.50	1717.0 msl	185.0	567.8	29.9
Bellwood	18.20	1353.0 msl	335.0	1,028.0	53.0
Loup Run	3.00	1448.0 msl	0.3	1.0	1.0
Tipton	8.57	1394.0 msl	320.0	982.0	42.3
Sub-Total	11.57		320.3	983.0	43.3
Total	66.01		2,848.9	8,743.8	386.5

Reservoir Operating Levels - Reservoir routing procedures dictate that operating levels be established in each reservoir to define effective storage capacities, elevations and surface areas. These operating levels are technically defined as "rules" or "rule curves" in simulation modeling. For evaluation of water supply reservoirs, operating levels and zones are simplified. Power generation, flood control, flood surcharge or other uses are not considerations in the Authority system. Only the normal and minimum levels need to be defined along with levels for multiple reservoir operation and buffering/rationing.

Normal reservoir capacity is established at the spillway overflow elevation of the dam (or the top of inflatable dam). Three inflatable rubber dams currently exist in the system at Lake Altoona, Impounding (Cochran) Dam and Mill Run Dam. For purposes of the Res-Sim 3.0 model, the dams are assumed to be fully inflated as standard operating procedures. Maximum storage capacity levels for each reservoir are found in Table 7:

Table 7 - Normal Reservoir Operating Levels

Reservoir	Normal Reservoir Operating Level (msl)	Overfow Structure
Mill Run	1508.0	Rubber Dam Inflated
Allegheny	1305.7	Broad Crested Weir
Kittanning Point	1496.0	Broad Crested Weir
Impounding (Cochran)	1434.6	Rubber Dam Inflated
Lake Altoona	1359.1	Rubber Dam Inflated
Homer Gap	1448.8	Ogee Weir
Blair Gap	1780.0	Broad Crested Weir
Muleshoe	1576.0	Ogee Weir
Plane Nine	1408.0	Ogee Weir
Kettle	1717.0	Ogee Weir
Bellwood	1353.0	Ogee Weir
Tipton	1394.0	Broad Crested Weir
Loup Run	1448.0	Ogee Weir

Minimum operating levels may involve separate considerations depending on the function of the individual reservoir. The minimum operating level could be the bottom of the reservoir or some point below which silt laden or poor quality water will be discharged. The release of sediment, excessive fish release, low dissolved oxygen or excessive concentrations of hydrogen sulfide, iron and manganese could have negative effects on downstream water quality and aquatic biology. Also, the type of intake structure may place an absolute level upon which the reservoir can be hydraulically drawn down.

Finally, reservoir levels can control gravity operation of a water treatment plant. In the case of the AWA water treatment plants, the minimum level is established by the water surface elevation of the ozone contact chambers. Table 8 is the minimum reservoir elevations used in the Res-Sim 3.0 model.

Table 8 - Minimum Reservoir Overflow Levels

Reservoir	Minimum Operating Level (msl)	Level Control
Mill Run	1430.0	Mill Run WTP Ozone Contactors W.S.
Allegheny	1289.0	Bottom Reservoir
Kittanning Point	1474.0	Top of Sediment Level
Impounding (Cochran)	1402.6	Pappas WTP Ozone Contactors W.S.
Lake Altoona	1305.0	Bottom Elevation at Intake Tower
Homer Gap	1433.8	Homer Gap WTP Ozone Contactors W.S.
Blair Gap	1740.0	Top of Sediment Level
Muleshoe	1536.1	Top of Sediment Level
Plane Nine	1381.5	Plane Nine WTP Ozone Contactors W.S.
Kettle	1682.5	Kettle WTP Ozone Contactors W.S.
Bellwood	1321.0	Bellwood WTP Ozone Contactors W.S.
Tipton	1333.0	Tipton WTP Ozone Contactors W.S.
Loup Run	1440.0	Bottom of Intake Structure W.S.

Note: W.S. denotes "water surface."

The following table summarizes the operating levels, depths of effective storage and total effective reservoir used in the Res-Sim 3.0 model.

Table 9 - Summary of Operating Levels and Effective Storage

Reservoir	Overflow Level (msl)	Minimum Level (msl)	Effective Depth (ft.)	Effective Storage (mg)
Mill Run	1508.0	1430.0	78.0	516.94
Allegheny	1305.65	1289.0	16.65	45.56
Sub-Total, Mill Run				562.50
Kittanning Point	1496.0	1474.0	22.0	50.17
Impounding (Cochran)	1434.6	1402.6	32.0	285.50
Lake Altoona	1359.1	1305.0	54.1	835.40
Sub-Total, Horseshoe Curve				1171.07
Homer Gap	1448.8	1433.8	15.0	24.35
Blair Gap	1780.0	1740.0	40.0	24.90
Muleshoe	1576.0	1536.1	39.9	71.17
Plane Nine	1408.0	1381.5	26.5	112.80
Sub-Total, Plane Nine				208.87
Kettle	1717.0	1682.5	34.5	172.85
Bellwood	1353.0	1321.0	32.0	303.06
Tipton	1394.0	1333.0	61.0	314.50
Loup Run	1448.0	1440.0	8.0	0.33
Sub-Total, Tipton				314.83
Total				2,757.53

Reservoir Intake Structures - A tabulation of water intake types and components are listed for each reservoir in Table 10. This elevation limit is the lowest taking point in the reservoir and absolute limit of useable storage for the Res-Sim 3.0 model.

Table 10 - Reservoir Intake Components

Reservoir	Intake Structure	Pipe Dia.	W.S. Elev. (msl)	Bottom El. Intake (msl)	Max. Depth	Min. El. (Depth) WTP Operation
Kettle	Rein. Concrete (Circular)	2-16 in.	1717.0	1675.0	42.0 ft.	1682.5 (34.5 ft.)
Bellwood	Concrete Box (Submerged)	1-36 in. 1-24 in.	1353.0	1304.5	48.5 ft.	1313 (40.0 ft.)
Tipton	Mounted Face - Masonry Dam (Sluice Gate)	1-36 in. 1-24 in.	1394.0	1318.0	76.0 ft.	1327.0 (67.0 ft.)
Plane Nine	Rein. Concrete (Circular)	1-30 in. 1-16 in.	1408.0	1377.0	31.0 ft.	1381.5 (29.5 ft.)
Muleshoe	Rein. Concrete (Circular)	1-36 in.	1576.0	1526.0	50.1 ft.	N/A
Blair Gap	Mounted Face - Masonry Dam	1-24 in. 1-16 in.	1780.0	1736.0	44.0 ft.	N/A
Allegheny	Concrete Box (Submerged)	1-8 in. 1-12 in.	1305.7	1285.0	20.7 ft.	N/A
Mill Run	Rein. Concrete (Circular)	1-42 in.	1508.0 1502.0	1429.25	78.75 ft. 72.75 ft.	1425.0 (83 ft./72 ft.)
Lake Altoona	Rein. Concrete (Square)	1-60 in. 1-36 in.	1359.1 1355.1	1304.0	55.1 ft. 51.1 ft.	N/A
Impounding	Rein. Concrete (Circular)	1-36 in.	1434.6 1429.6	1386.0	48.6 ft. 43.6 ft.	1402.6 (32 ft./27 ft.)
Kittanning Pt.	Masonry (Square)	2-24 in.	1496.0	1463.0	33.0 ft.	N/A
Homer Gap	Brick (Circular)	1-24 in. 1-16 in.	1448.8	1421.8	27.0 ft.	1433.8 (15 ft.)

Reservoir Sedimentation - Another factor in loss of reservoir storage is sediment deposition. Two kinds of sediment load are of concern - suspended load and bed load. Sediment deposition results as flow velocities decrease as streams encounter the reservoir. Deposition begins with formation of deltas in the upstream reaches, but can also occur near the dam as the semi-fluid bed mass migrates downstream. In addition, the suspended load can deposit sediment along the reservoir, depending on the inflow rate and hydraulic characteristics of the particles. Also, some sediment flows are carried through the reservoir via density currents. These silt bearing waters have greater specific gravity and lower temperatures and can be released through outlet pipes. The "trap efficiency" of the reservoir also has an effect on these sediment loads.

Obviously, reservoir sedimentation is greatest during flood events. Therefore, the rate of sedimentation is highly variable and difficult to quantify without periodic removal, all reservoirs will fill with sediment, a process that can take many decades for some reservoirs.

For purposes of our analysis, each reservoir is evaluated for sediment deposition. Where possible, recent hydrographic surveys are used to provide the most accurate storage volumes for the Res-Sim 3.0 model.

- **Kittanning Point Reservoir** - Located at the head of the Horseshoe Curve, this reservoir had served as a sedimentation trap for runoff from the converging streams of Glen White Run and Kittanning Run. This watershed was formerly heavily mined and received a century's worth of cinder deposition from steam locomotives. This reservoir was hydrographically surveyed in May 1979 resulting in accurate elevation-storage-area curves. The dam was modified in 1985 including a levee floodwall/side channel spillway. Additional material was required to build this levee, but it was discovered that the foundation material contained heavy silt deposits. These deposits were removed (6,390 CY) along with additional basin dredging to help offset the additional levee material placed in the reservoir (8539 CY). Intakes allow normal flows to enter Kittanning Point while allowing heavy silt laden flow to bypass during storm events. In recent years, watershed restoration has reduced watershed erosion and sedimentation. For purposes of the Res-Sim 3.0 model, the 1979 hydrographic survey will be used as sediment deposition has been reduced over this time.

- **Cochran-Impounding Reservoir** - Located just downstream of Kittanning Point Reservoir, the Impounding Reservoir is located off-stream from adjacent Burgoon Run. It only receives overflow directly from Kittanning Point Reservoir. A 1979 hydrographic survey provides the current storage volume used in Res-Sim 3.0. During a 1988 dam upgrade, an inspection of the basin showed little sediment deposition. Some loss of storage resulted from installation of a rock toe at the dam (54,820 CY). This loss of storage (11 mg) has been accounted for in the storage computation for current and projected conditions in Res-Sim 3.0.

- **Lake Altoona** - This reservoir is located next to the Burgoon Run bypass channel. Lake Altoona was subject to heavy siltation in the early 1900's as manifested by the complete siltation of its major tributary dam, Scotch Gap Run. The reservoir basin was surveyed in 1998 while drained for construction. About 287,000 cubic yards of silt occupying an equivalent 58 million gallons was computed. This represented 7% of the total volume and accumulated at a rate of 0.08% per year since 1908. The silt was not removed in 1998 due to the high cost. The resulting storage-area-elevation curve was used in the Res-Sim 3.0 model. Because of land restoration efforts, siltation since 1998 is considered insignificant.

- **Homer Gap Reservoir** - This reservoir was surveyed in 1979 and dredged in 1984. Approximately 12,400 CY of material was removed, which translated to 2.5 mg of storage. A small upstream pond/intake helps to trap silt before entering Homer Gap reservoir. Given that sediment deposition exceeded the sediment removed, the 1979 survey data will be used for Res-Sim 3.0 for current and projected conditions.

- **Allegheny Reservoir** - This reservoir is another off-line impoundment that receives very little sediment deposition. A valve regulated inlet in an adjacent stream channel admits water to the reservoir. Since this reservoir is used sporadically, the water is admitted to maintain a normal pool. Given these factors, sediment deposition is nominal, a fact confirmed when the reservoir was drained in 1979 for a basin survey. Therefore, this hydrographic survey will be considered applicable for the Res-Sim 3.0 model simulation for current and projected conditions.

- **Mill Run Reservoir** - This reservoir was the last one constructed in the AWA inventory. The volume is based on the original 1950's basin survey. Since the original feasibility study included ultimate sediment deposition in the storage-area-elevation computations, these values will be used in the Res-Sim 3.0 model simulation for current and projected conditions.

- **Kettle Reservoir** - A detailed photogrammetric map was prepared of the Kettle Reservoir basin in 1985 for a dam improvement project. An inspection of the basin revealed nominal sediment deposition in the basin area near the dam. This sediment was not removed during the project since it seals the valley flow and helps prevent leakage. Some delta deposition was noted at the backwater areas. Given the age of the reservoir (2nd oldest in AWA inventory), more deposition was expected. This may be due to the heavy forested watershed that is virtually undeveloped. Therefore, the 1985 survey will be used in the Res-Sim 3.0 model simulation for current and projected conditions.

- **Blair Gap Reservoir** - In 1989, this reservoir was dredged with over 60,000 CY of accumulated sediment removed, resulting in 12 mg of additional capacity. A basin survey was conducted thereafter to determine reservoir capacity. Given the small size of this reservoir, the 1989 survey data is considered applicable. Recent inspections of the drained reservoir in 2006 show nominal sediment build-up. The storage-area-elevation data will be used in Res-Sim 3.0 model simulations for current and projected conditions.

- **Muleshoe Reservoir** - Basin survey data for this reservoir was provided by a consulting engineer for the dam owner (Borough of Hollidaysburg). An intermunicipal agreement allows the AWA to operate the reservoir in the Plane Nine system. A 1992 storage curve was provided showing a sediment allowance. Given the age (1956) and undeveloped nature of the watershed (including State Game Lands), the basin data will be used in the Res-Sim 3.0 model simulation for current and projected conditions.

- **Plane Nine Reservoir** - In 1989, the reservoir was dredged with over 94,250 CY of accumulated sediment removed resulting in an additional 19 mg of storage (+16%). A basin survey was conducted thereafter to determine reservoir capacity in 1989 and is considered applicable for the planning period. It will be used in the Res-Sim 3.0 model simulation for current and projected conditions. A 10% reduction factor was applied to account for accumulated sediment.

- **Bellwood Reservoir** - Basin survey data and capacity curves for the reservoir was provided by a consulting engineer for the former dam owner (General Waterworks Corporation). GD&F used this storage-area-elevation curve in the 1993 water allocation permit to determine safe yield. However, it should be noted that the Bellwood watershed has been subjected to surface mining. This has resulted in significant delta deposition at the reservoir backwater zone. Recently, significant land restoration work has decreased the sediment producing potential of the watershed. The 10% factor reserved for Bellwood sediment deposition is valid for the study planning period. The rating curve will be used in the Res-Sim 3.0 model simulation for current and projected conditions.

- **Tipton Reservoir -** GD&F used the original 1920's basin survey to determine the elevation-area-storage relationship in the Res-Sim 3.0 model. An adjustment for accumulated sediment was included in the calculations. Due to the forested nature of the watershed, sediment deposition is considered similar to Kettle Reservoir.

Evaporation - Evaporation from reservoirs can be a key consideration in modeling conservation storage operations. The Res-Sim 3.0 model computes evaporation loss by multiplying the average water surface area by an evaporation rate for a monthly computational interval. The rate is expressed in terms of cubic feet/second which is converted into a monthly (inches/month) value.

In previous studies, evaporation rates were computed in accordance with PADEP Bulletin No. 7. These studies were referenced in previous water allocation permit applications and the 2004 reservoir routing study. This extensive study used a methodology that incorporated factors such as air temperature, solar radiation, vapor pressure, dew point and wind movement. The DEP study made a significant observation. The exact joint probability between the reservoir low flow and the evaporation is unknown. That is, the probability of a 50-year low flow frequency (or reoccurrence) period and a similar 50-year evaporation event could not be correlated. The probability of them occurring simultaneously is remote, especially for a long period of record.

To elaborate, event comparisons with several statewide reservoirs concluded that:

a. There is no strong relationship between the low flow of certain duration and frequency and evaporation loss of the same duration and frequency when the duration is minimal. This would apply to the critical duration of the Altoona reservoirs which range from 3-5 months during low flow conditions.

b. When the duration increases, the correlation is stronger, however, this case would not apply to Altoona. All reservoirs drain and refill within the "water year" as will be demonstrated.

c. Simultaneous occurrence of low flow and net evaporation loss of the same return period tends to underestimate the evaporation loss of short duration and small return periods, but overestimate that of short duration and large return periods.

d. In an attempt to normalize or correlate low flow and evaporation data, DEP developed an evaporation adjustment factor based on critical duration (months) and the low flow return period (years). This coefficient is applied to the net evaporation loss with its own critical duration and return period. The critical duration is the time period from when a reservoir begins to drain and when it begins to fill.

For the purposes of our study, the "mean" evaporation loss is more applicable for a long term reservoir simulation study. That is, the evaporation is computed for a 50% probability of occurring in any year. This is compared to a higher return period that may or may not consistently occur for all critical durations over the 65 period of record.

Not all meterological conditions are the same from year-to-year for each critical duration period. The evaporation rates computed for the water allocation permit application and the 2004 reservoir routing study were based on a 50-year (or 2% probability) low flow and evaporation rates. These rates may apply for a low flow study to determine safe yield or drought operations, but do not accurately reflect a long-term reservoir simulation model. If the rates were applied to our model, evaporation loss would be overstated and result in lower reservoir outputs. Therefore, net evaporation rates will be determined based on a recurrence interval of 2 years with a 50% probability of occurring in any one year.

The calculation of reservoir evaporation rates follow DEP Technical Bulletin No. 7. This may be summarized as follows:

a. Conversion of reservoir storage into inches of storage per unit of drainage area.

b. Selection of a gaged stream station near the drainage area. In this case, the Bald Eagle Creek at Tyrone gaging station was used (USGS Station 5575). Again, this station satisfies critical correlation conditions including close proximity to AWA reservoirs and similar lithology and meterological conditions. Reference page 125 of Bulletin No. 7.

c. Application of gage low-flow frequency and yield-storage-frequency curves to reservoir. To reflect the long term simulation model, the low flow recurrence interval used is 8 years (12.5% probability of occurring on an annual basis). This is the lowest return period on the curves and will slightly overstate the "critical duration" but is considered acceptable for our study. No lower return periods are shown, but Bulletin No. 7 focuses on "low flow" and "safe yield." Reference page 125 of Bulletin No. 7.

d. Net evaporation losses and rates assumes a mean evaporation return period of 2 years. Reference page 206 of Bulletin No. 7 for the net lake evaporation frequency curve for a nearby station (Pittsburgh). The amount of net evaporation loss (EDN) is found by the critical duration and return period. The evaporation adjustment factor (C) is found on page 50 of Bulletin No. 7 for a low flow period of 8 years resulting in C = 1.02, a nominal adjustment. The application of this factor results in a net evaporation loss expressed in feet.

e. The effective evaporation surface area of the reservoir may be considered the elevation where the storage above equals storage below. Bulletin No. 7 assumes this as 65% of the surface area at spillway level. This factor is applied to the normal pool area.

f. The evaporation rate is determined by computing the net evaporation times the effective surface area (65%) divided by the critical duration. This rate is expressed in terms of cubic feet per second/cubic feet per month and entered into the Res-Sim 3.0 model.

Detailed mean evaporation rates for each reservoir are provided in the Appendix. A summary of the evaporation rates for each reservoir are shown in Table 11.

Table 11 - Mean Evaporation Rates for Reservoirs

Reservoir	Evaporation Rate (cfs)	Evaporation Rate (mgd)
Mill Run	0.060	0.039
Allegheny	0.024	0.016
Kittanning Point	0.027	0.017
Impounding (Cochran)	0.068	0.044
Lake Altoona	0.125	0.081
Homer Gap	0.021	0.013
Blair Gap	0.0085	0.0055
Muleshoe	0.025	0.016
Plane Nine	0.057	0.036
Kettle	0.0381	0.0246
Bellwood	0.085	0.055
Tipton	0.060	0.0385

Projected Water Demand - A key Res-Sim 3.0 model component is accounting for realistic system outputs, the most important of which is water supply demand. This factor determines the dependable yield of the reservoir system, critical durations, shortage indices, drought indicators and storage depletion. Our study will examine a range of demands, through minimum and maximum conditions in Table 12.

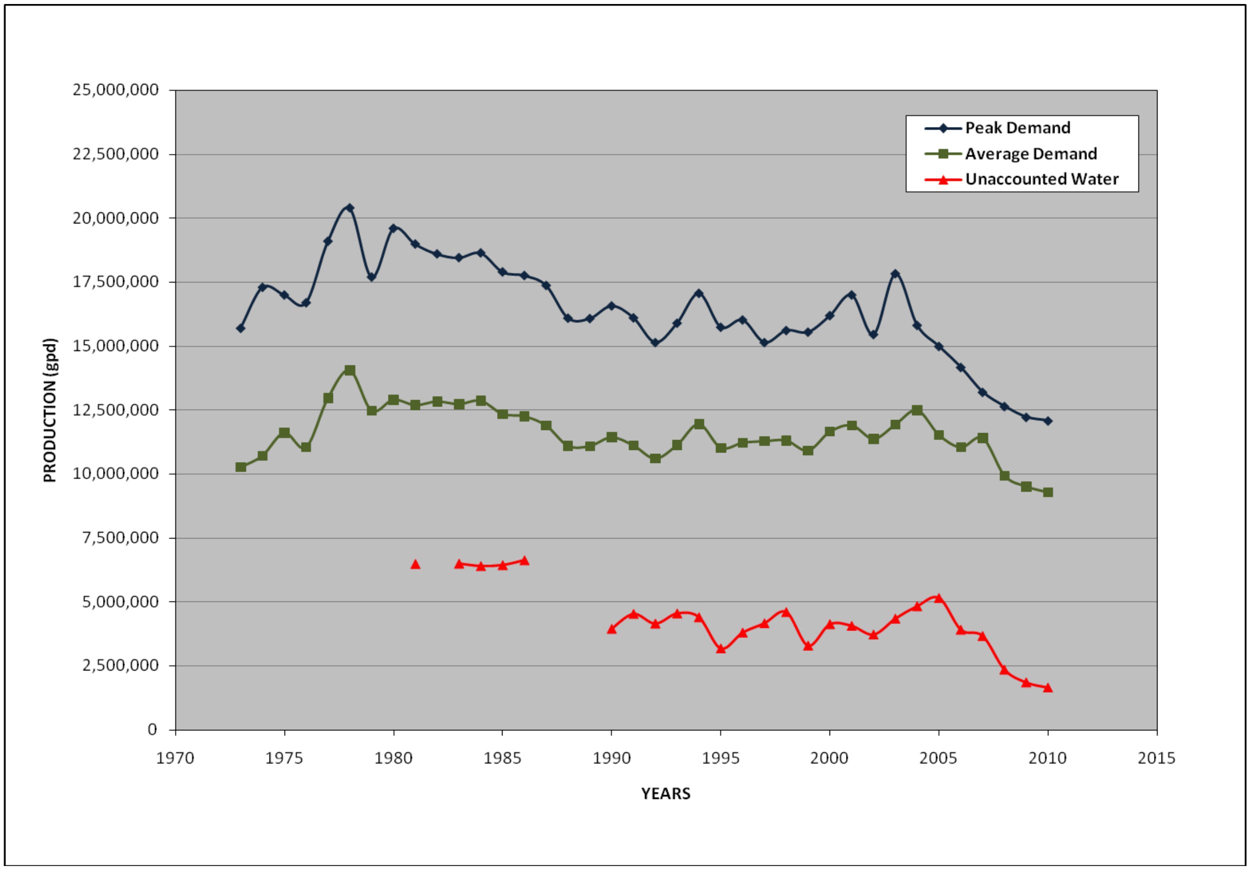
Historical Water Use - Before examining specific model inputs, a review of historical water demand is useful if only to show current trends and past system performance. The following data was gathered from past water allocation reports, annual water supply reports and AWA/GD&F records. This data also reflects system production since the Authority assumed ownership of the Blair Gap water system and overall operational control from the City water department in 1981.

Table 12 - Historical Water Demand

Year	Average Demand (gpd)	Peak Demand (gpd)	UAW (Loss) (gpd)	UAW%
1973[1]	10,258,000	15,700,000		
1974[1]	10,710,000	17,300,000		
1975[1]	11,608,000	17,000,000		
1976[1]	11,038,000	16,700,000		
1977[1]	12,959,000	19,100,000		
1978[1]	14,049,000	20,400,000		
1979[1]	12,479,000	17,700,000		
1980[1]	12,899,000	19,600,000		
1981[1]	12,690,000	18,990,000[2]	6,486,000	51.1
1982	12,830,000	18,603,500	-	-
1983	12,730,000	18,458,500	6,499,000	51.0
1984	12,858,000	18,644,100	6,403,000	49.8
1985	12,346,000	17,901,700	6,438,000	52.1
1986	12,250,000	17,762,500	6,630,000	54.1
1987	11,891,000	17,372,450	-	-
1988	11,100,000	16,095,000	-	-
1989	11,090,000	16,080,500	-	-
1990	11,430,000	16,573,500	3,947,000	34.5
1991	11,110,000	16,109,500	4,528,702	40.8
1992	10,600,000	15,144,000[2]	4,150,000	39.2
1993	11,132,649	15,900,000[2]	4,550,000	40.2
1994	11,045,964	17,066,000[2]	4,400,000	36.8
1995	11,018,271	15,742,000[2]	3,180,000	28.9
1996	11,218,314	16,027,000[2]	3,800,000	33.8
1997	11,279,000	15,143,239	4,165,000	36.9
1998	11,305,389	15,613,528	4,602,168	40.7
1999	10,911,000	15,550,592	3,291,000	30.2
2000	11,648,470	16,194,970	4,127,882	35.4
2001	11,896,174	17,000,867	4,062,283	34.1
2002	11,371,138	15,456,769	3,723,050	32.7
2003	11,931,006	17,830,318	4,348,473	36.4
2004	12,486,656	15,814,769	4,832,619	38.7
2005	11,517,128	14,992,381	5,154,883	44.8
2006	11,041,290	14,172,341	3,910,122	35.4
2007	11,399,476	13,202,705	3,668,000	32.2
2008	9,932,799	12,645,880	2,351,602	23.7
2009	9,506,298	12,224,406	1,848,951	19.4
2010	9,277,409	12,084,004	1,647,768	17.8

Notes:
[1] Combined City of Altoona & Blair Gap Water Supply Water Use
[2] Projected Peak Demand from Adjacent Years Ratio-of-Peak-to-Average Day
Box Area Represents Data Before System Ownership.
UAW is Defined as Unaccounted-for-Water.

As the following graph shows, total production has declined mainly because of effective loss control efforts, decline in metered consumption and water saving plumbing fixtures.



The more recent decline in total production has greatly affected operation of the reservoir system. In fact, operational changes have been driven by the economics of water treatment. The recent production average of 9.0 mgd is seen as the "new normal" relative to current consumption and lost-water control. Obviously, production trends will be subject to future events such as sale of water for shale gas drilling or other large consumption needs.

Current Demand - Current reservoir operations, dictated by shrinking production and budget constraints, have resulted in the provisional decommissioning of Kettle and Homer Gap reservoirs. The treatment plants at the reservoirs have been temporarily decommissioned. The Kettle and Homer Gap reservoirs are maintained at full capacity and all inflow is released downstream at this time.

The Mill Run plant has been also decommissioned but the reservoir is still used for water supply. The flow is diverted to the Horseshoe Curve system by virtue of a gravity 24" transmission main. Recent production from the sources, along with their service areas, are listed in the following table. The "boxed" columns are used in the Res-Sim 3.0 model for historical (2002) and current (2010) demand conditions.

Table 13 - Reservoir System Production

Reservoir System	2002	2003	2004	2005	2006	2007	2008	2009	2010	Avg.
	Production (mgd)									
Mill Run	2.0	2.5	3.1	2.3	2.6	2.6	2.6	2.4	2.6	2.5
Horseshoe Curve	3.1	3.6	2.7	3.4	2.9	3.5	2.1	2.7	1.5	2.9
Homer Gap	0.5	0.8	0.7	0.2	-	-	-	-	-	-
Plane Nine	1.6	1.6	2.0	1.8	1.8	1.8	1.7	1.4	1.6	1.7
Kettle	0.6	0.9	0.8	0.3	0.3	-	0.3	-	-	-
Bellwood	2.3	1.5	2.2	2.5	2.5	2.4	2.4	2.1	2.1	2.2
Tipton	0.9	0.7	1.0	1.0	0.9	1.1	0.8	0.9	1.2	1.0
Total	11.0	11.6	12.5	11.5	11.0	11.4	9.9	9.5	9.0	10.3

Planning Period Demands - Water demand projections were based on previous planning studies. These include the 1990 AWA plan of water system improvements and in water allocation permit applications. Each reservoir system includes water demand projections for a 25-year planning period (from 2008 to 2033). These projected demands are set forth below and will be assessed in the Res-Sim 3.0 simulation model.

Table 14 - Projected Reservoir System Demands/Withdrawals

Reservoir System	Dams	Projected Demand/ Withdrawal (mgd)
Bellwood	Bellwood	3.089
Tipton	Tipton	1.145
	Loup Run	
Mill Run	Mill Run	2.649
	Allegheny	
Kettle	Kettle	0.802
Plane Nine	Plane Nine	2.117
	Muleshoe	
	Blair Gap	
Homer Gap	Homer Gap	0.609
Horseshoe Curve	Kittanning Point	4.227
	Impounding (Cochran)	
	Lake Altoona	
Total		14.638

Maximum Treatment Rate Demands - The water treatment plants were designed on the basis of the 1990 AWA plan of water system improvements. Projected average and peak key demands were incorporated into the design of the treatment plants. This data is of interest since the Res-Sim 3.0 model will simulate individual reliability and related critical durations. Admittedly, these demands cannot be sustained over periods of shortage. However, some insight into the operational durations during maximum demand conditions is useful, if only to show the magnitude of reservoir depletion.

The following data is a summary of the water treatment plant design capacities for each reservoir system. These flow rates were formalized in the 2008 DEP water allocation permit. They also represent the maximum permissible withdrawals from each reservoir system.

Table 15 - Treatment Plant Capacity

Reservoir System	Dams	Treatment Plant Capacity (mgd)
Bellwood	Bellwood	5.0
Tipton	Tipton Loup Run	4.0
Mill Run	Mill Run Allegheny	5.0
Kettle	Kettle	2.0
Plane Nine	Plane Nine Muleshoe Blair Gap	4.0
Homer Gap	Homer Gap	1.0
Horseshoe Curve	Kittanning Point Impounding (Chochran) Lake Altoona	7.5
Total		28.5

Withdrawals from all reservoirs systems are summarized in Table 16. These flows are used in various modeling simulations in Res-Sim 3.0.

Table 16 - Summary of Reservoir System Withdrawals

Reservoir System	2002 WTF Withdrawal cfs	2002 WTF Withdrawal mgd	2010 WTF Withdrawal cfs	2010 WTF Withdrawal mgd	2033 WTF Withdrawal cfs	2033 WTF Withdrawal mgd
Bellwood	3.573	2.305	3.179	2.051	4.788	3.089
Kettle	0.927	0.598			1.243	0.802
Homer Gap	0.694	0.448			0.944	0.609
Tipton	1.307	0.843	1.871	1.207	1.775	1.145
Mill Run	3.024	1.951	4.046	2.610	4.108	2.650
Plane Nine	2.416	1.559	2.584	1.667	3.281	2.117
Horseshoe Curve	4.824	3.112	2.209	1.427	6.552	4.227
Total	16.765	10.816	13.889	8.962	22.690	14.639

Minor Losses - Seepage is categorized as a loss in reservoir routing models as an output from the system. Several seepage mechanisms exist including leakage through the dam and basin floor.

Basin seepage is difficult to quantify. Indirectly, measurements are made of all inputs and outputs to arrive at the difference. This rarely can be done precisely or economically. Several factors tend to minimize excessive basin seepage in the AWA watersheds. Bedrock geology underlying the Allegheny Front is of the Upper Devonian era with tightly bedded sandstone and shale units. These units have low permeability which minimizes basin seepage through the valley floors. Also, fine silt deposition on the reservoir floor can minimize seepage.

Concerning dam seepage, the Authority is required to collect and monitor for dam safety reasons. Dam seepage can be a variable quantity, depending on reservoir levels. This flow often forms a majority of the downstream conservation release, in some cases the entire release. For our model simulation, dam seepage is part of the conservation release and not accounted for separately.

Conservation Releases - A major system output are reservoir releases to maintain downstream flow for environmental purposes. Known as conservation releases, these outflows are an important part of the Res-Sim 3.0 simulation model. They have been formalized in the DEP 2008 water allocation permit. Theoretically, during extreme droughts and severe storage depletion, the reservoirs will completely drain and inflow will pass through the reservoir and comprise the entire streamflow. This rare case has never been experienced in the Altoona system by virtue of plentiful reservoir storage. The following conservation releases (as stipulated in the water allocation permit) and mean inflows are presented in the following table. In addition, an analysis of inflows to each reservoir was performed to produce mean inflow valves. Of course, these rely on the long term period record at the Bald Eagle Creek gaging station.

Table 17 - Reservoir Conservation Releases and Mean Average Inflows

Reservoir	Conservation Release (mgd)	Conservation Release (cfs)	Mean Inflow (cfs)	Mean Inflow (mgd)
Mill Run	0.466	0.721	5.68	3.67
Allegheny	0.283	0.438	8.33	5.38
Kittanning Point	N/A	N/A	12.02	7.77
Impounding (Cochran)	N/A	N/A	12.79	8.27
Lake Altoona	0.562	0.870	16.60	7.70
Homer Gap	0.130	0.201	3.22	2.08
Blair Gap	0.248	0.384	4.55	2.94
Muleshoe	0.600	0.928	9.62	6.22
Plane Nine	0.570	0.882	16.85	10.89
Kettle	0.240	0.371	3.34	2.16
Bellwood	1.080	1.671	24.3	15.70
Tipton	0.670	1.037	11.63	7.52
Loup Run	0.140	0.217	3.84	2.48

Diversions - Another subset of reservoir routing parameters are diversions to and from adjoining reservoir systems. In the case of the AWA systems, there are several direct and indirect diversions that need to be taken into account for the Res-Sim 3.0 model. Direct diversions are not considered water withdrawals by PADEP and must be accounted for as net inflow to the reservoir. For modeling purposes, indirect diversions are considered that part of the reservoir withdrawal that occurs within the total water demand. The "indirect" transfer is made in the distribution system downstream from the reservoir. The specific reservoir diversion narratives are as follows:

- **Blair Gap Reservoir** - A 12-inch gravity transmission main was constructed from Blair Gap reservoir to the Horseshoe Curve watershed in 1907. This five mile pipeline was built by the original reservoir builder, the Pennsylvania Railroad, to fill water tanks at Kittanning Point for steam locomotive tenders. Although long abandoned for these purposes, this line has supplemented the Impounding (Cochran) Reservoir with short term, high quality water. A 1980 flow study gaged the capacity of this line at 1.0 mgd.

  The flow transfer from Blair Gap reservoir to the Horseshoe Curve system is necessarily limited by the yield of the Blair Gap watershed and storage capacity at Blair Gap Reservoir. It is used to supplement water quality and short term storage needs at the Impounding (Cochran) Reservoir when stream flow conditions allow. The 2008 water allocation permit limits the flow from this transfer to 0.45 MGD. According to the 2008 water allocation permit, *"…Any water diverted from the Blair Gap Reservoir to the Horseshoe Curve Reservoir system shall not be considered part of the daily withdrawal from the Plane Nine Reservoir System…"* The Res-Sim 3.0 model will reflect these limitations when evaluating alternatives. This is considered a direct diversion by PADEP and not a water withdrawal for modeling purposes.

- **Mill Run Reservoir/Lake Altoona** - A 24-inch gravity transmission main connects Mill Run Reservoir and the Horseshoe Curve water treatment plant. Constructed in 1969, this main has a maximum gravity transfer rate of 10 mgd (refer to Appendix). Since the provisional decommissioning of the Mill Run water treatment plant, all water withdrawn from the Mill Run watershed has been diverted to the Horseshoe Curve system for treatment. The water allocation permit states that water transferred from Mill Run to the Horseshoe Curve shall be considered part of the withdrawal from the Mill Run watershed, subject to the restrictions placed on Mill Run Reservoir (maximum withdrawal of 5.0 MGD).

  This is an indirect diversion and is considered a withdrawal as the water passes through the reservoir as an output.

  Conversely, the Lake Altoona pump station (5.0 mgd capacity) can transfer water to the Mill Run water treatment plant, when the Horseshoe Curve plant has been shut down for maintenance and construction purposes. It is not considered a feasible, long term operating mode. Additional cost is incurred for pumping and treating lower quality Lake Altoona water at the Mill Run WTP.

  Our evaluation will consider the economic aspects of this indirect diversion, rather than the hydraulic and operational aspects. The Mill Run system was designed to serve to the High Service gradient of the City while also supplementing Low Service. The Horseshoe Plant can provide service to either gradient. This plant is preferred because of the centralized location and is more amenable to a consolidated operation. Our economic evaluation will test these assumptions. Either way, withdrawals from either basin serve the City gradients. Normal reservoir operation, while important, may not be the overriding consideration when compared to water quality, plant consolidation and treatment economics. The Res-Sim 3.0 model will be primarily concerned with the consequences of drought shortages from these reservoirs.

System Transfer Capability - The Authority water system is entirely integrated and interconnected through a network of transmission mains, pumping stations and storage tanks. The Authority has the ability to provide a redundant water supply anywhere in the service area and, in most cases, the ability to supplement these supplies. This is an extremely important factor in the reservoir evaluation. When individual reservoir systems are depleted during extreme drought periods, other reservoirs can supplement their demand. Res-Sim 3.0 can model these conditions by increasing the demand/ withdrawal from the supplementing reservoir and reducing the demand/ withdrawal from the reservoir in deficiency. The ability to transfer water throughout the service area is a key drought contingency factor. These supplementing flows will be considered "withdrawals" in the Res-Sim 3.0 model. We consider them system transfers since they occur downstream. Reference is made to the hydraulic profile of the system for information on system hydraulic gradients and transfer (pump stations, tank) components. These scenarios are described as follows:

- **Plane Nine - Horseshoe Curve -** Water may be transferred to and from the Plane Nine system by the Westerly booster pump system at the 31st well field and a 16" water main. The pump station has a capacity of 1,440 gpm - 2,880 gpm (2 - 4 mgd). The operating scenario would be to pump water from either the Low or High service gradients (Horseshoe Curve reservoir system) to the Plane Nine gradient. Water from the sources would be credited against withdrawals from the Horseshoe Curve reservoirs. Water can also be pumped into Low or High Service from Plane Nine at other locations at about the same capacity. But this would be considered a short duration, emergency interconnection. The yield from Plane Nine cannot provide a sustained demand of the magnitude to supply either High or Low Service and the Plane Nine service gradients simultaneously.

- **Kettle - Horseshoe Curve -** Water may be transformed to and from the Kettle system by several mechanisms. The Pottsgrove storage tank can hydraulically fill the Oakton tanks (High Service) or Prospect Tank (Low Service) by gravity. A cleaning and lining project on the old 12-inch main (from Pottsgrove Tank to the City) enhanced its transmission capacity up to 1.0 mgd. Conversely, the Pottsgrove tank can be filled by pumping from High Service (0.144 mgd) at the East CSO booster pumping station. Since the Kettle water treatment plant is provisionally decommissioned, the Kettle system (Greenwood/Bellemead) is fed from Altoona High Service. Withdrawals for this service area are credited against the Horseshoe Curve and/or Mill Run reservoir systems. Transfers from the Kettle system to the Altoona service gradients would be on a supplemental or emergency basis. The sustained yield is insufficient to meet sizeable demands of the City system. The more likely scenarios is for Kettle to feed its own service area (Greenwood) to relieve nominal demands on the City service gradients.

- **Homer Gap - Horseshoe Curve -** Homer Gap and the City High Service gradients are interconnected and can fill their respective systems by gravity. The transfer rate is at least 1.0 mgd. Currently, the Homer Gap water treatment plant is provisionally decommissioned and the service area is fed by High Service. Withdrawals to feed this service area are credited against the Horseshoe Curve or Mill Run reservoir systems. Transfers from the Homer Gap system to the Altoona service gradients would be of a supplemental or emergency basis. The sustained yield is insufficient to meet sizeable demands of the City system. The more likely scenario is for Homer Gap to feed its own service area (Juniata) to relieve nominal demands on the City service gradients.

- **Horseshoe Curve - Tipton/Bellwood -** The Easterly water booster pumping system is located at 4th Avenue and 9th Street in the Juniata section of the City. The system is capable of transferring water from the City Service gradients to-and-from the Bellwood and Tipton service area. The pumps have a capacity of 1,440 gpm - 2,880 gpm (2.0 - 4.0 mgd) and connect to the Bellwood and Tipton 16-inch transmission mains. The operating scenario would be to pump water from either the Low or High Service gradients to either the Bellwood or Tipton gradients (or both). Water from these sources would be credited against withdrawals from the Horseshoe Curve reservoir. Water can also be pumped into the City service gradients from either the Bellwood or Tipton gradients at the same location and at the same capacity (2.0 mgd). But, these are considered short-term, emergency interconnections. The sustained yield from Tipton and/or Bellwood cannot supply either High or Low Service on a long-term basis.

- **Bellwood - Tipton -** The Bellwood water booster pump station can transfer water from the Bellwood gradient to the Tipton gradient at a capacity of 1,440 - 2,880 gpm (2 - 4 mgd). It is located along the Norfolk Southern main line and Becker Road (T-490). Conversely, Tipton water can be transferred to the Bellwood gradient by gravity at this location and other interconnection points.

Multiple Reservoir Systems - A condition of the water allocation permit stipulates *"… any reservoir modeling… shall treat individual reservoirs in multiple reservoir systems separately rather than as one massive reservoir…"* In typical multiple reservoir operations, downstream reservoirs should be depleted first before using upstream reservoirs. Overflows from upstream reservoirs may be stored in downstream reservoirs. This procedure minimizes system loss and maximizes the storage value of the system. The Authority has several multiple reservoir systems including those at Mill Run, Horseshoe Curve, Plane Nine and Tipton. Each will be discussed as follows:

- **Plane Nine Reservoir System -** Three reservoirs comprise the Plane Nine system. Blair Gap and Muleshoe Reservoirs are located on tributary forks above Plane Nine Reservoir. For purposes of the Res-Sim 3.0 model and in keeping with classic multiple reservoir operation, the two upstream reservoirs will be maintained at full capacity while Plane Nine Reservoir is drawn down for operating purposes. When Plane Nine reaches its critical operating level, both Muleshoe and Blair Gap dams are drawn down to replenish Plane Nine Reservoir. The release from Muleshoe Reservoir is restricted to 2 mgd according to the water allocation permit. This is done to maintain water quality in Blair Gap Run between the reservoirs. The Blair Gap Reservoir diversion (0.45 mgd to the Horseshoe Curve) is not considered in our model simulation due to its intermittent use. When minimum storage levels are reached in Muleshoe and Blair Gap Reservoirs, inflow equals outflow and passes downstream to Plane Nine Reservoir. The multiple reservoir sub-routine in the Res-Sim 3.0 model will be utilized to evaluate the Plane Nine Reservoir system.

- **Tipton - Loup Run Reservoir System -** A small intake on Loup Run supplements flow to Tipton Reservoir. Res-Sim 3.0 recognizes the Loup Run intake as an input upstream to Tipton Reservoir. Due to the small intake size, inflow equals outflow. The hydraulic capacity of the 18-inch line to Tipton Reservoir is 18.7 cfs (12.1 mgd). Please refer to the Appendix for calculations. During low flow conditions, Loup Run intake is restricted due to its conservative release of 0.217 cfs (0.14 mgd). This system is not considered a classic series (or tandem operation rule) since the Loup Run intake storage is insignificant and no operating rule in Tipton Reservoir controls discharge from Loup Run. Basically, the model recognizes the "inflow-equals-outflow" operation of Loup Run intake.

- **Mill Run - Allegheny Reservoir System -** This reservoir system is actually the reverse of an in-series reservoir system. The upstream Mill Run reservoir is operating and depleted before Allegheny Reservoir is activated. When Mill Run Reservoir is drawn down to the critical operating level, Allegheny Reservoir is activated and starts releasing at 900 gpm (both pumps). During this time, Mill Run Reservoir decreases its withdrawal by the same rate. This flow is recognized by Res-Sim 3.0 as an additional input.

- **Horseshoe Curve Reservoir System -** This reservoir system is considered a hybrid. The upper reservoir (Kittanning Point) spills into the second downstream (Cochran-Impounding) reservoir. The spill from this reservoir overflows into a bypass channel around Lake Altoona. The third downstream reservoir (Lake Altoona) is located off stream and is kept full by its own drainage area and releases from the Cochran-Impounding Reservoir. During normal operations, the Impounding Reservoir serves as gravity control on the Horseshoe Curve treatment plant. (It is also blended with water from Mill Run Reservoir, as previously discussed). When the Cochran-Impounding Reservoir reaches the critical operating level, water is pumped back to the Horseshoe Curve plant up to a maximum rate of 5.0 mgd from Lake Altoona. When Lake Altoona reaches its critical operating level, Kittanning Point reservoir is released to Impounding Reservoir by gravity. Res-Sim 3.0 will simulate these reservoir scenarios with rules for minimum storage levels and additional input from the upstream and downstream reservoirs.

RESERVOIR SYSTEM DEPENDABLE FLOW MODELING

Before evaluation of integrated reservoir system operations, a discussion of individual reservoir modeling is appropriate. Specifically, this section will discuss the dependable flow or "safe yield" for each reservoir system based on Res-Sim 3.0 model simulation.

Bellwood Reservoir System - A summary of the operating characteristics used in the model simulation is as follows:

**Table 18 - Summary of Bellwood Reservoir System
Res-Sim 3.0 Operating Conditions**

1. Bellwood Reservoir

a.	Drainage Area	18.2	sq. mi.
b.	Storage Volume	335.0	mg
c.	Storage Volume/Drainage Area	18.4	mg/sq. mi.
d.	Overflow Operating Level	1353.0	msl
e.	Minimum Operating Level	1321.0	msl
f.	Effective Depth	32.0	ft.
g.	Effective Storage	303.06	mg (930.1 ac. ft.)
h.	Conservation Release	1.671	cfs (1.080 mgd)
i.	Evaporation Rate	0.085	cfs (1.75 in/mon)
j.	Withdrawal Scenarios	3.173	cfs (2.051 mgd) 2010 Avg. Demand
		3.567	cfs (2.305 mgd) 2002 Avg. Demand
		4.788	cfs (3.089 mgd) 2033 Proj. Demand
		7.737	cfs (5.00 mgd) Treatment Plant Capacity
k.	Contracted Water Supply	1.315	cfs (0.85 mgd) Bellwood Borough
l.	Diversions	None	
m.	Stream Inflow Record	41.5%	Bald Eagle (Tyrone) Gage Record
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss

Dependable Flow - The Bellwood Reservoir system will produce a dependable flow of 1.84 mgd under the above operating conditions. This is the minimum flow that can be safely delivered with no shortages based on a 65-year period of record.

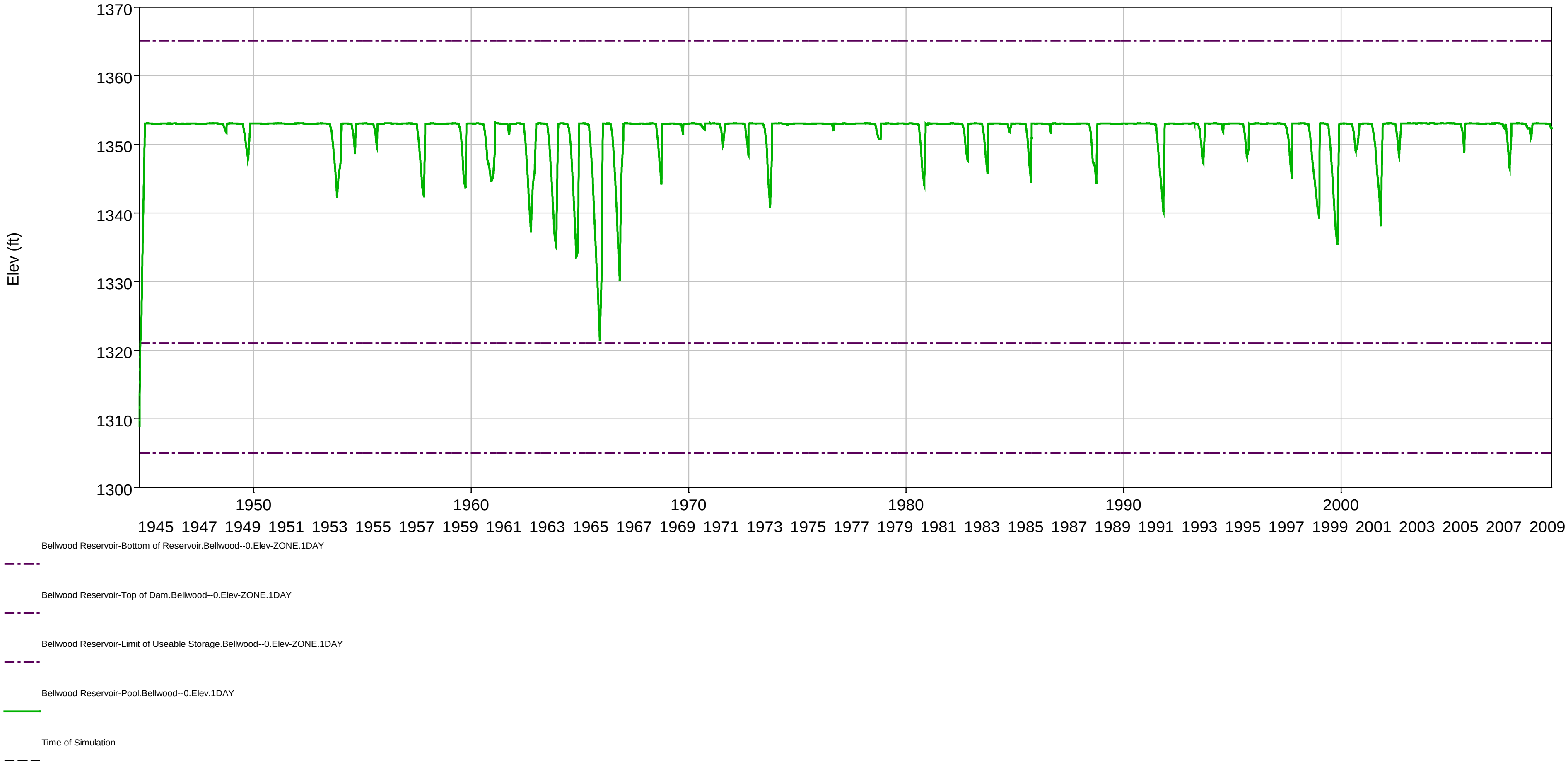
The dependable flow of 1.84 is compared to GD&F's "safe yield" calculated in the Water Allocation Permit application. The "safe yield" for Bellwood Reservoir is 2.049 mgd (which corresponds to the 2010 average demand). This figure is based on a stream flow expected once every ten years for a period of 7-consecutive days (i.e., $Q_{7\text{-}10}$). The 10-year frequency interval corresponds to a return period of 10-

years (or a 10% chance of occurring in any one year). Therefore, one can expect a shortage period for a Q_{7-10} stream flow as compared to a smaller "dependable flow" that would never produce a shortage. The Res-Sim 3.0 modeling tends to validate GD&F's original "safe yield" calculations.

The Res-Sim 3.0 model is provided in the Appendix, including the detailed input parameters. It contains the month-by-month storage-input-output valves, statistical analysis of data, storage-elevation graphs, and depletion values for the period of record. A summary of the storage/stage levels for the Bellwood Reservoir system is shown in the following graphs.

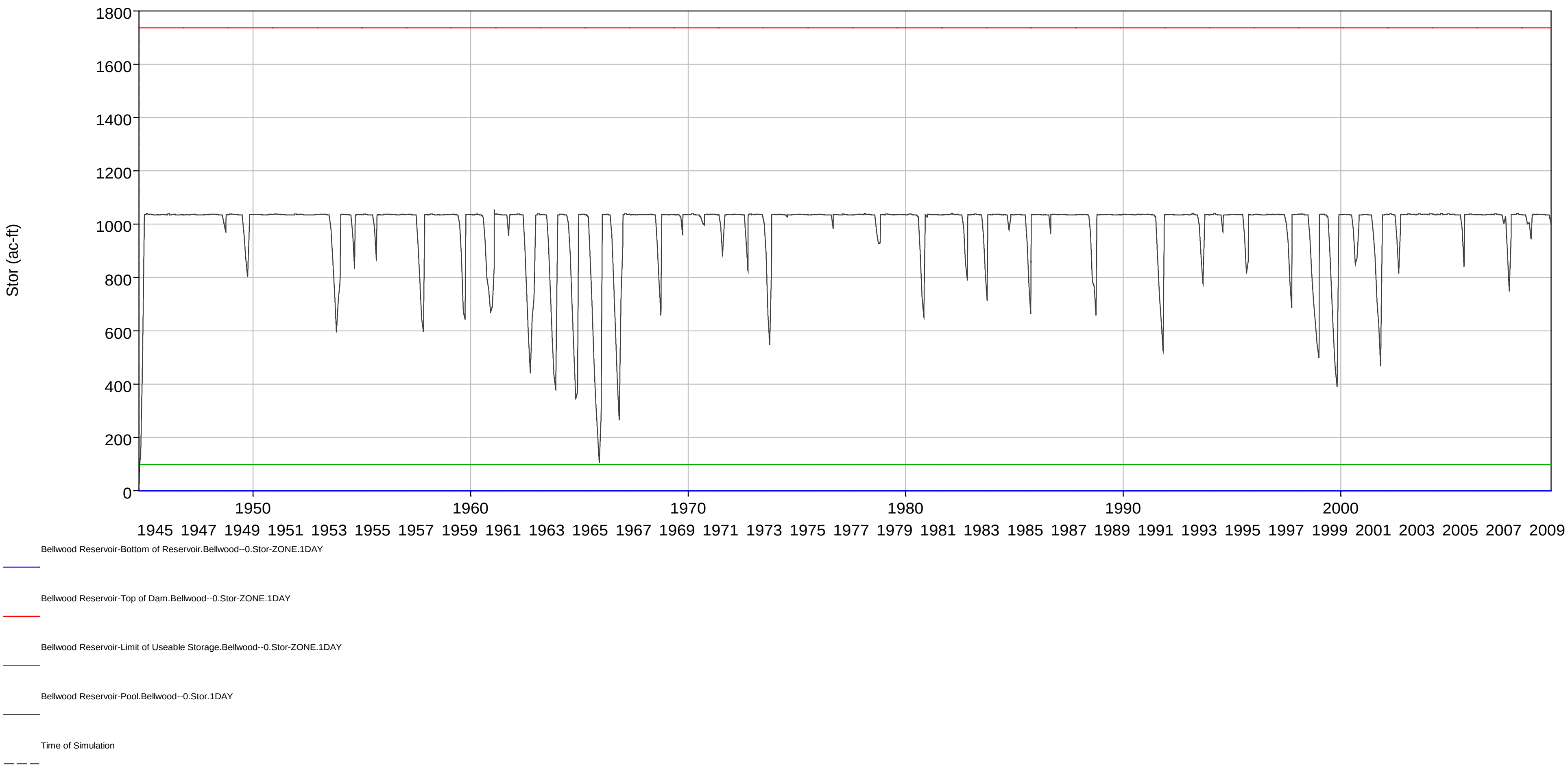
Bellwood Reservoir
Storage Elevation vs. Time
October 1944 – September 2009

Withdrawal = 2.85 cfs (1.84 mgd)
"Dependable Flow"



Bellwood Reservoir
Storage vs. Time
October 1944 – September 2009

Withdrawal = 2.85 cfs (1.84 mgd)
"Dependable Flow"



Tipton Reservoir System - A summary of the operating characteristics used in the model simulation is as follows:

Table 19 - Summary of Tipton Reservoir System
Res-Sim 3.0 Operating Conditions

1. Tipton Reservoir

a.	Drainage Area	8.57	sq. mi.
b.	Storage Volume	320.0	mg
c.	Storage Volume/Drainage Area	37.3	mg/sq. mi.
d.	Overflow Operating Level	1494.0	msl
e.	Minimum Operating Level	1333.0	msl
f.	Effective Depth	61.0	ft.
g.	Effective Storage	314.5	mg (1103.3 ac. ft.)
h.	Conservation Release	1.037	cfs (0.670 mgd)
i.	Evaporation Rate	0.060	cfs (1.38 in/mon)
j.	Withdrawal Scenarios	1.871	cfs (1.207 mgd) 2010 Avg. Demand
		1.307	cfs (0.843 mgd) 2002 Avg. Demand
		1.775	cfs (1.145 mgd) 2033 Proj. Demand
		3.096	cfs (2.00 mgd) Intermediate Demand
		6.192	cfs (4.00 mgd) Treatment Plant Capacity
k.	Contracted Water Supply	None	
l.	Diversions	None	
m.	Stream Inflow Record	19.7%	Bald Eagle (Tyrone) Gage Record
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss d. Tipton Reservoir receives Inflow from Loup Run Intake up to 18 cfs. maximum

2. Loup Run Intake

a.	Drainage Area	3.0	sq. mi.
b.	Storage Volume	0.33	mg
c.	Storage Volume/Drainage Area	0.11	mg/sq. mi.
d.	Overflow Operating Level	1448.0	msl
e.	Minimum Operating Level	1440.0	msl
f.	Effective Depth	8.0	ft.
g.	Effective Storage	0.33	mg (1.0 ac. ft.)
h.	Conservation Release	0.217	cfs (0.140 mgd)
i.	Evaporation Rate	N/A	
j.	Withdrawal Scenarios	None	
k.	Diversions	Discharge to Tipton Reservoir (18 cfs. max)	
l.	Stream Inflow Record	6.8%	Bald Eagle (Tyrone) Gage Record

m. Operating Rules (Model)

a. Reservoir operations modeled between Minimum & Overflow Operating Levels
b. When Min. Operating Level is reached, Inflow = Outflow
c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss
d. Diversion to Tipton Reservoir limited to capacity of Loup Run Intake Line (18 cfs)

Dependable Flow - The Tipton Reservoir system will produce a dependable flow of 1.63 mgd under the above operating conditions. This is the minimum flow that can be safely delivered with no shortages based on a 65-year period of record.

The dependable flow of 1.63 is compared to GD&F's "safe yield" calculated in the Water Allocation Permit application. The "safe yield" for Tipton Reservoir is 1.634 mgd (which corresponds to the 2010 average demand). This is based on a low stream flow expected once every ten years for a period of 7-consecutive days (i.e., Q_{7-10}). The 10-year frequency interval corresponds to a return period of 10-years (or a 10% chance of occurring in any one year). Therefore, one can expect a shortage period for a Q_{7-10} stream flow as compared to a smaller "dependable flow" that would never produce a shortage. This analysis indicates that GD&F's original "safe yield" calculations may have understated the Q_{7-10} yield from Tipton Reservoir. It should be noted that the previous calculations did not include the Loup Run watershed which would increase the safe yield. A Q_{7-10} yield of 2.0 mgd is considered more representative.

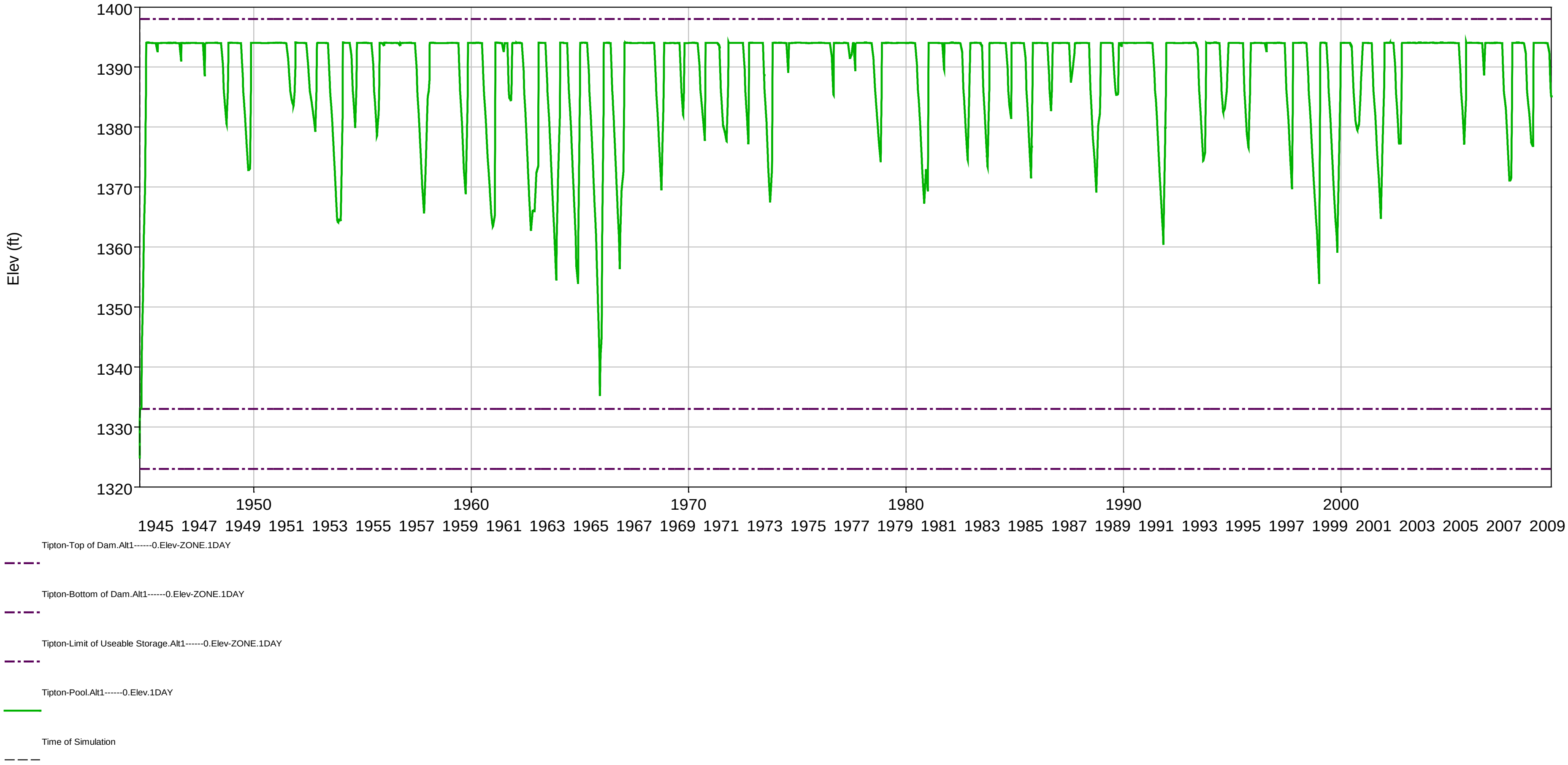
The Res-Sim 3.0 model is provided in the Appendix, including the detailed input parameters. It contains the month-by-month storage-input-output valves, statistical analysis of data, storage-elevation graphs, and depletion values for the period of record.

We also evaluated the dependable flow if the Loup Run Intake was removed from model calculations. The resulting yield of 1.50 mgd is a 0.13 mgd reduction. The Loup Run dependable flow is equivalent to the yield from Homer Gap Reservoir.

A summary of the storage/stage levels for the Tipton Reservoir system is shown in the following graphs.

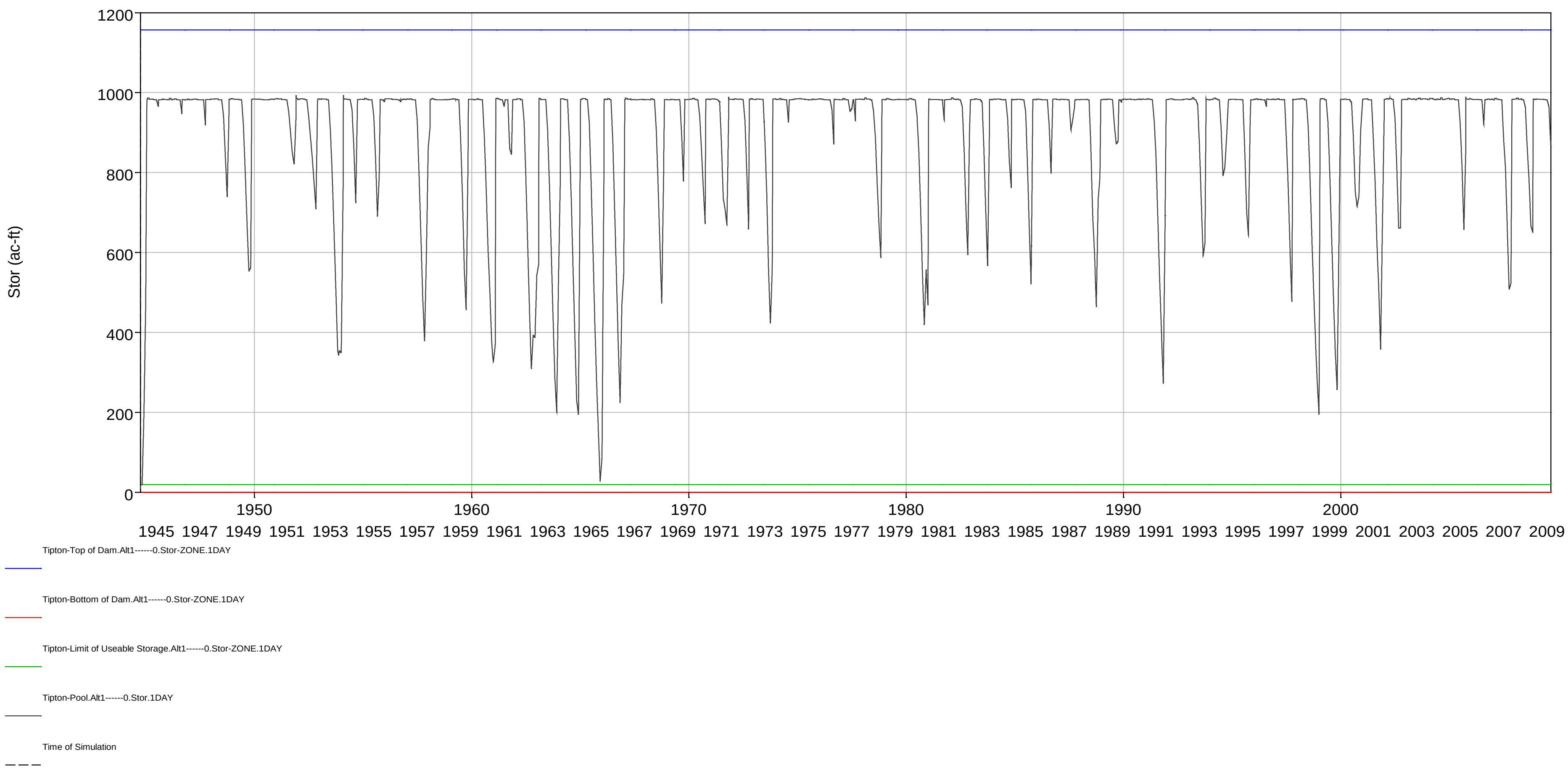
Tipton Reservoir
Storage Elevation vs. Time
October 1944 – September 2009

Withdrawal = 2.52 cfs (1.63 mgd)
Dependable Flow



Tipton Reservoir
Storage vs. Time
October 1944 – September 2009

Withdrawal = 2.52 cfs (1.63 mgd)
Dependable Flow



Kettle Reservoir System - A summary of the operating characteristics used in the model simulation is as follows:

Table 20 - Summary of Kettle Reservoir System
Res-Sim 3.0 Operating Conditions

1. Kettle Reservoir

a.	Drainage Area	2.50	sq. mi.
b.	Storage Volume	185.0	mg
c.	Storage Volume/Drainage Area	74.0	mg/sq. mi.
d.	Overflow Operating Level	1717.0	msl
e.	Minimum Operating Level	1682.5	msl
f.	Effective Depth	34.5	ft.
g.	Effective Storage	177.85	mg (530.3 ac. ft.)
h.	Conservation Release	0.371	cfs (0.240 mgd)
i.	Evaporation Rate	0.0381	cfs (1.39 in/mon)
j.	Withdrawal Scenarios	0.927	cfs (0.598 mgd) 2002 Avg. Demand
		1.243	cfs (0.802 mgd) 2033 Proj. Demand
		1.94	cfs (1.25 mgd) Intermediate
		3.095	cfs (2.00 mgd) Treatment Plant Capacity
k.	Contracted Water Supply	None	
l.	Diversions	None	
m.	Stream Inflow Record	5.9%	Bald Eagle (Tyrone) Gage Record
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss

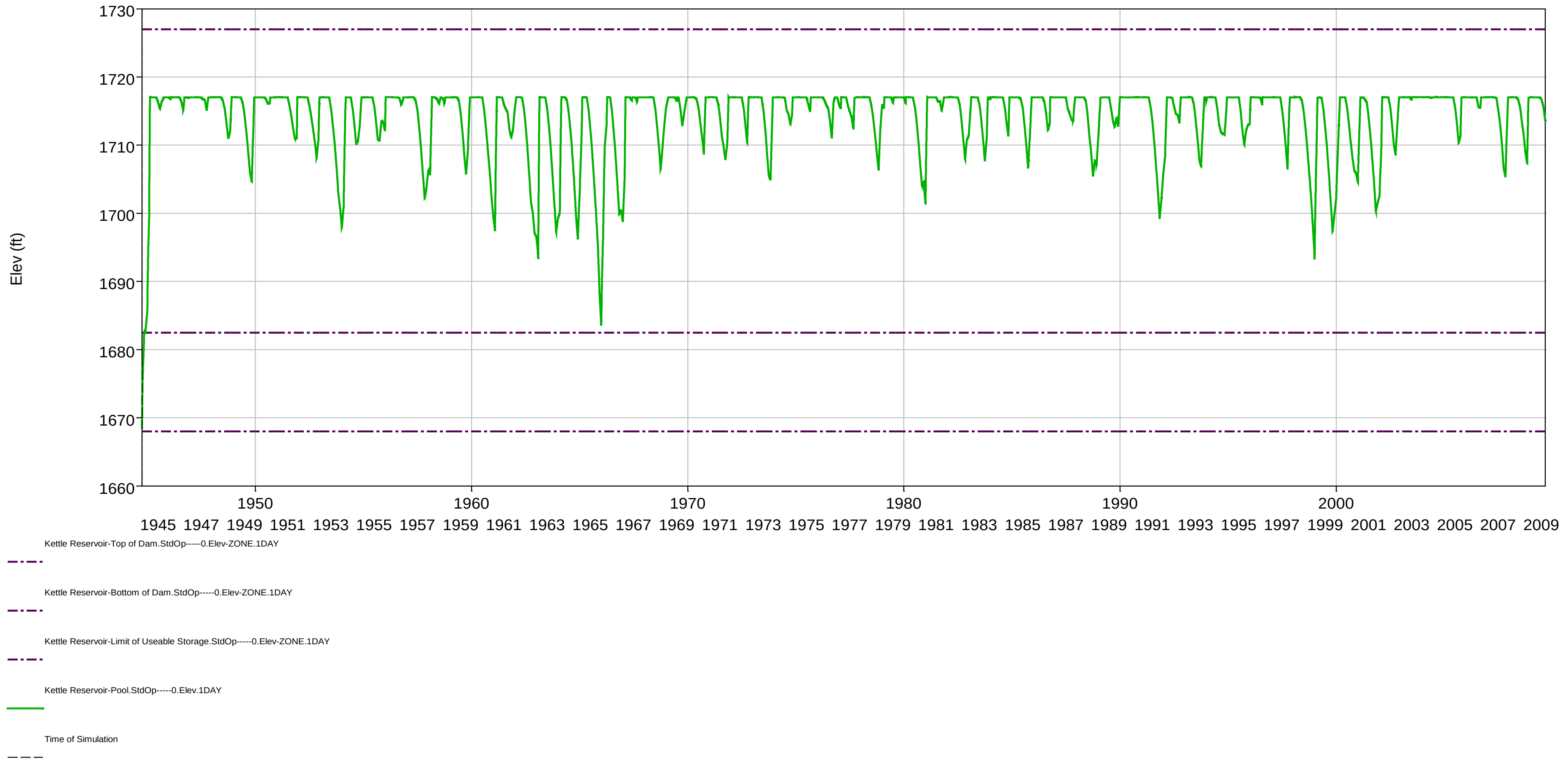
Dependable Flow - The Kettle Reservoir system will produce a dependable flow of 0.723 mgd under the above operating conditions. This is the minimum flow that can be safely delivered with no shortages based on a 65-year period of record.

The dependable flow of 0.723 is compared to GD&F's "safe yield" calculated in the Water Allocation Permit application. The "safe yield" for Kettle Reservoir is 0.708 mgd (which corresponds to the 2010 average demand). This is based on a low stream flow expected once every ten years for a period of 7-consecutive days (i.e., Q_{7-10}). The 10-year frequency interval corresponds to a return period of 10-years (or a 10% chance of occurring in any one year). Therefore, one can expect a shortage period for a Q_{7-10} stream flow as compared to a smaller "dependable flow" that would never produce a shortage. This analysis would indicate GD&F's original "safe yield" calculations may have been understated the Q_{7-10} yield for Kettle Reservoir. A Q_{7-10} yield of 0.85 mgd is considered more likely.

The Res-Sim 3.0 model is provided in the Appendix, including the detailed input parameters. It contains the month-by-month storage-input-output valves, statistical analysis of data, storage-elevation graphs, and depletion values for the period of record. A summary of the storage/stage levels for the Kettle Reservoir system is shown in the following graphs.

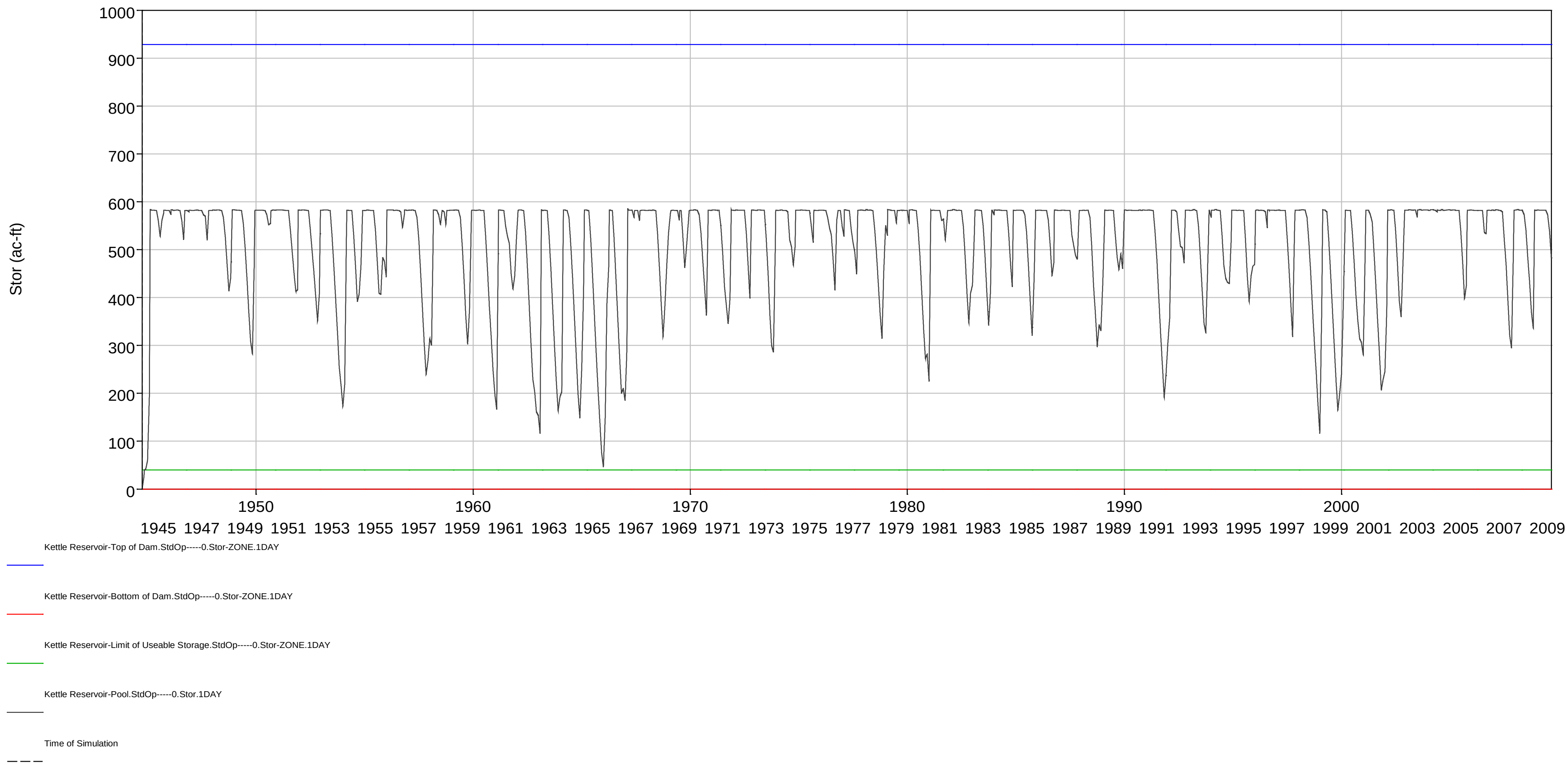
Kettle Reservoir
Storage Elevation vs. Time
October 1944 – September 2009

Withdrawal = 1.12 cfs (0.723 mgd)
"Dependable Flow"



Kettle Reservoir
Storage vs. Time
October 1944 – September 2009

Withdrawal = 1.12 cfs (0.723 mgd)
"Dependable Flow"



Plane Nine Reservoir System - A summary of the operating characteristics used in the model simulation is as follows:

Table 21 - Summary of Plane Nine Reservoir System
Res-Sim 3.0 Operating Conditions

1. Plane Nine Reservoir

a.	Drainage Area	2.0	sq. mi.
b.	Storage Volume	120.0	mg
c.	Storage Volume/Drainage Area	9.52	mg/sq. mi.
d.	Overflow Operating Level	1408.0	msl
e.	Minimum Operating Level	1381.5	msl
f.	Effective Depth	26.5	ft.
g.	Effective Storage	112.8	mg (346.2 ac. ft.)
h.	Conservation Release	0.882	cfs (0.570 mgd)
i.	Evaporation Rate	0.057	cfs (2.06 in/mon)
j.	Withdrawal Scenarios	2.584	cfs (1.667 mgd) 2010 Avg. Demand
		2.416	cfs (1.559 mgd) 2002 Avg. Demand
		3.281	cfs (2.117 mgd) 2033 Proj. Demand
		6.192	cfs (4.00 mgd) Treatment Plant Capacity
k.	Contracted Water Supply	1.45	cfs (0.937 mgd) Hollidaysburg Borough
l.	Diversions	None	
m.	Stream Inflow Record	4.5%	Bald Eagle (Tyrone) Gage Record (Less Upstream Reservoir Flow Regulation)
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels
			b. When Min. Operating Level is reached, Inflow = Outflow
			c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss
			d. When Reservoir level reaches El. 1395 (halfway), Muleshoe and Blair Gap storage is released up to 2 MGD (3 cfs) and operates between Plane Nine Reservoir El. 1381.5 to 1395 and ceases when El. 1395 is reattained (if sufficient storage exists)

2. Muleshoe Reservoir

a.	Drainage Area	7.2	sq. mi.
b.	Storage Volume	72.0	mg
c.	Storage Volume/Drainage Area	10.0	mg/sq. mi.
d.	Overflow Operating Level	1534.0	msl
e.	Minimum Operating Level	1536.1	msl

f.	Effective Depth	39.9	ft.
g.	Effective Storage	71.17	mg (218.4 ac. ft.)
h.	Conservation Release	0.928	cfs (0.600 mgd)
i.	Evaporation Rate	0.025	cfs (2.06 in/mon)
j.	Withdrawal Scenarios	None	
k.	Contracted Water Supply	N/A	
l.	Diversions	None	
m.	Stream Inflow Record	16.3%	Bald Eagle (Tyrone) Gage Record
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss d. Reservoir remains full and overflows when Plane Nine Reservoir operates between El. 1408 to El. 1395 e. Reservoir releases storage at a maximum rate of 2.0 MGD when Plane Nine Reservoir reaches El. 1395 and operates between Plane Nine Reservoir El. 1381.5 to 1395. Release ceases when Plane Nine reservoir level is re-attained at 1395 (if sufficient storage exists).

3. Blair Gap Reservoir

a.	Drainage Area	3.4	sq. mi.
b.	Storage Volume	25.0	mg
c.	Storage Volume/Drainage Area	7.35	mg/sq. mi.
a.	Overflow Operating Level	1780.0	msl
b.	Minimum Operating Level	1740.0	msl
c.	Effective Depth	40.0	ft.
d.	Effective Storage	24.90	mg (218.4 ac. ft.)
e.	Conservation Release	0.384	cfs (0.600 mgd)
f.	Evaporation Rate	0.0085	cfs (2.33 in/mon)
g.	Withdrawal Scenarios	None	
h.	Contracted Water Supply	N/A	
i.	Diversions	0.45 mgd to Horseshoe Curve Watershed (not included in model simulation)	
j.	Stream Inflow Record	7.7%	Bald Eagle (Tyrone) Gage Record
k.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow

c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss
d. Reservoir remains full and overflows when Plane Nine Reservoir operates between El. 1408 to El. 1395
e. Reservoir releases storage at a maximum rate of 2.0 MGD when Plane Nine Reservoir reaches El. 1395 and operates between Plane Nine Reservoir El. 1381.5 to 1395. Release ceases when Plane Nine reservoir level is re-attained at 1395 (if sufficient storage exists).

Dependable Flow - The Plane Nine Reservoir system will produce a dependable flow of 1.45 mgd under the above operating conditions. This is the minimum flow that can be safely delivered with no shortages based on a 65-year period of record.

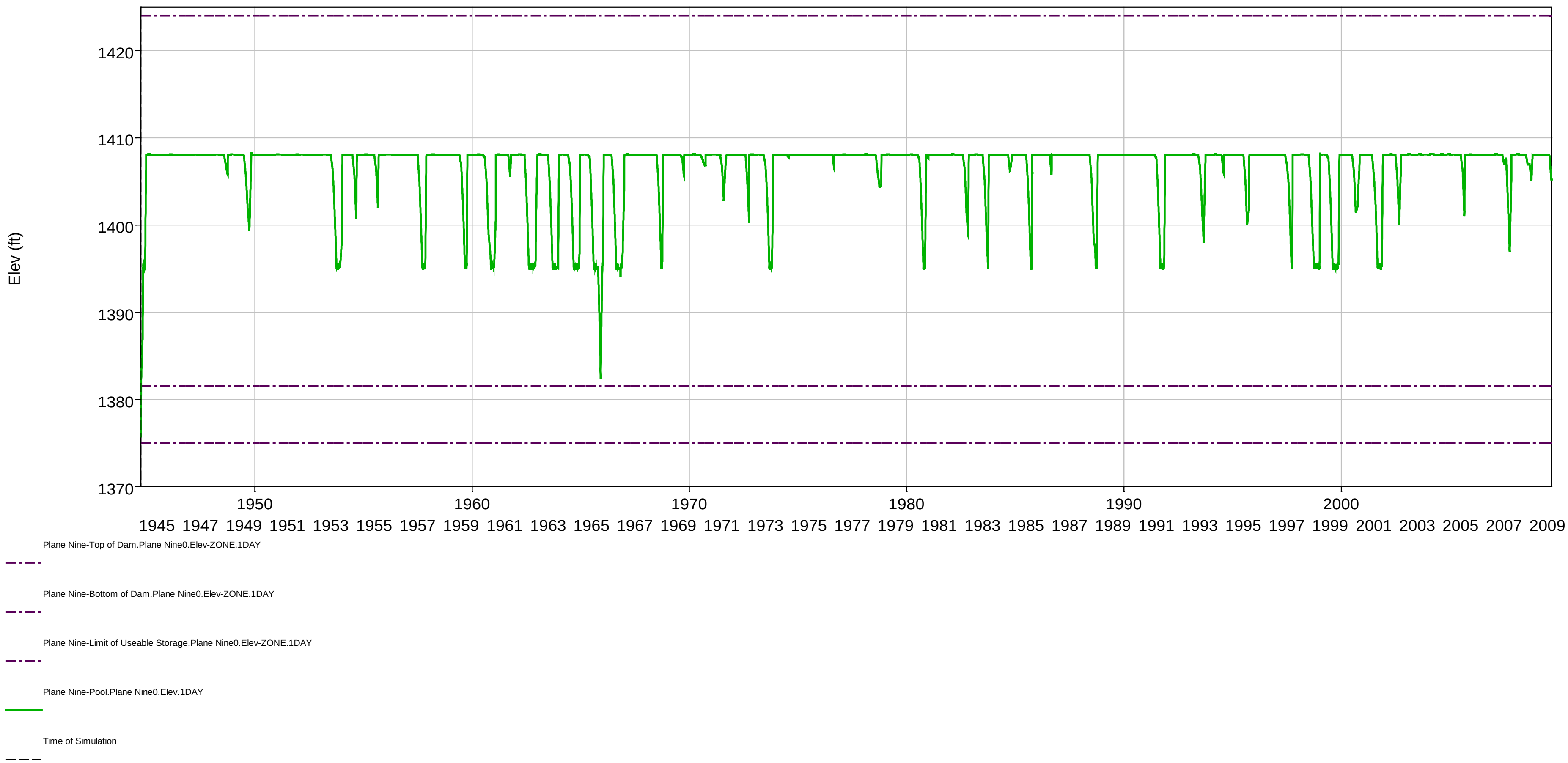
The dependable flow of 1.45 is compared to GD&F's "safe yield" calculated in the Water Allocation Permit application. The "safe yield" for Plane Nine Reservoir is 1.30 mgd (which corresponds to the 2010 average demand). This is based on a low stream flow expected once every ten years for a period of 7-consecutive days (i.e., Q_{7-10}). The 10-year frequency interval corresponds to a return period of 10-years (or a 10% chance of occurring in any one year). Therefore, one can expect a shortage period for a Q_{7-10} stream flow as compared to a smaller "dependable flow" that would never produce a shortage. This analysis indicates that GD&F's original "safe yield" calculations may have understated the Q_{7-10} from Plane Nine Reservoir. The projected conservation release then was almost twice the actual release in the water allocation permit. A Q_{7-10} yield of 1.62 mgd is considered more representative.

It should be noted that the Blair Gap Reservoir diversion to the Horseshoe Curve Watershed (0.45 mgd) was not included in the simulation model runs. As previously mentioned, this diversion is a provisional source to Cochran Impounding Reservoir for water quality considerations. It is used only when sufficient streamflow is available on average 3-4 months per year.

The Res-Sim 3.0 model is provided in the Appendix, including the detailed input parameters. It contains the month-by-month storage-input-output valves, statistical analysis of data, storage-elevation graphs, and depletion values for the period of record. A summary of the storage/stage levels for the Plane Nine Reservoir system is shown in the following graphs.

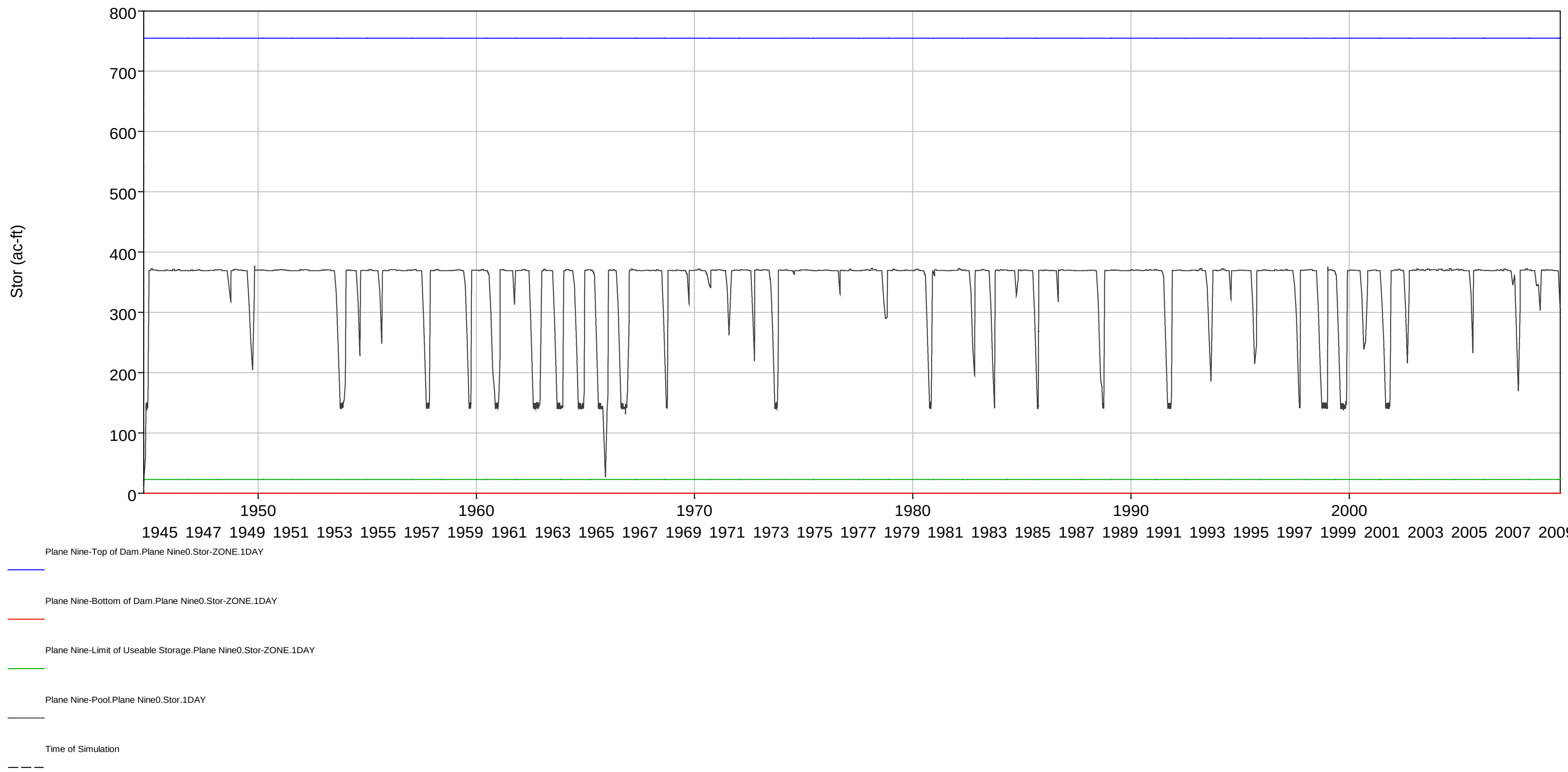
Plane Nine Reservoir
Storage Elevation vs. Time
October 1944 – September 2009

Withdrawal = 2.25 cfs (1.45 mgd)
Dependable Flow



Plane Nine Reservoir
Storage vs. Time
October 1944 – September 2009

Withdrawal = 2.25 cfs (1.45 mgd)
Dependable Flow



Horseshoe Curve Reservoir System - A summary of the operating characteristics used in the model simulation is as follows:

Table 22 - Summary of Horseshoe Reservoir System
Res-Sim 3.0 Operating Conditions

1. Impounding (Cochran) Reservoir

a.	Drainage Area	0.59	sq. mi.
b.	Storage Volume	309.0	mg (rubber dam inflated)
c.	Storage Volume/Drainage Area	32.3	mg/sq. mi.
d.	Overflow Operating Level	1434.6	msl
e.	Minimum Operating Level	1402.6	msl
f.	Effective Depth	32.0	ft.
g.	Effective Storage	285.50	mg (876.2 ac. ft.)
h.	Conservation Release	N/A	
i.	Evaporation Rate	0.068	cfs (1.75 in/mon)
j.	Withdrawal Scenarios	6.257	cfs (4.037 mgd) 2010 Avg. Demand
		4.824	cfs (3.112 mgd) 2002 Avg. Demand
		6.552	cfs (4.227 mgd) 2033 Proj. Demand
		9.75	cfs (6.3 mgd) Intermediate Demand
		11.610	cfs (7.50 mgd) Treatment Plant Capacity
k.	Contracted Water Supply	None	
l.	Diversions	None	
m.	Stream Inflow Record	1.3%	Bald Eagle (Tyrone) Gage Record (Less Upstream Reservoir Flow Regulation)
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss d. When Impounding Reservoir level reaches El. 1416, Lake Altoona storage is pumped back at a maximum rate of 5.0 mgd, withdrawal from Impounding Reservoir is reduced a corresponding amount. The 5.0 mgd rate operates from El. 1416 to 1402.6 and ceases when El. 1416 is re-attained. e. When Lake Altoona level reaches El. 1330, Kittanning Point storage is released to Impounding Reservoir up to a rate of 3.0 mgd. The 3.0 mgd rate operates from El. 1330 to 1305 (Lake Altoona) and ceases when El. 1330 is re-attained.

2. Lake Altoona Reservoir

a.	Drainage Area	2.84	sq. mi.
b.	Storage Volume	835.0	mg (rubber dam inflated)
c.	Storage Volume/Drainage Area	67.2	mg/sq. mi.
d.	Overflow Operating Level	1359.1	msl
e.	Minimum Operating Level	1305.0	msl
f.	Effective Depth	54.1	ft.
g.	Effective Storage	835.4	mg (2563 ac. ft.)
h.	Conservation Release	0.870	cfs (0.562 mgd)
i.	Evaporation Rate	0.125	cfs (1.17 in/mon)
j.	Withdrawal Scenarios	None	
k.	Contracted Water Supply	None	
l.	Diversions	None	
m.	Stream Inflow Record	6.4%	Bald Eagle (Tyrone) Gage Record (Less Upstream Reservoir Flow Regulation)
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow c. Reservoir Begins to Refill from Min. Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss d. When Impounding Reservoir reaches El. 1416, Lake Altoona storage is pumped back at a maximum rate of 5 mgd, (capacity of Lake Altoona Pump Station). The 5 mgd rate operates from El. 1416 and 1402.6 and ceases when El. 1416 is re-attained.

3. Kittanning Point Reservoir

a.	Drainage Area	8.99	sq. mi.
b.	Storage Volume	52.6	mg
c.	Storage Volume/Drainage Area	5.96	mg/sq. mi.
d.	Overflow Operating Level	1496.0	msl
e.	Minimum Operating Level	1474.0	msl
f.	Effective Depth	22.0	ft.
g.	Effective Storage	50.17	mg (154.0 ac. ft.)
h.	Conservation Release	None	
i.	Evaporation Rate	0.027	cfs (2.33 in/mon)
j.	Withdrawal Scenarios	None	
k.	Contracted Water Supply	None	
l.	Diversions	None	
m.	Stream Inflow Record	20.4%	Bald Eagle (Tyrone) Gage Record

n. Operating Rules (Model)

a. Reservoir operations modeled between Minimum & Overflow Operating Levels
b. When Min. Operating Level is reached, Inflow = Outflow
c. Reservoir Begins to Refill from Min. Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss
d. When Lake Altoona level reaches El. 1330, Kittanning Point Reservoir storage is released to Impounding Reservoir up to a rate of 3.0 mgd and operates to a range El. 1330-1305 (Lake Altoona) and ceases when Lake Altoona level of El. 1330 is re-attained (if sufficient storage exists).

Dependable Flow - The Horseshoe Curve Reservoir system will produce a dependable flow of 5.10 mgd under the above operating conditions. This is the minimum flow that can be safely delivered with no shortages based on a 65-year period of record.

The dependable flow of 5.10 mgd is compared to GD&F's "safe yield" calculated in the Water Allocation Permit application. The "safe yield" for the Horseshoe Curve Reservoir system is 6.32 mgd (which corresponds to the 2010 average demand). This is based on a low stream flow expected once every ten years for a period of 7-consecutive days (i.e., Q_{7-10}). The 10-year frequency interval corresponds to a return period of 10-years (or a 10% chance of occurring in any one year). Therefore, one can expect a shortage period for a Q_{7-10} stream flow as compared to a smaller "dependable flow" that would never produce a shortage. This analysis would tend to validate GD&F's original "safe yield" calculations. It should be noted that no provision for a conservation release was included in the original calculation. If this figure (0.562 mgd) is subtracted, the Q_{7-10} yield is 5.758 mgd. This is still considered valid when compared to a dependable flow of 5.35 mgd.

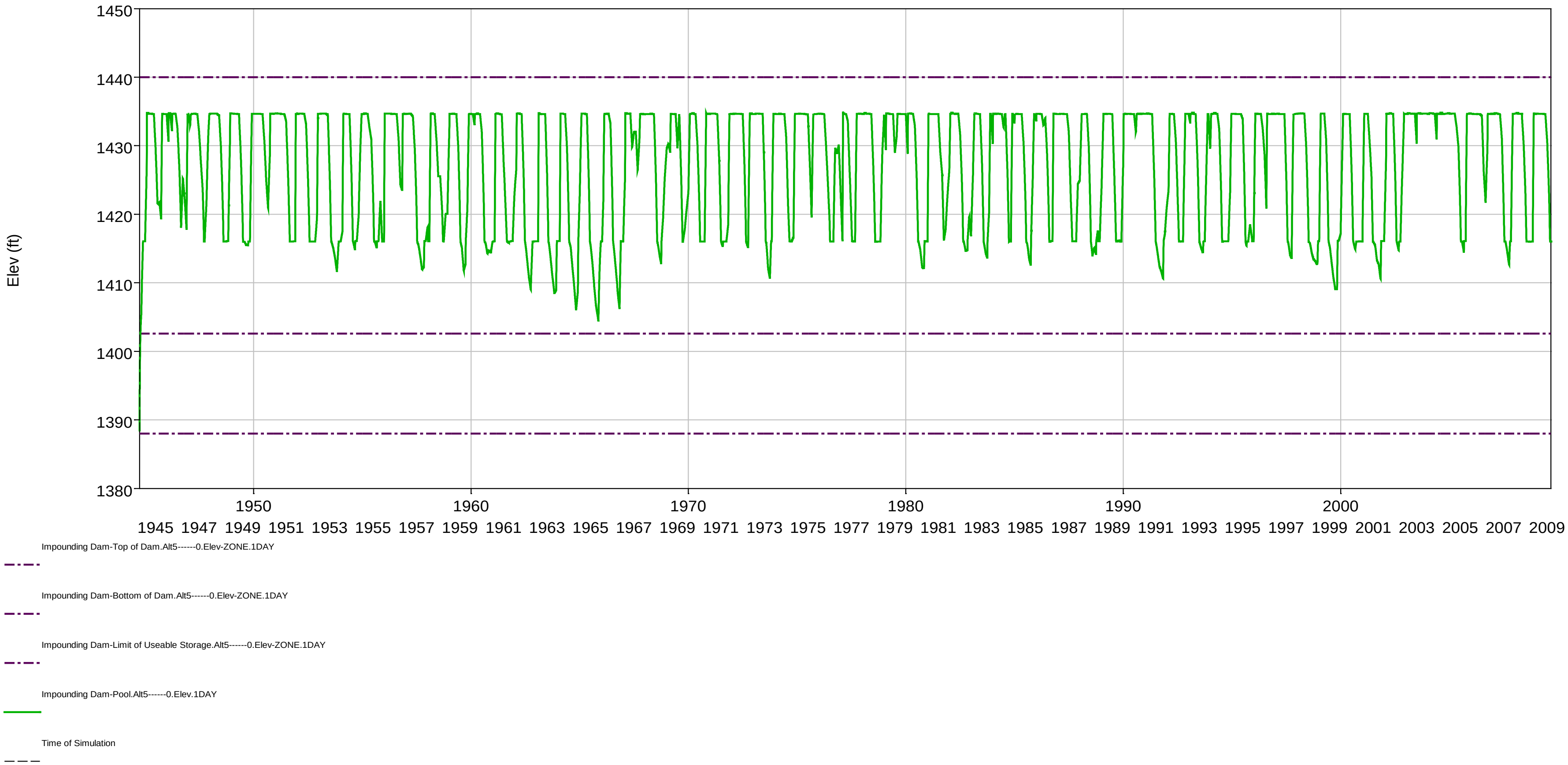
The Cochran-Impounding Reservoir graphs shows a large annual fluctuation. This is due to its function as a control reservoir for the Pappas WTP. Lake Altoona's graphs show periodic fluctuation because of its function as a supplemental source for the Cochran-Impounding Reservoir. Both simulations assume that both reservoirs have fully inflated rubber dams for maximum storage. The importance of the Lake Altoona and Cochran-Impounding Reservoir rubber dams was found by a Res-Sim 3.0 simulation run.

If the rubber dams are not inflated, the model simulation suggests a reduction of dependable yield to 4.39 mgd (18%). They add 0.71 mgd (14%) of safe yield and are, therefore, an indispensible component of the storage system.

The Res-Sim 3.0 model is provided in the Appendix, including the detailed input parameters. It contains the month-by-month storage-input-output valves, statistical analysis of data, storage-elevation graphs, and related values for the period of record. A summary of the storage/stage levels for the Horseshoe Curve Reservoir system is shown in the following graphs.

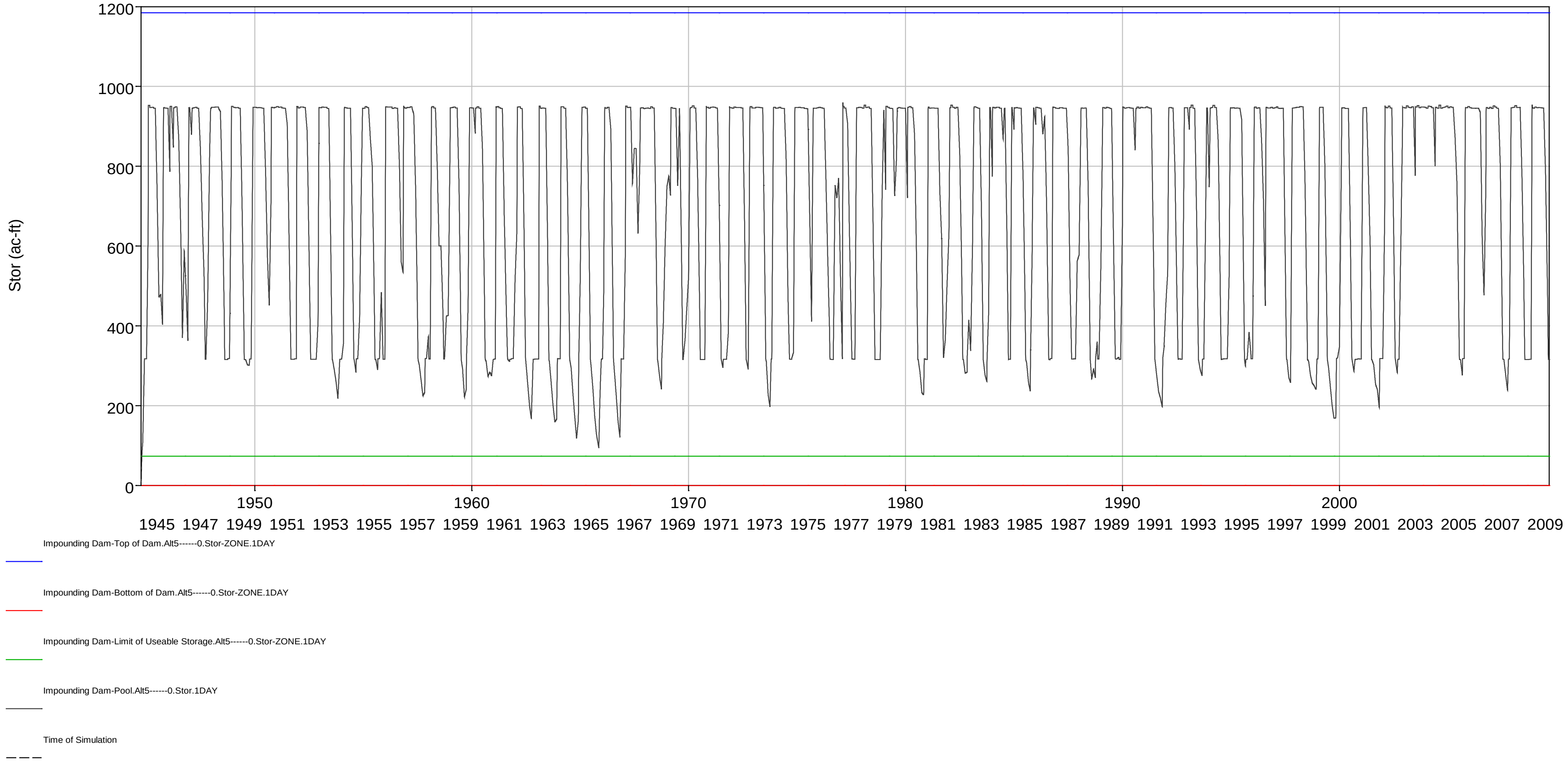
Impounding Dam
Storage Elevation vs. Time
October 1944 – September 2009

Withdrawal = 7.91 cfs (5.10 mgd)
Dependable Flow
With Rubber Dam Extended



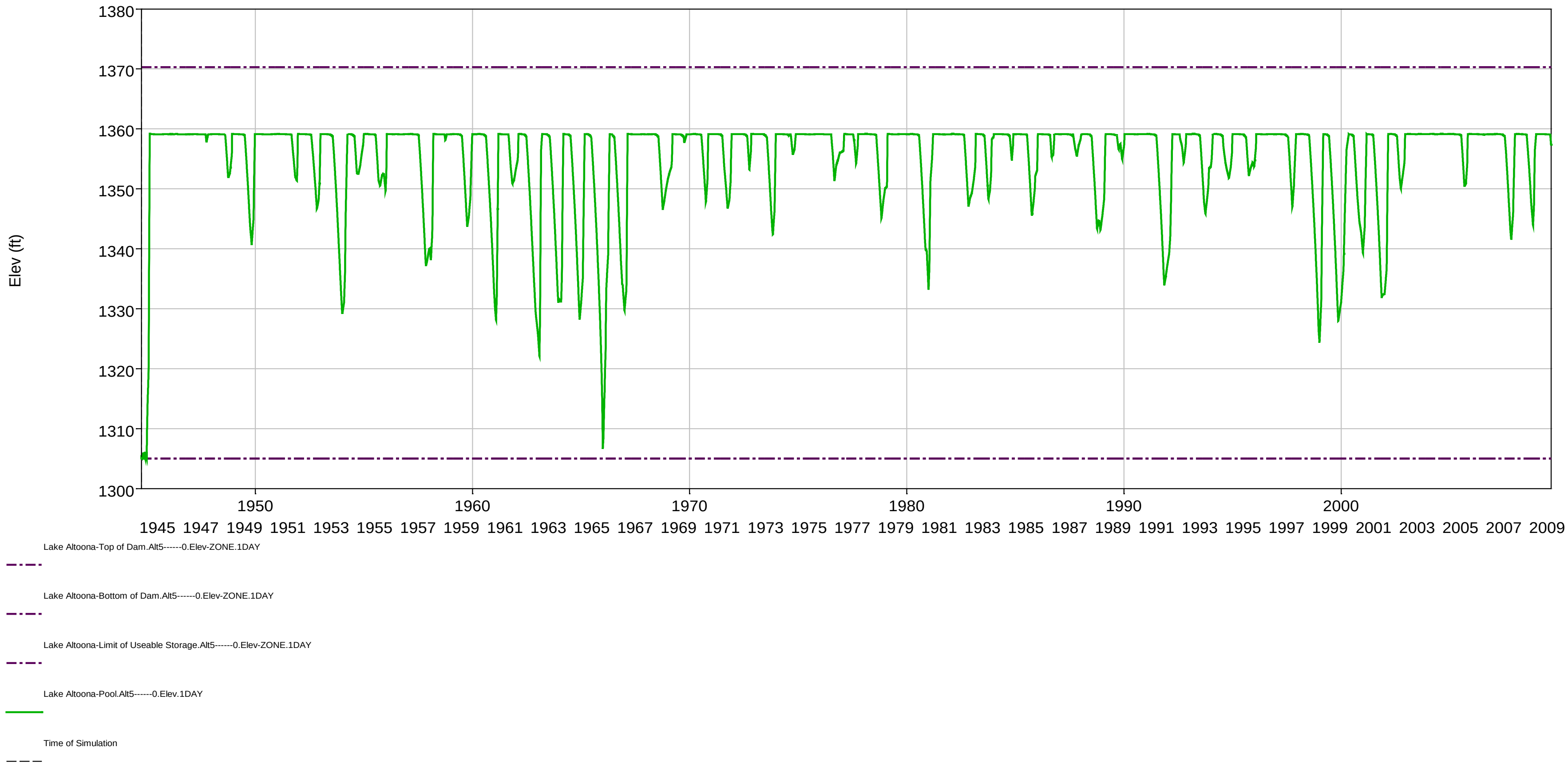
Impounding Dam
Storage vs. Time
October 1944 – September 2009

Withdrawal = 7.91 cfs (5.10 mgd)
Dependable Flow
With Rubber Dam Extended



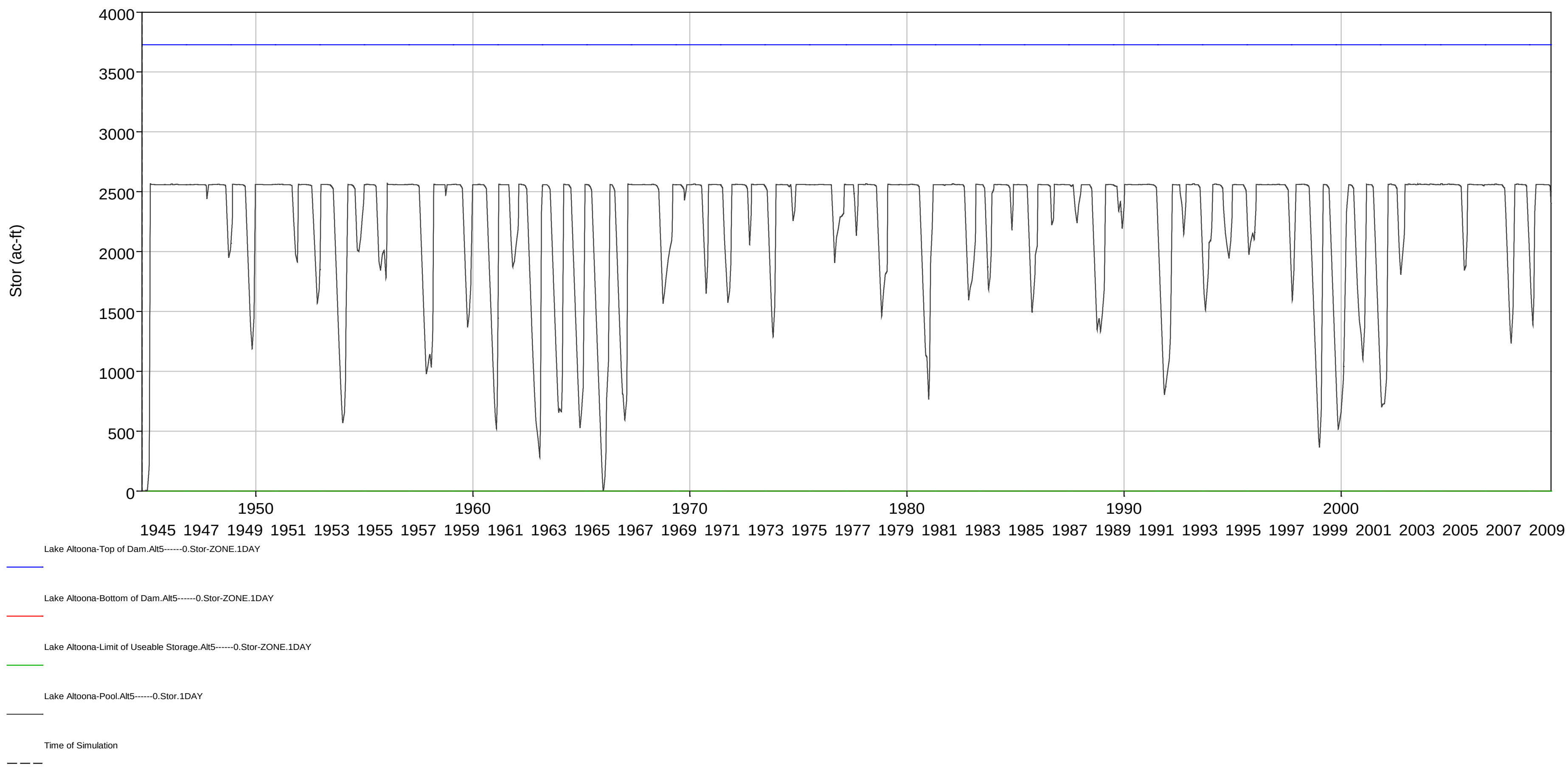
Lake Altoona
Storage Elevation vs. Time
October 1944 – September 2009

Withdrawal = 7.91 cfs (5.10 mgd)
Dependable Flow
With Rubber Dam Extended



Lake Altoona
Storage vs. Time
October 1944 – September 2009

Withdrawal = (5.10 mgd)
Dependable Flow
With Rubber Dam Extended



Mill Run Reservoir System - A summary of the operating characteristics used in the model simulation is as follows:

Table 23 - Summary of Mill Run Reservoir System
Res-Sim 3.0 Operating Conditions

1. Mill Run Reservoir

a.	Drainage Area	4.25	sq. mi.
b.	Storage Volume	519.0	mg (rubber dam inflated)
c.	Storage Volume/Drainage Area	122.1	mg/sq. mi.
d.	Overflow Operating Level	1508.0	msl
e.	Minimum Operating Level	1430.0	msl
f.	Effective Depth	78.0	ft.
g.	Effective Storage	516.94	mg (1587 ac. ft.)
h.	Conservation Release	0.721	cfs (0.466 mgd)
i.	Evaporation Rate	0.060	cfs (1.28 in/mon)
j.	Withdrawal Scenarios	3.024	cfs (1.95 mgd) 2002 Avg. Demand
		4.046	cfs (2.61 mgd) 2010 Avg. Demand
		4.108	cfs (2.650 mgd) 2033 Proj. Demand
		7.737	cfs (5.00 mgd) Treatment Plant Capacity
k.	Contracted Water Supply	None	
l.	Diversions	None	
m.	Stream Inflow Record	9.6%	Bald Eagle (Tyrone) Gage Record
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss d. When Mill Run Reservoir level reaches El. 1465, Allegheny Reservoir storage is pumped back to Mill Run WTF at a maximum rate of 2.0 cfs and operates between El. 1465 -1430 and ceases when Mill Run reservoir re-attains El. 1465. e. Mill Run withdrawal is reduced a corresponding amount (2.0 cfs) during the time Allegheny Reservoir storage is pumped back to Mill Run WTF.

2. Allegheny Reservoir

a.	Drainage Area	2.00	sq. mi.
b.	Storage Volume	49.3	mg
c.	Storage Volume/Drainage Area	7.9	mg/sq. mi.

d.	Overflow Operating Level	1305.65	msl
e.	Minimum Operating Level	1289.0	msl
f.	Effective Depth	16.65	ft.
g.	Effective Storage	45.56	mg (139.8 ac. ft.)
h.	Conservation Release	1.159	cfs (0.749 mgd)
i.	Evaporation Rate	0.024	cfs (2.33 in/mon)
j.	Withdrawal Scenarios	None	
k.	Contracted Water Supply	None	
l.	Diversions	None	
m.	Stream Inflow Record	4.5%	Bald Eagle (Tyrone) Gage Record (Less Upstream Reservoir Flow Regulation)
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow c. Reservoir Begins to Refill from Min. Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss d. When Mill Run level reaches El. 1465, Allegheny Reservoir storage is pumped back at a maximum rate of 2.0 cfs and operates between El. 1465 -1430 and ceases when Mill Run reservoir re-attains El. 1465.

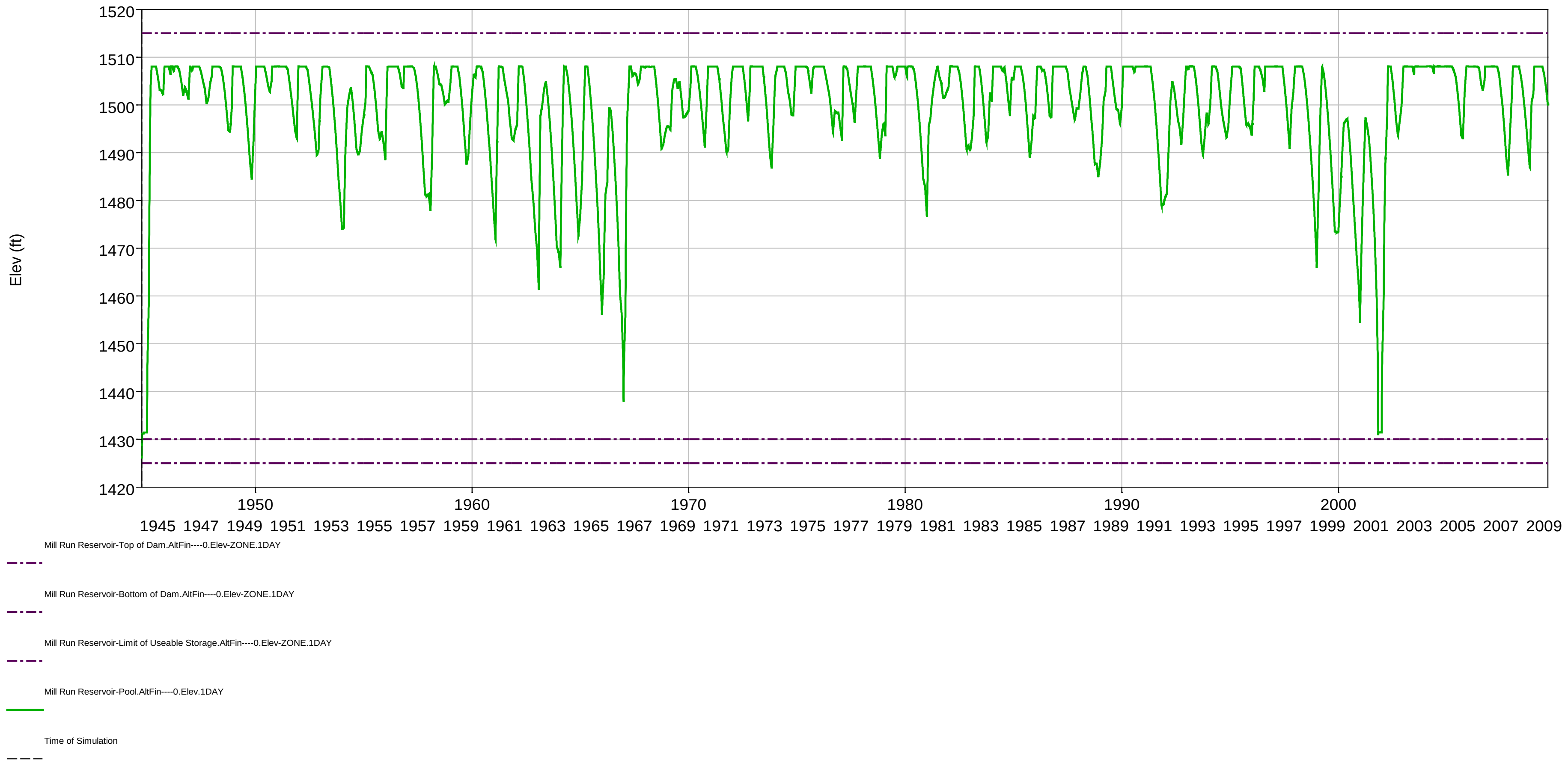
Dependable Flow - The Mill Run Reservoir system will produce a dependable flow of 1.90 mgd under the above operating conditions. This is the minimum flow that can be safely delivered with no shortages based on a 65-year period of record.

The dependable flow of 1.90 is compared to GD&F's "safe yield" calculated in the Water Allocation Permit application. The "safe yield" for Mill Run Reservoir is 2.397 mgd (which corresponds to the 2010 average demand). This is based on a low stream flow expected once every ten years for a period of 7-consecutive days (i.e., $Q_{7\text{-}10}$). The 10-year frequency interval corresponds to a return period of 10-years (or a 10% chance of occurring in any one year). Therefore, one can expect a shortage period for a $Q_{7\text{-}10}$ stream flow as compared to a smaller "dependable flow" that would never produce a shortage. This analysis indicates that GD&F's original "safe yield" calculations may have overstated the $Q_{7\text{-}10}$ yield. A $Q_{7\text{-}10}$ yield of about 2.10 mgd is considered reasonable.

The Res-Sim 3.0 model is provided in the Appendix, including the detailed input parameters. It contains the month-by-month storage-input-output valves, statistical analysis of data, storage-elevation graphs, and depletion values for the period of record. A summary of the storage/stage levels for the Mill Run Reservoir system is shown in the following graphs. Allegheny Reservoir adds 0.17 mgd (9%) of the total yield for the Mill Run system.

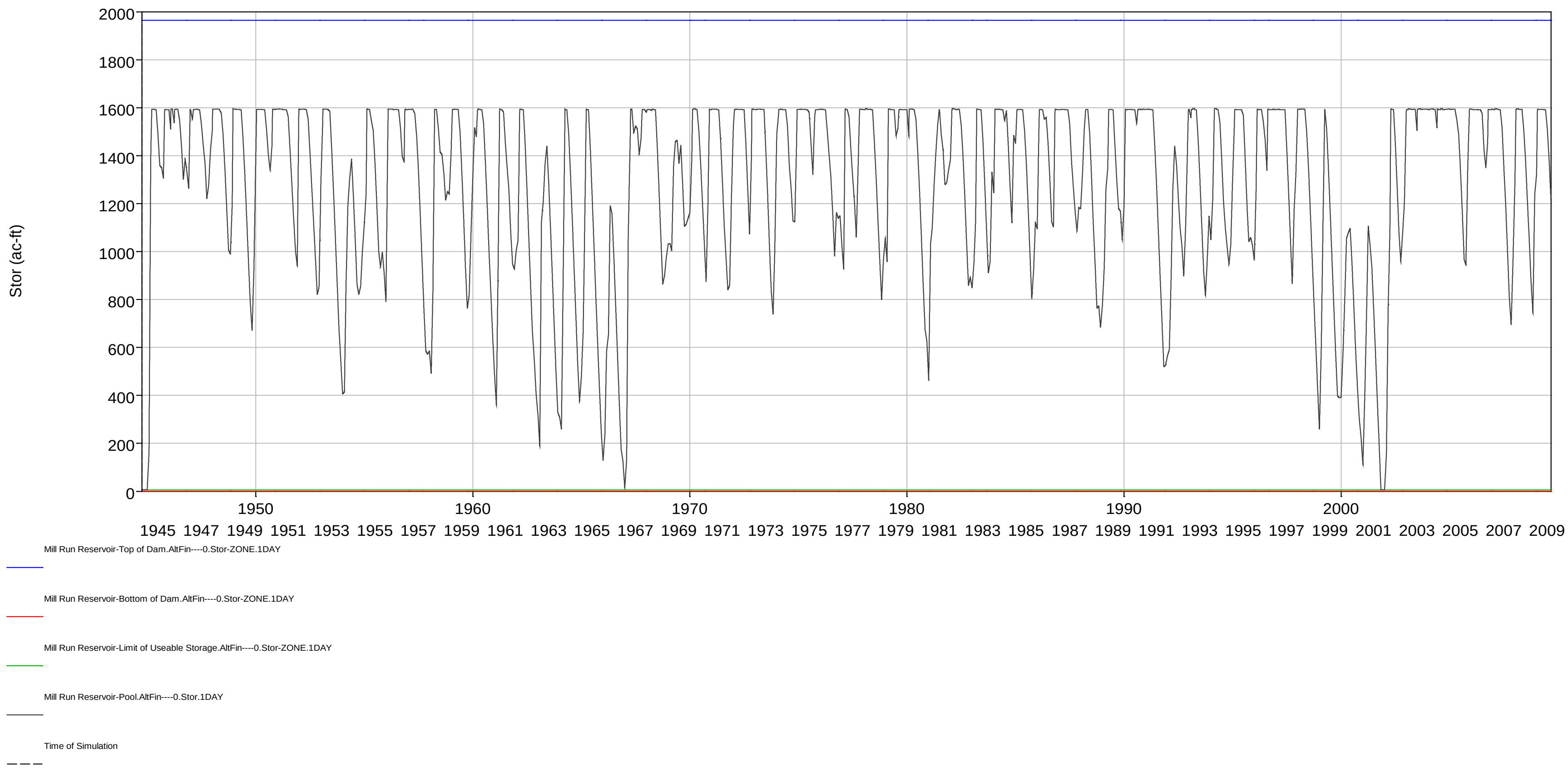
Mill Run Reservoir
Storage Elevation vs. Time
October 1944 – September 2009

Withdrawal = 2.95 cfs (1.90 mgd)
Dependable Flow
Rubber Dam Extended



Mill Run Reservoir
Storage vs. Time
October 1944 – September 2009

Withdrawal = 2.95 cfs (1.90 mgd)
Dependable Flow
Rubber Dam Extended



Homer Gap Reservoir System - A summary of the operating characteristics used in the model simulation is as follows:

Table 24 - Summary of Homer Gap Reservoir System
Res-Sim 3.0 Operating Conditions

1. Homer Gap Reservoir

a.	Drainage Area	2.47	sq. mi.
b.	Storage Volume	26.7	mg
c.	Storage Volume/Drainage Area	10.8	mg/sq. mi.
d.	Overflow Operating Level	1448.8	msl
e.	Minimum Operating Level	1433.8	msl
f.	Effective Depth	15.0	ft.
g.	Effective Storage	24.35	mg (74.7 ac. ft.)
h.	Conservation Release	0.201	cfs (0.13 mgd)
i.	Evaporation Rate	0.021	cfs (2.06 in/mon)
j.	Withdrawal Scenarios	0.694	cfs (0.448 mgd) 2002 Avg. Demand
		0.944	cfs (0.609 mgd) 2033 Proj. Demand
		0.425	cfs (0.275 mgd) Intermediate Demand
		1.547	cfs (1.00 mgd) Treatment Plant Capacity
k.	Contracted Water Supply	None	
l.	Diversions	None	
m.	Stream Inflow Record	5.20%	Bald Eagle (Tyrone) Gage Record
n.	Operating Rules (Model)		a. Reservoir operations modeled between Minimum & Overflow Operating Levels b. When Min. Operating Level is reached, Inflow = Outflow c. Reservoir Begins to Refill from Minimum Oper. Level When Inflow Exceeds Conservation Release + Evap. Loss

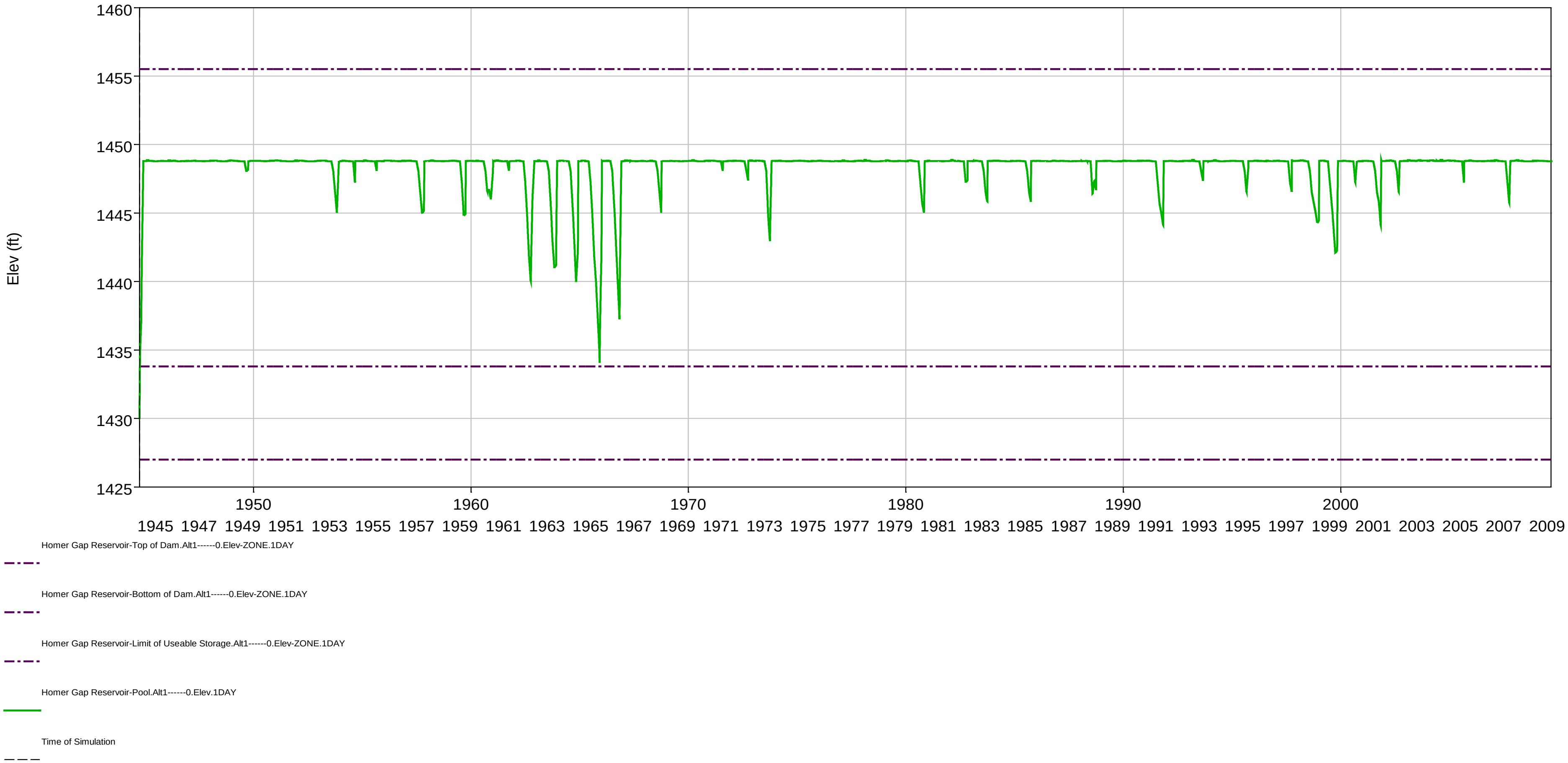
Dependable Flow - The Homer Gap Reservoir system will produce a dependable flow of 0.171 mgd under the above operating conditions. This is the minimum flow that can be safely delivered with no shortages based on a 65-year period of record.

The dependable flow of 0.171 is compared to GD&F's "safe yield" calculated in the Water Allocation Permit application. The "safe yield" for Homer Gap Reservoir is 0.202 mgd (which corresponds to the 2010 average demand). This is based on a low stream flow expected once every ten years for a period of 7-consecutive days (i.e., $Q_{7\text{-}10}$). The 10-year frequency interval corresponds to a return period of 10-years (or a 10% chance of occurring in any one year). Therefore, one can expect a shortage period for a $Q_{7\text{-}10}$ stream flow as compared to a smaller "dependable flow" that would never produce a shortage. This analysis would tend to validate GD&F's original "safe yield" calculations.

The Res-Sim 3.0 model is provided in the Appendix, including the detailed input parameters. It contains the month-by-month storage-input-output valves, statistical analysis of data, storage-elevation graphs, and related values for the period of record. A summary of the storage/stage levels for the Homer Gap Reservoir system is shown in the following graphs.

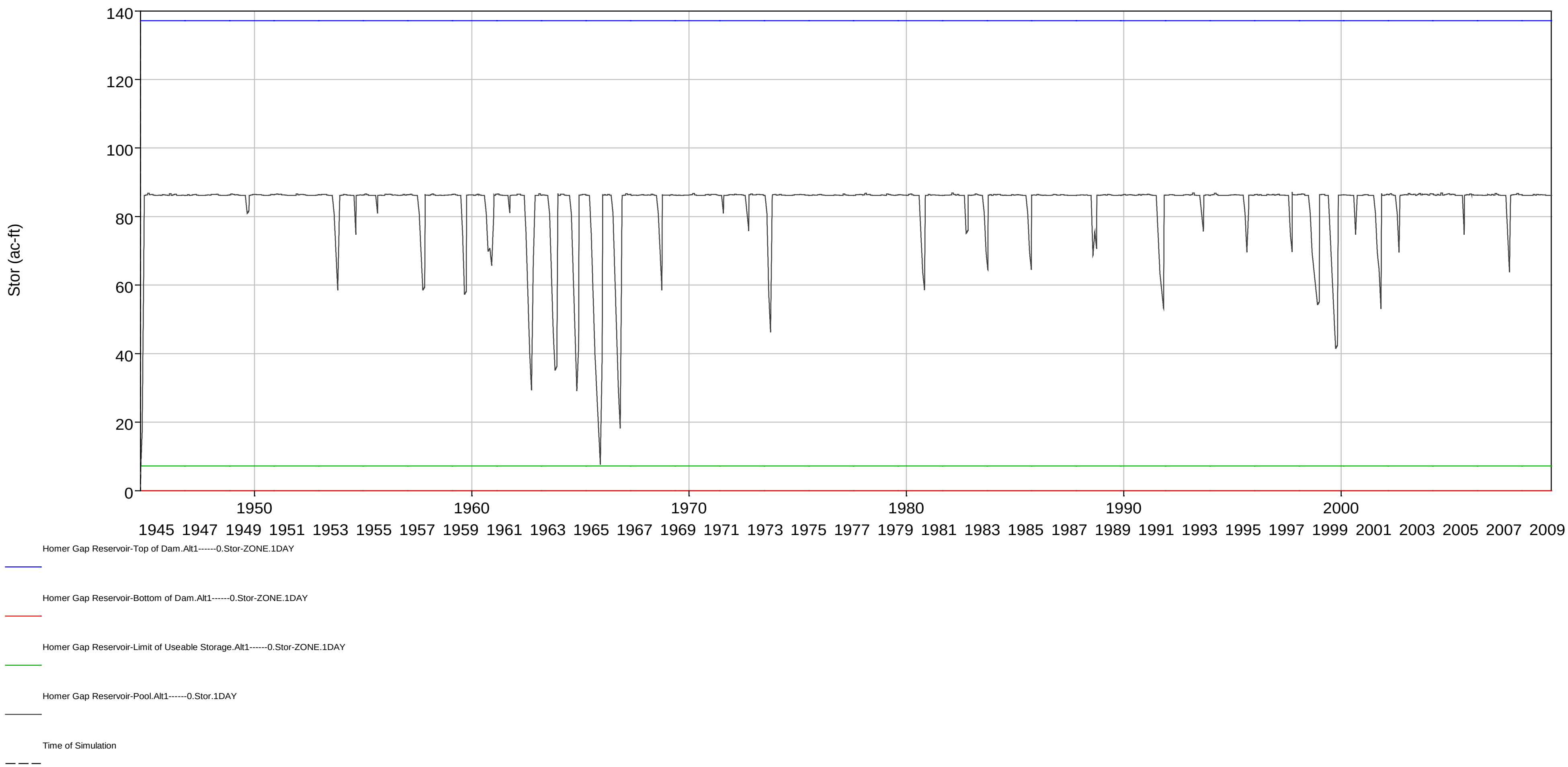
Homer Gap Reservoir
Storage Elevation vs. Time
October 1944 – September 2009

Withdrawal = 0.265 cfs (0.171 mgd)
"Dependable Flow"



Homer Gap Reservoir
Storage vs. Time
October 1944 – September 2009

Withdrawal = 0.265 cfs (0.171 mgd)
"Dependable Flow"



The dependable flow and safe yield for each reservoir system is summarized in the following table:

Table 25 - Summary of Total Reservoir Systems Dependable Flow (Safe Yield)

Reservoir Systems	Dependable Flow/Safe Yield (mgd)
Bellwood*	1.840
Tipton*	1.630
Kettle	0.723
Plane Nine*	1.450
Horseshoe Curve*	5.100
Mill Run*	1.900
Homer Gap	0.171
Total	12.814

*Reservoirs Currently in Operation

Assessment - The significance of the Res-Sim 3.0 evaluation is that on an aggregate basis, the AWA reservoir system is sufficient for all demands up to 11.93 (use 12 mgd) for the current system configuration or up to 12.82 mgd (use 13 mgd) for the total reservoir system.

Over the 65-year period of record, the total reservoir system could sustain these yields without any shortages, deficiencies, demand restrictions or water rationing. Theoretically, the system could be considered "drought-proof" up to these yields. Although a 65-year time frame is an impressive statistical record with which to base a simulation model, it is possible that more severe drought periods could occur greater than those indicated.

RESERVOIR SYSTEM RELIABILITY AND DEFICIENCY MODELING

Reservoir Reliability and Deficiency Methodology - Several criteria have been established to measure the reliability of a reservoir system. Since absolute guarantees of water yield are not possible, estimates of shortages that could reasonably develop in supplying the demands from available storage is necessary.

According to Corps of Engineers Manual EM 1110-2-420, *"…shortages are generally considered to be intolerable for purposes such as drinking water; although some reduction in the quantity of municipal supply can be tolerated without serious economic effects. Shortages greater than 10 percent may cause serious hardship…"* Many reservoirs are designed based on supplying a firm or "dependable" yield during the most critical drought of record.

For the existing system, the situation is reversed because many of the Authority reservoirs were designed without the benefit of long-term stream records and modern routing analysis. In these cases, the analysis becomes one of finding the "safe" yield after the fact and adjusting demand for shortages (drought contingency planning). Several criteria that measure reliability used in our evaluation of Res-Sim 3.0 model output include:

- Computation of "dependable" yield for each reservoir will be done by adjusting withdrawals in the Res-Sim 3.0 model to produce zero shortages for the period of record. This is one of the most important "measurables" resulting from this study. Dependable flow has often been defined as the "safe yield" or "firm yield."

- Degree of control by a reservoir can be judged both in terms of duration and quantity. The "degree of duration control" may be defined as the percent of the total period of study during which releases are equal to or greater than demand. The "degree of discharge" control is the useable release in percent of the total demand. These measures are often of the same order of magnitude and, if no rationed releases are provided, they are often equal. These measures can be misleading to the casual observer since a 90% reservoir reliability could be considered acceptable. As mentioned before, a 90% reliable yield is possibly unsustainable and can produce intolerable shortages.

- A better approach is to use a "shortage index" that *"…is equal to the sum of the squares of the annual shortages over a 100-year period when each annual shortage is expressed as a ratio to the annual requirements…"* The shortage index is expressed below:

$$SI = \frac{100\left[\sum_{i=1}^{N}\left(\frac{S_A}{D_A}\right)^2\right]}{N}$$

SI = Shortage Index
N = Number of Years in Routing Study
S_A = Annual Shortage (annual demand volume minus annual volume actually supplied)
D_A = Annual Demand Volume

According to the Corps, the shortage index, *"reflects the observation that the economic and social effects are roughly proportional to the square of the degree of shortage…"* To illustrate, a shortage of 40 percent is assumed to be four times as severe as a shortage of 20 percent. The shortage index is considered to be superior over shortage frequency alone as a measure of severity because shortage frequency considers neither magnitude nor duration. Obviously, the lower the "shortage index" the higher the reliability. It should be noted that "average annual deficiency" is a useful measurement in itself and is expressed as S_A/D_A.

- Examination of deficiency events for each reservoir is done using frequency analysis techniques. The log-Pearson III distribution is widely applied for low flow analysis. Since all reservoir recovery periods occur within the "water year," this maintains the assumption of event independence in the frequency analysis. The discrete deficiency events were entered into a log-Pearson III spreadsheet program which produced probability plots for reservoir drawdown. The purpose is to examine the expected reservoir drawdown during deficiency events.

The above parameters have been computed for each reservoir at various demand conditions. In addition, the number, duration and volumes of annual deficiencies are included. A brief evaluation of the data analysis follows each section.

The Res-Sim 3.0 model simulated individual reservoir performance for the various withdrawal demands for each reservoir system. This data output includes a reliability and deficiency analysis using standard evaluation criteria. Total duration periods and storage deficiency values are also shown. A brief analysis of each model simulation is included for each reservoir. Finally, a ranking of each reservoir system according to reliability and deficiency dependability are also included.

Table 26 - Bellwood Reservoir System
Regulation Storage Evaluation and Model Simulation Results

Criteria	Dependable Flow	2010 Avg. Production	2002 Production	Projected Production	Treatment Capacity
a. Withdrawal/Demand (mgd)	1.84	2.051	2.305	3.089	5.00
b. No. of Deficiency Periods (1944 - 2009)	0	1	2	14	34
c. Total Duration of Deficiency (mon.)	0	0.99	2.17	16.3	35.8
d. Maximum Event Duration (mon.)	0	0.99	1.87	3.29	5.03
e. Minimum Event Duration (mon.)	0	0.99	0.30	0.16	0.10
f. Average Duration (mon.)	0	0.99	1.085	1.16	1.06
g. Total Demand Deficiency (mg) (1944-2009)	0	61.53	152.14	1,549.86	5,445
h. Maximum Event Demand Deficiency (mg)	0	61.53	131.39	313.10	765
i. Minimum Event Demand Deficiency (mg)	0	61.53	20.75	15.66	15
j. Average Demand Deficiency (mg)	0	61.53	76.07	110.70	160.15
k. Degree of Duration Control (%)	-	99.87	99.72	97.91	95.4
l. Degree of Discharge Control (%)	-	99.87	99.72	97.91	95.4
m. Average Annual Deficiency (%)	-	8.22	9.04	9.69	8.77
n. Deficiency Index	-	0.01	0.025	0.20	0.40
o. Deficiency Drawdown (ft.), 2 yr. Frequency	-	3.7	4.7	9.0	Empty
p. Deficiency Drawdown (ft.), 10 yr. Frequency	-	17.4	22.9	Empty	Empty
q. Deficiency Drawdown (ft.), 25 yr. Frequency	-	31.4	Empty	Empty	Empty
r. Deficiency Drawdown (ft.), 50 yr. Frequency	-	Empty	Empty	Empty	Empty
s. Limit of Useable Storage (ft.)	32.0	32.0	32.0	32.0	32.0

Assessment - Bellwood Reservoir has a dependable flow or safe yield of 1.84 mgd for the 1994 - 2009 period of record. For recent production (2002 - 2010) of 2.0 to 2.3 mgd, only 3 deficiency periods were generated, indicating a very high degree of reliability. The degree of discharge control is on the order of 99.72% - 99.87% (or only 1 or 2 months, total, over the last 65 years) with very low deficiency indices (0.01 to 0.025). For the projected 2033 production of 3.13 mgd, 14 deficiency periods are indicated, with low reliability (97.91%) and a deficiency index (0.20) 10 to 20 times more severe than recent production.

Since Bellwood Reservoir has a contractual supply agreement with Bellwood Borough, maintaining production levels during shortages is a priority. Transfer of water from surplus system such as Tipton (gravity interconnection) or Horseshoe Curve (Easterly booster station) will be considered in a later evaluation.

Relative to the frequency of deficiency drawdown, this has application to drought contingency planning. We performed a frequency analysis of drought storage/drawdown for deficiency periods only (inflow less than outflow). The tabulation shows that at the specified demand rates, the reservoirs are generally empty for deficiency periods of 10-50 years. Although these are unusual drought periods, the need for system transfers or demand reductions are required.

An examination of monthly critical durations show that they occur in the latter half of the year. DEP has identified February 28 when reservoir refill and recovery will typically occur. Therefore, the emptying and filling of the reservoir occurs annually or within the March-February water year. This occurs even during the most severe drought conditions on record. This qualifies Bellwood Reservoir as a "small reservoir" under the DEP drought management criteria.

In summary, model simulation shows Bellwood Reservoir to be highly reliable with one of the highest values of dependable yield in the system. At current production levels, the reservoir is sufficient for all but 1-2 drought events during the 65-year period of record. However, a projected planning levels (3.089 mgd), it is more vulnerable to drought events. This would require reductions in either demand levels or transfer of flow from other systems.

It is interesting to note that Bellwood has one of the lowest storage volumes-to-drainage area ratios of the larger reservoirs. Given the sizeable drainage area (18.2 sq. mi.), Bellwood Reservoir could be expanded for additional storage, if future demand dictates. Raising the dam 15-feet could increase reservoir capacity to 500 million gallons and the dependable yield to 3 mgd. Also, the topography of the dam site is favorable for dam expansion, more so than any other Authority dam.

Table 27 - Kettle Reservoir System
Regulation Storage Evaluation and Model Simulation Results

Criteria	Dependable Flow	2002 Production	Projected Production	Intermediate Production	Treatment Capacity
a. Withdrawal/Demand (mgd)	0.723	0.598	0.802	1.25	2.0
b. No. of Deficiency Periods (1944 - 2009)	0	0	1	21	65
c. Total Duration of Deficiency (mon.)	0	0	2.27	38.1	175
d. Maximum Event Duration (mon.)	0	0	2.27	3.78	5.79
e. Minimum Event Duration (mon.)	0	0	2.27	0.03	0.03
f. Average Duration (mon.)	0	0	2.27	1.81	2.69
g. Total Demand Deficiency (mg) (1944-2009)	0	0	55.96	1,449	10,648
h. Maximum Event Demand Deficiency (mg)	0	0	55.96	143.75	352
i. Minimum Event Demand Deficiency (mg)	0	0	55.96	1.25	15
j. Average Demand Deficiency (mg)	0	0	55.96	69.0	163.8
k. Degree of Duration Control (%)	-	-	99.71	95.1	77.5
l. Degree of Discharge Control (%)	-	-	99.71	95.1	77.5
m. Average Annual Deficiency (%)	-	-	18.8	15.1	22.4
n. Deficiency Index	-	-	0.055	1.02	5.03
o. Deficiency Drawdown (ft.), 2 yr. Frequency	-	5.7	10.5	26.9	Empty
p. Deficiency Drawdown (ft.), 10 yr. Frequency	-	15.9	26.1	Empty	Empty
q. Deficiency Drawdown (ft.), 25 yr. Frequency	-	21.6	33.4	Empty	Empty
r. Deficiency Drawdown (ft.), 50 yr. Frequency	-	25.8	Empty	Empty	Empty
s. Limit of Useable Storage (ft.)	34.5	34.5	34.5	34.5	34.5

Assessment - Kettle Reservoir has a dependable flow of 0.723 mgd for the 1944 - 2009 period of record. Pre-2006 production indicates no deficiencies with a high degree of reliability. For projected production (0.802 mgd), only one (1) shortage period was indicated. At intermediate and treatment capacity production values (1.25 to 2.0 mgd), the degree of discharge control increases dramatically as does the deficiency index. Flows at these levels obviously cannot be sustained. Higher production values can only be utilized for peak flow periods of less than 1-2 month's duration.

Kettle Reservoir has been decommissioned for economic reasons since 2006. It is considered a provisional source for low flow periods, scheduled plant maintenance shutdowns, higher sustained production and emergency service.

Kettle's value is the ability to provide service to discrete areas by virtue of its elevation, the second highest in the system. Kettle can supplement service to Altoona High Service and provide full service to its former service area (Pottsgrove-Greenwood). It should be noted that Kettle Reservoir possesses the second highest storage ratio (74 mg/sq. mi.) in the Authority system. Having large available storage at a high elevation is a significant hydraulic factor in terms of operational flexibility.

Table 28 - Homer Gap Reservoir System
Regulation Storage Evaluation and Model Simulation Results

Criteria	Dependable Flow	Intermediate Production	2002 Production	Projected Production	Treatment Capacity
a. Withdrawal/Demand (mgd)	0.171	0.275	0.448	0.609	1.00
b. No. of Deficiency Periods (1944 - 2009)	0	8	28	39	47
c. Total Duration of Deficiency (mon.)	0	8.91	48.72	98.17	142.8
d. Maximum Event Duration (mon.)	0	2.96	4.50	185	6.48
e. Minimum Event Duration (mon.)	0	0.10	0.16	12	0.03
f. Average Duration (mon.)	0	1.11	1.74	2.52	3.04
g. Total Demand Deficiency (mg) (1944-2009)	0	74.55	664	1818	4,343
h. Maximum Event Demand Deficiency (mg)	0	24.75	61.38	112.7	197
i. Minimum Event Demand Deficiency (mg)	0	0.83	0.45	7.31	1
j. Average Demand Deficiency (mg)	0	9.31	23.7	46.6	92.4
k. Degree of Duration Control (%)	-	98.86	93.75	87.4	81.7
l. Degree of Discharge Control (%)	-	98.86	93.75	87.4	81.7
m. Average Annual Deficiency (%)	-	9.27	14.5	21.0	25.3
n. Deficiency Index	-	0.16	1.36	3.48	4.62
o. Deficiency Drawdown (ft.), 2 yr. Frequency	-	3.0	7.1	11.7	Empty
p. Deficiency Drawdown (ft.), 10 yr. Frequency	-	12.9	Empty	Empty	Empty
q. Deficiency Drawdown (ft.), 25 yr. Frequency	-	Empty	Empty	Empty	Empty
r. Deficiency Drawdown (ft.), 50 yr. Frequency	-	Empty	Empty	Empty	Empty
s. Limit of Useable Storage	15.0	15.0	15.0	15.0	15.0

Assessment - Homer Gap Reservoir has a dependable flow of 0.171 mgd for the 1944 - 2009 period of record. Pre-2006 production indicates 36 shortage periods. Degree of discharge control valves range from 93.75 to 98.86%. Deficiency indexes were 0.16 to 1.36. These values indicate a medium-to-low reservoir reliability. Projected production (0.609 mgd) unreliability is higher yet with deficiency periods occurring every other year. The deficiency index is almost 2.5 times more severe than the pre-2006 production. It is apparent that low yield from the Homer Gap watershed combined with a low storage volume (10.8 mg) and storage-to-drainage area ratio (10.8) causes the Homer Gap system to have little utility during drought periods. This system would have to be entirely supplemented by the Horseshoe Curve system during these times.

Homer Gap Reservoir has been decommissioned for economic reasons over the last 5 years. It is considered a provisional source for low flow periods, scheduled plant maintenance, higher sustained production and emergency service.

The main value of the Homer Gap system is the ability to serve portions of the City's Juniata service area. Depending on demand conditions, this portion can be "divisioned off" from the City's High Service gradient and fed entirely by Homer Gap with effective withdrawals ranging from 0.171 mgd (dependable flow) to 0.20 mgd.

Table 29 - Mill Run Reservoir System
Regulation Storage Evaluation and Model Simulation Results

Criteria	Dependable Flow	2002 Production	2010 Avg. Production	Projected Production	Treatment Capacity
a. Withdrawal/Demand (mgd)	1.90	1.951	2.61	2.65	5.0
b. No. of Deficiency Periods (1944 - 2009)	0	2	11	14	43
c. Total Duration of Deficiency (mon.)	0	0.92	15.5	19.2	82.26
d. Maximum Event Duration (mon.)	0	0.69	2.96	4.57	6.04
e. Minimum Event Duration (mon.)	0	0.23	0.03	0.03	0.03
f. Average Duration (mon.)	0	0.46	1.41	1.37	1.913
g. Total Demand Deficiency (mg) (1944-2009)	0	54.63	1235	1548	12.510
h. Maximum Event Demand Deficiency (mg)	0	40.97	234.90	368.35	920
i. Minimum Event Demand Deficiency (mg)	0	13.66	2.61	2.65	5.0
j. Average Demand Deficiency (mg)	0	27.32	112.3	110.6	290.9
k. Degree of Duration Control (%)	-	99.89	98.0	97.5	89.5
l. Degree of Discharge Control (%)	-	99.89	98.0	97.5	89.5
m. Average Annual Deficiency (%)	-	3.8	11.8	11.4	15.9
n. Deficiency Index	-	0.006	0.34	0.52	1.67
o. Deficiency Drawdown (ft.), 2 yr. Frequency	-	25.8	53.7	55.5	Empty
p. Deficiency Drawdown (ft.), 10 yr. Frequency	-	58.5	Empty	Empty	Empty
q. Deficiency Drawdown (ft.), 25 yr. Frequency	-	Empty	Empty	Empty	Empty
r. Deficiency Drawdown (ft.), 50 yr. Frequency	-	Empty	Empty	Empty	Empty
s. Limit of Useable Storage (ft.)	72.0	72.0	72.0	72.0	72.0

Assessment - Mill Run Reservoir has a dependable flow of 1.90 mgd for the 1944 - 2009 period of record. Recent production (2002 - 2010) indicates a flow of 2.0 to 2.3 mgd. Two (2) deficiency periods resulted for 1.951 mgd (2002 production). This is a slight increase from the 1.9 mgd dependable flow (50,000 gpd). A sensitivity analysis would no doubt reveal that this system is "sensitive" or vulnerable to slight increases in demand. This is validated by the 2010 production of 2.61 mgd that produced 11 events and a deficiency index 50 times more severe the 1.951 mgd demand. We believe this sensitivity results from a small drainage area and large storage volume. During drought events, storage can be rapidly depleted and cannot compensate for low inflow from the watershed. Emptying of the reservoir can be rather dramatic in these instances despite Mill Run's highest storage index of 122.1.

Projected production (2.65) would exacerbate the severity of drought effects; over 85 times more severe than 2002 production (1.951). This is also reflected in the degree of discharge control (97.5%) which is indicative of low reliability. The frequency analysis of drought storage/drawdown (for deficiency periods only) reveals the reservoir to be generally empty for the 10-50 year frequency periods. For most shortage periods, reduction in the withdrawal will accelerate reservoir recovery.

An examination of monthly critical durations shows an average of 1 to 4.5 months occurring in the fall. DEP has identified February 28 when reservoir refill and recovery will typically occur. Therefore, the emptying-and-filling occurs annually or within the March-to-February water year, even during the most severe drought conditions on record. This qualifies the Mill Run Reservoir system as a "small reservoir" under the DEP drought management criteria.

A separate analysis of the contribution of Allegheny Reservoir was made. This separate dependable flow analysis reveals that Allegheny contributes only 0.17 mgd to the total of 1.9 mgd. This is equivalent to the dependable yield from Homer Gap Reservoir. The yield is limited by the storage capacity of Allegheny Reservoir (49.3 mg), transfer pumping capacity (1.3 mgd) and magnitude of conservation release. The intervening drainage area below Mill Run is insufficient to produce appreciable inflow to Allegheny Reservoir.

The Mill Run Reservoir system is a valuable component of the Authority water supply. It has the second highest dependable yield of any reservoir system. The source is considered very reliable for flows up to 2 mgd. The system becomes more vulnerable as demands reach 2.65 mgd (projected production). The principal value of this source is the excellent water quality and treatment potential at the Horseshoe Curve plant. Since the Mill Run treatment facility is temporarily decommissioned for economic reasons, Mill Run water is transferred and treated at the Horseshoe Curve plant for flows ranging from 2-5 mgd. The Authority operates the reservoir to maximize its blending capacity which reduces chemical costs. Since Mill Run is a gravity source, the conveyance cost is negligible. Typically, this reservoir is operated in this fashion 9-10 months (at flows of 2.5 to 5.0 mgd) and is allowed to recover in the fall-winter.

In terms of long term drought management, Mill Run is essentially a component of the Horseshoe Curve system. The reliability and deficiency functions are not as critical for Mill Run because it does not feed a discrete service area and is operated more as a storage/water quality source for the Horseshoe Curve system, with its large combined storage volume. Horseshoe Curve water is utilized to its fullest extent in drought periods, essentially serving as the ultimate storage "buffer" for the entire system.

Concerning Allegheny Reservoir, the Authority should consider the ultimate disposition of this nominal yield producer. It accounts for less than 1% of the total system yield and 1.5% of total system storage. The decision to maintain Allegheny Reservoir as a water supply source should be determined upon renewal of the Water Allocation Permit (2033). Meanwhile, periodic maintenance should be performed as required. Due to new PADEP dam safety criteria, the adjacent bypass channel may need to be enlarged to accommodate higher flood flows.

Table 30 - Tipton Reservoir System
Regulation Storage Evaluation and Model Simulation Results

Criteria	Dependable Flow	Projected Production	2010 Avg. Production	Intermediate Production	Treatment Capacity
a. Withdrawal/Demand (mgd)	1.63	1.145	1.207	2.0	4.0
b. No. of Deficiency Periods (1944 - 2009)	0	0	0	4	36
c. Total Duration of Deficiency (mon.)	0	0	0	1.8	83.2
d. Maximum Event Duration (mon.)	0	0	0	1.48	6.25
e. Minimum Event Duration (mon.)	0	0	0	0.03	0.49
f. Average Duration (mon.)	0	0	0	0.45	2.31
g. Total Demand Deficiency (mg) (1944-2009)	0	0	0	110	10,128
h. Maximum Event Demand Deficiency (mg)	0	0	0	90	760
i. Minimum Event Demand Deficiency (mg)	0	0	0	2	60
j. Average Demand Deficiency (mg)	0	0	0	27.5	281.3
k. Degree of Duration Control (%)	-	-	-	99.77	89.3
l. Degree of Discharge Control (%)	-	-	-	99.77	89.3
m. Average Annual Deficiency (%)	-	-	-	3.8	19.3
n. Deficiency Index	-	-	-	0.024	2.06
o. Deficiency Drawdown (ft.), 2 yr. Frequency	-	7.6	8.4	19.3	55.4
p. Deficiency Drawdown (ft.), 10 yr. Frequency	-	28.7	30.2	53.5	Empty
q. Deficiency Drawdown (ft.), 25 yr. Frequency	-	42.4	43.6	Empty	Empty
r. Deficiency Drawdown (ft.), 50 yr. Frequency	-	53.2	53.8	Empty	Empty
s. Limit of Useable Storage	61.0	61.0	61.0	61.0	61.0

Assessment - Tipton Reservoir has a dependable flow of 1.63 mgd for the 1944 - 2009 period of record. This dependable flow is sufficient for all past, current and projected demands through 2033. This surplus capacity can be used to make up drought deficiencies in other systems (i.e., Bellwood). Even at higher demands (2.0 to 4.0 mgd), reliability and deficiency factors are not considered excessive when compared to other reservoir systems. The reason for this is the relatively high storage index (37.3 mg/sq. mi.).

Historically, Tipton Reservoir has not been heavily utilized in the normal operational plan. Tipton has largely supplied the Juniata railroad shops and old Proctor-Silex complex throughout its existence along with the Village's of Tipton and Pinecroft. As industrial consumption has declined, the demand on Tipton Reservoir has also diminished. However, the service area potential versus available supply capacity for Tipton is greater than any of the other "Blair Gap" reservoirs.

The Authority should consider the greater utilization of Tipton Reservoir. Based on the configuration of its transmission lines, Tipton could provide service anywhere from Tyrone Borough to the City of Altoona along the I-99 corridor. Tipton possesses excellent water quality; on a par with Mill Run as a high quality source. Tipton could potentially feed portions of the Bellwood (principally) and Greenwood/Pottsgrove (secondarily) service areas, in addition to some portions of the City service areas. The cleaning and lining of the 16-inch mains has lowered pumping costs for this system.

The Loup Run intake has directed water from the Loup Run watershed (3.0 sq. mi.) to Tipton Reservoir. A separate simulation run has shown that it adds little to the safe yield of the Tipton system (0.13 mgd). Although having a larger drainage area than either Allegheny or Kettle Reservoirs, the small storage capacity and conservation release produce nominal yield. During the late summer/early fall, the inflow passes through the intake entirely as a conservation release to Loup Run. The cost to increase the capacity to product a safe yield of 1 mgd cannot be justified. Therefore, the Authority will need to evaluate whether to maintain Loup Run as a component of its water supply system. This decision should be made prior to renewal of the Water Allocation Permit (2033). However, routine maintenance of the intake structure (dredging, concrete repairs, pipe replacement) should be performed meanwhile.

Table 31 - Plane Nine Reservoir System
Regulation Storage Evaluation and Model Simulation Results

Criteria - Plane Nine Reservoir	Dependable Flow	2002 Production	2010 Avg. Production	Projected Production	Treatment Capacity
a. Withdrawal/Demand (mgd)	1.45	1.559	1.667	2.117	4
b. No. of Deficiency Periods (1944 - 2009)	0	1	1	9	42
c. Total Duration of Deficiency (mon.)	0	0.59	1.05	10.4	98.6
d. Maximum Event Duration (mon.)	0	0.59	1.05	2.73	6.70
e. Minimum Event Duration (mon.)	0	0.59	1.05	0.16	0.07
f. Average Duration (mon.)	0	0.59	1.05	1.16	2.35
g. Total Demand Deficiency (mg) (1944-2009)	0	28.06	53.34	671.1	12,000
h. Maximum Event Demand Deficiency (mg)	0	28.06	53.34	175.7	816
i. Minimum Event Demand Deficiency (mg)	0	28.06	53.34	16.94	8
j. Average Demand Deficiency (mg)	0	28.06	53.34	74.6	285.7
k. Degree of Duration Control (%)	-	99.92	99.86	98.67	87.3
l. Degree of Discharge Control (%)	-	99.92	99.86	98.67	87.3
m. Average Annual Deficiency (%)	-	4.9	8.7	9.6	19.6
n. Deficiency Index	-	0.004	0.012	0.19	2.47
o. Deficiency Drawdown (ft.), 2 yr. Frequency	-	4.6	5.1	8.03	25.4
p. Deficiency Drawdown (ft.), 10 yr. Frequency	-	18.1	20.1	Empty	Empty
q. Deficiency Drawdown (ft.), 25 yr. Frequency	-	Empty	Empty	Empty	Empty
r. Deficiency Drawdown (ft.), 50 yr. Frequency	-	Empty	Empty	Empty	Empty
s. Limit of Useable Storage (ft.)	26.5	26.5	26.5	26.5	26.5

Assessment - Plane Nine Reservoir has a dependable flow or safe yield of 1.45 mgd for the 1944 - 2009 period of record. Recent production (2002 - 2010) indicates a flow of about 1.6 mgd. Only one deficiency period was generated, indicated a very high degree of reliability. The degree of discharge control is 99.92% or only one (1) month (total) over the last 65 years with a very low deficiency indices (0.004 to 0.12). For the projected 2033 demand of 2.12 mgd, a deficiency period is indicated with lower reliability (98.67%) and a deficiency index 20 times more severe than current production.

The Plane Nine system is a conventional "multiple reservoir" arrangement. It has two upstream feeder reservoirs and a downstream "operating" reservoir. A separate model simulation shows that the upstream reservoirs (Muleshoe and Blair Gap) contribute significantly to the total yield. These reservoirs contribute 35% (0.51 mgd) of the dependable yield (1.45 mgd). Also, the 2.0 mgd withdrawal restriction on Muleshoe Reservoir does not seem to affect the yield from this source.

Plane Nine system is considered one of the most heavily utilized of the old "Blair Gap" reservoirs. The system feeds the entire southern service area which includes Frankstown Township, Juniata Township, Allegheny Township, Blair Township, Freedom Township and Hollidaysburg Borough and Duncansville Borough (emergency). Plane Nine has contractual supply obligations with four of these municipalities. Maintaining production levels in this system is an obvious priority. It has always been the plan to supplement Plane Nine with Altoona Low/High Service (Horseshoe Curve) during drought periods. A 16"-main extends from the City to the Meadows area for this purpose and is fed by the Westerly booster station. Reduction in demand is not considered necessary since the projected deficiency (during drought events) is only 0.45 mgd (315 gpm) and can be easily provided by Low/High service.

A frequency analysis of Plane Nine deficiency drawdown was performed for the shortage periods. For the specified demand rates, the reservoir flocculates within its operating zone without emptying for the 2-year return period. For the 10, 25 and 50-year drought occurrences, the reservoir empties thus necessitating a supplemental supply from the Horseshoe Curve system. An examination of monthly critical durations shows that the maximum duration is 2.7 months with most averaging about one month. These typically occur in the fall. Therefore, emptying and filling occurs on an annual basis or within the Water Year (March - February), even in the most severe droughts. Plane Nine would be classified as a "small reservoir" under the PADEP drought management criteria.

In summary, the Plane Nine system is extremely reliable at current production levels. Downstream demands, both contractual and otherwise, dictate that production be maintained during shortages. This shortfall can be easily provided by the adjacent Horseshoe Curve system.

Table 32 - Horseshoe Curve Reservoir System
Regulation Storage Evaluation and Model Simulation Results

Criteria - (Cochran Impounding Reservoir)	Dependable Flow	2002 Production	Projected Production	Intermediate Production	Treatment Capacity
a. Withdrawal/Demand (mgd)	5.11	3.112	4.227	6.30	7.5
b. No. of Deficiency Periods (1944 - 2009)	0	0	0	65	66
c. Total Duration of Deficiency (mon.)	0	0	0	238	301
d. Maximum Event Duration (mon.)	0	0	0	7.66	7.85
e. Minimum Event Duration (mon.)	0	0	0	0.30	1.08
f. Average Duration (mon.)	0	0	0	3.66	4.55
g. Total Demand Deficiency (mg) (1944-2009)	0	0	0	45,593	68,595
h. Maximum Event Demand Deficiency (mg)	0	0	0	1,468	1,793
i. Minimum Event Demand Deficiency (mg)	0	0	0	56.7	247.5
j. Average Demand Deficiency (mg)	0	0	0	701	1,039
k. Degree of Duration Control (%)	-	-	-	69.4	61.4
l. Degree of Discharge Control (%)	-	-	-	69.4	61.4
m. Average Annual Deficiency (%)	-	-	-	30.5	38.0
n. Deficiency Index	-	-	-	9.29	14.6
o. Deficiency Drawdown (ft.), 2 yr. Frequency	-	7.8	14.2	6.3	Empty
p. Deficiency Drawdown (ft.), 10 yr. Frequency	-	14.4	16.5	Empty	Empty
q. Deficiency Drawdown (ft.), 25 yr. Frequency	-	15.8	16.5	Empty	Empty
r. Deficiency Drawdown (ft.), 50 yr. Frequency	-	16.5	16.5	Empty	Empty
s. Limit of Useable Storage (ft.)	27.0	27.0	27.0	27.0	27.0

Assessment - The Horseshoe Curve Reservoir system has a dependable flow of 5.11 mgd for the 1944 - 2009 period of record. This dependable flow is sufficient for all past, present and projected demands through 2033. Horseshoe Curve is the principal water supply for the majority of the service area, including the entire City of Altoona and large portions of Logan and Allegheny Townships. It is the watershed of last resort for all other reservoir systems by virtue of system storage and transmission capability. Up to 2.0 mgd (4.0 mgd, max.) can be directed to the northern and southern service areas by the Easterly and Westerly water booster pumping stations, respectfully. Its excess capacity can be dedicated to numerous reservoir systems in deficit. For instance, flow could be directed to the Plane Nine system during shortage periods.

As has been noted, the Mill Run reservoir feeds the City distribution system and is a necessary component of the Horseshoe Curve system. Mill Run water can be transferred to the Horseshoe Curve plant for treatment to a maximum of 5 mgd. Plant operation, seasonal water quality and simple economics dictate the amount of Mill Run water needed for treatment. Typically, the Mill Run source is used 8-9 months per year and is left to recover the remaining 3-4 months. If Mill Run was utilized on a strictly consistent basis, any deficiencies in Mill Run Reservoir could be offset by greater drafts from the Horseshoe Curve reservoirs. For instance, the 2033 withdrawal of 6.877 mgd (combined Mill Run (2.65 mgd) and Horseshoe Curve (4.227 mgd) is projected for City Low Service and High Service. Under drought conditions, Mill Run is limited to 1.9 mgd (dependable yield) for full reliability. The difference (0.75 mgd) is easily made up from the Horseshoe Curve surplus (0.883 mgd) between dependable flow and projected demand.

The Horseshoe Curve reservoir system is the most reliable and dependable source in the Authority inventory. It serves as the ultimate shortage buffer for the entire system. The ability to transfer water throughout the service area from this source provides great system flexibility and operational reliability.

Table 33 - Reservoir Reliability Analysis

Previous Production (2002)				Current Production (2010)				Projected Production (2033)				Treatment Plant Capacity			
Rank	Reservoir	DI	DDC	Rank	Reservoir	DI	DDC	Rank	Reservoir	DI	DDC	Rank	Reservoir	DI	DDC
1	Horseshoe Curve	0	100	1	Horseshoe Curve	0	100	1	Horseshoe Curve	0	100	1	Bellwood	0.40	95.40
2	Tipton	0	100	2	Tipton	0	100	2	Tipton	0	100	2	Mill Run	1.67	89.50
3	Kettle	0	100	3	Bellwood	0.010	99.87	3	Kettle	0.055	99.71	3	Tipton	2.06	89.30
4	Plane Nine	0.004	99.92	4	Plane Nine	0.012	99.86	4	Plane Nine	0.19	98.67	4	Plane Nine	2.47	87.30
5	Mill Run	0.006	99.89	5	Mill Run	0.034	98.00	5	Bellwood	0.20	97.91	5	Homer Gap	4.62	81.70
6	Bellwood	0.025	99.72	-	Kettle	-	-	6	Mill Run	0.52	97.50	6	Kettle	5.03	77.50
7	Homer Gap	1.36	98.86	-	Homer Gap	-	-	7	Homer Gap	3.48	87.40	7	Horseshoe Curve	14.6	61.40

Notes: Homer Gap and Kettle Reservoirs temporarily decommissioned in 2006.
DI denotes "Deficiency Index"
DDC denotes "Degree of Discharge Control"

Table 34 - Reservoir Deficiency Analysis

Reservoir System	Previous Production (2002)			Current Production (2010)			Projected Production (2033)			Treatment Plant Capacity			Reservoir System
	Safe Yield	Demand	Surplus/ (Deficit)	Safe Yield	Demand	Surplus/ (Deficit)	Safe Yield	Demand	Surplus/ (Deficit)	Safe Yield	Demand	Surplus/ (Deficit)	
Horseshoe Curve	5.10	3.112	1.988	5.10	4.037	1.063	5.10	4.227	0.873	5.10	7.5	(2.4)	Horseshoe Curve
Mill Run	1.900	1.951	(0.051)	1.900	2.610	(0.710)	1.900	2.650	(0.750)	1.900	5.0	(3.100)	Mill Run
Homer Gap	0.171	0.448	(0.277)	0.171	-	0.171	0.171	0.609	(0.438)	0.171	1.0	(0.829)	Homer Gap
Kettle	0.723	0.598	0.125	0.723	-	0.723	0.723	0.802	(0.079)	0.723	2.0	(1.277)	Kettle
Plane Nine	1.450	1.559	(0.109)	1.450	1.667	(0.217)	1.450	2.117	(0.667)	1.450	4.0	(2.550)	Plane Nine
Bellwood	1.840	2.305	(0.465)	1.840	2.051	(0.211)	1.840	3.089	(1.249)	1.840	5.0	(3.160)	Bellwood
Tipton	1.630	0.843	0.787	1.630	1.207	0.423	1.630	1.145	0.485	1.630	4.0	(2.370)	Tipton
Total	12.814	10.816	1.998	12.814	11.572	1.242	12.814	14.639	(1.825)	12.814	28.5	(15.686)	Total

Notes: All values shown in million gallons per day (mgd).
Homer Gap and Kettle Reservoirs temporarily decommissioned in 2006.

Table 35 - Maximum Drought Durations and Depletion

Reservoir	Withdrawal Year/Rate(mgd)		Drought Period (Start/End)		Duration (days)	Total Depletion (MG)
Bellwood	2002	2.305	10/5/1965	11/30/1965	57	131.4
	2010	2.051	11/7/1965	11/28/1965	30	61.5
	2033	3.131	8/23/1965	11/30/1965	100	313.1
Kettle	2002	0.598	No Drought Periods		-	0.0
	2033	0.802	10/24/1965	12/31/1965	69	56.0
	Inter.	1.250	9/17/1962	1/31/1963	115	143.8
Homer Gap	2002	0.448	7/17/1965	11/30/1965	137	61.4
	2010	0.000	No Drought Periods		-	0.0
	2033	0.609	6/28/1965	12/29/1965	185	112.7
	Inter.	0.275	9/2/1965	11/30/1965	90	24.8
Tipton	2002	0.843	No Drought Periods		-	0.0
	2033	1.145	No Drought Periods		-	0.0
	2010	1.207	No Drought Periods		-	0.0
	Inter.	2.000	10/17/1965	11/30/1965	45	90.0
Mill Run	2002	1.951	10/12/2001	11/1/2001	21	41.0
	2010	2.610	8/3/2001	11/1/2001	90	234.9
	2033	2.650	8/1/2001	12/17/2001	139	368.4
Plane Nine	2002	1.559	11/10/1965	11/27/1965	18	28.1
	2010	1.667	10/21/1965	11/21/1965	32	53.3
	2033	2.117	9/9/1965	11/30/1965	83	175.7
Horseshoe Curve	2002	3.112	No Drought Periods		-	0.0
	2010	4.037	No Drought Periods		-	0.0
	2033	4.227	No Drought Periods		-	0.0

Table 33 compares safe or dependable yield with various demands for each reservoir system. As expected, Horseshoe Curve has the highest surplus ranging from 0.9 to 2.0 mgd for all demand conditions. Next, Tipton Reservoir maintains a surplus of 0.3 to 0.5 mgd for all demand conditions. Kettle Reservoir is the only other system that shows a nominal surplus. The other systems are in deficit with Mill Run and Bellwood being the most stressed followed by Plane Nine and Homer Gap to a lesser extent.

Table 34 ranks reservoir reliability based on various demand factors and reinforces the above deficiency analysis where Horseshoe Curve and Tipton Reservoirs rank highest in reliability. For current production (9.1 mgd, total), these reservoirs are followed by (in order) Bellwood, Plane Nine and Mill Run. For projected production (14.8 mgd, total), Horseshoe Curve, Tipton, Kettle, Plane Nine, Bellwood, Mill Run and Homer Gap rank from highest to lowest in terms of reliability. At these levels, Plane Nine, Bellwood, Mill Run and Homer Gap are in severe deficit during extreme droughts.

Table 35 shows the maximum drought duration and depletion for each reservoir system at various demand rates. This table shows, along with time-storage/level graphs, that the "drought of record" occurred in late 1965. In fact, 6 major droughts occurred in the 1960's. Another period of stress was from 1997 to 2004 with 4 major droughts. In all cases, the reservoirs recovered well within the water year, in most cases within 3-4 months. For purposes of our report, the 1965 drought will be considered the "50-year drought" for the 65-year evaluation period which corresponds to a PADEP Stage III drought condition. In terms of the worst case duration (excluding Homer Gap Reservoir - a poor indicator), the maximum critical period is Mill Run at 4.6 months, but still less than the 169-day DEP recovery time.

Reservoir Drought Planning - We can draw several conclusions from the reliability and deficiency analysis. Theoretically, for all production up to 12.83 mgd, the total system is not in a deficit condition, although individual reservoirs may be. These "deficit" systems would be supplemented by other reservoirs in "surplus" through the transmission network. For production above 12.83 mgd during severe drought conditions, a combination of voluntary and mandatory restrictions will be evaluated.

Projected demand (14.64 mgd) in combination with a drought event capable of producing a minimum yield condition (12.82 mgd) is statistically remote. Production in recent years has trended downward. In fact, the last time annual production reached 12.82 mgd was in 1984. Minimum yield (dependable or safe yield) is based on a combination of the most severe shortages on record since 1944. However, water supply planning dictates that worse case scenarios be considered. A severe shortage would be intolerable in terms of health (water quality), safety (fire protection) and economic consequences (business layoffs and plant shutdowns).

The maximum potential deficit for the Authority system is its projected 2033 production (14.64 mgd) minus the dependable yield (12.82 mgd as computed by Res-Sim 3.0). This amounts to 1.8 mgd, a target attainable with voluntary and mandatory restrictions. The restriction level depends on the severity of the drought. In most cases, voluntary restrictions should be sufficient for shortage events up to the 10-year drought. This drought event is expected to occur once every 10 years of a 10% chance of occurring in any one year. For the minimum reduction of 5%, this would correspond to a 13.5 mgd production rate, which is 5% above the dependable flow rate. For more severe droughts (25-50 years), mandatory restrictions may be in order. This would require cutbacks in demand prescribed in the AWA's drought contingency plan. The goal for mandatory restrictions is 10-25%.

The Res-Sim 3.0 model simulated rationing scenarios based on several assumptions. The 2033 projected withdrawal (14.64 mgd) and dependable flow (12.82 mgd) was equally apportioned to each reservoir as previously simulated. An initial storage baseline was established based on days of remaining storage at a selected Stage I warning level. This volume was apportioned to each reservoir on a proportional storage basis and the corresponding reservoir levels determined. This assumption is valid for planning purposes.

Demand was reduced to 5% at a Stage I-II level corresponding to the estimated effect of voluntary restrictions. This reduces the withdrawal to 13.9 mgd. A more aggressive voluntary restriction program (with shedding customers) could increase this figure from 5 to 10% at Stage II. However, to be conservative, we only assumed a 5% reduction at the end of Stage II. At the Stage III level, rationing (mandatory restrictions) go into effect with the goal of reducing demand to the 20-25% range. These reductions in withdrawal, whether voluntary or mandatory, are what can be reasonably expected based on previous studies.

The above stages generally correspond to the PADEP drought planning guidelines. Operating rules are then established for Res-Sim 3.0 to reflect these criteria. Simulation runs are made and storage days adjusted (along with corresponding storage capacity and stage levels) to arrive at targeted reduction levels without draining the reservoirs. The targeted ration goals are conservative to allow for drought levels exceeding previous shortages and to allow for more rapid reservoir recovery. The Res-Sim 3.0 model also simulated an intermediate demand of 13.73 mgd, the midpoint between the dependable flow (12.82 mgd) and projected flow (14.64 mgd). The results of the evaluation are shown in Tables 35 and 36 and in the Appendix.

Table 36 - Res-Sim 3.0 Simulation Results
Voluntary/Mandatory Restrictions at Projected 2033 Withdrawal (14.64 mgd)

	2033 Projected Withdrawal (Q_{33})	Dependable Flow	Difference	Effective Storage	Stage I Storage	Stage I Level	Stage II Storage	Stage II Level	Stage II Withdrawal*	Stage III Storage	Stage III Level	Stage III Withdrawal**
Reservoir	**mgd**	**mgd**	**mgd**	**mg**	**mg**	**Ft**	**mg**	**Ft**	**mgd**	**mg**	**Ft**	**mgd**
Bellwood	3.089	1.839	-1.25	303.06	241.33	1346.4	160.89	1339.1	2.95	128.71	1335.9	0.97
Kettle	0.802	0.723	-0.079	172.85	137.64	1711.2	91.76	1704.6	0.76	73.41	1701.3	0.63
Homer Gap	0.609	0.171	-0.438	24.35	19.39	1445.2	12.93	1441.7	0.58	10.34	1440.4	0.08
Tipton (w/ Loup Intake)	1.145	1.626	0.481	314.83	250.70	1382.0	167.13	1378.0	1.09	133.71	1369.0	1.63
Mill Run	2.65	1.903	-0.747	516.94	411.64	1501.1	274.43	1490.1	2.52	219.54	1484.5	1.46
Allegheny				45.56	36.28	1302.3	24.19	1298.5		19.35	1296.9	
Plane Nine	2.117	1.452	-0.665	112.80	89.82	1403.5	59.88	1397.7	2.01	47.91	1395.2	1.19
Blair Gap				24.90	19.83	1775.1	13.22	1768.6		10.58	1765.7	
Muleshoe				71.17	56.67	1571.5	37.78	1565.6		30.23	1562.7	
Impounding Reservoir	4.227	5.103	0.876	285.50	227.35	1428.2	151.56	1421.2	4.02	121.25	1418.2	5.10
Lake Altoona				835.40	665.24	1353.1	443.49	1343.6		354.79	1339.2	
Kittanning Point				50.17	39.95	1492.6	26.63	1488.1		21.31	1486.3	
Total	**14.639**	**12.817**	**-1.822**	**2757.53**	**2195.85**		**1463.90**		**13.93**	**1171.12**		**11.06**
												24% Reduction

*5% Reductionof Q_{33}
** Permitted withdrawal that will not drain the reservoir

2033 W.D	Stage I Storage (150 days)	Stage II Storage (100 Days)	Stage III Storage (80 Days)
mgd	**MG**	**MG**	**MG**
14.639	2195.85	1463.9	1171.12

Table 37 - Res-Sim 3.0 Simulation Results
Voluntary/Mandatory Restrictions at Intermediate Demand (13.73 mgd)

	Withdrawal (Q)	Dependable Flow	Difference	Effective Storage	Stage I Storage	Stage I Level	Stage II Storage	Stage II Level	Stage II Withdrawal*	Stage III Storage	Stage III Level	Stage III Withdrawal**
Reservoir	**mgd**	**mgd**	**mgd**	**mg**	**mg**	**Ft**	**mg**	**Ft**	**mgd**	**mg**	**Ft**	**mgd**
Bellwood	2.897	1.839	-1.058	303.06	165.96	1340.8	120.70	1334.6	2.75	90.52	1330.8	0.81
Kettle	0.752	0.723	-0.029	172.85	94.66	1705.3	68.84	1700.5	0.71	51.63	1696.7	0.65
Homer Gap	0.571	0.171	-0.400	24.35	13.33	1442.0	9.70	1440.2	0.54	7.27	1438.3	0.04
Tipton (w/ Loup Intake)	1.074	1.626	0.552	314.83	172.41	1378.0	125.39	1368.0	1.02	94.04	1362.0	1.63
Mill Run	2.485	1.903	-0.582	516.94	283.09	1491.0	205.88	1483.0	2.36	154.41	1477.0	1.42
Allegheny				45.56	24.95	1298.7	18.15	1296.4		13.61	1295.4	
Plane Nine	1.985	1.452	-0.533	112.80	61.77	1398.2	44.92	1394.7	1.89	33.69	1391.6	0.87
Blair Gap				24.90	13.64	1769.4	9.92	1765.0		7.44	1761.3	
Muleshoe				71.17	38.97	1565.7	28.34	1561.9		21.26	1558.8	
Impounding Reservoir	3.964	5.103	1.139	285.50	156.35	1421.7	113.71	1417.2	3.77	85.28	1413.7	5.10
Lake Altoona				835.40	457.48	1344.4	332.71	1338.9		249.54	1333.3	
Kittanning Point				50.17	27.47	1488.5	19.98	1485.6		14.99	1483.6	
Total	**13.728**	**12.817**	**-0.911**	**2757.53**	**1510.08**		**1098.24**		**13.04**	**823.68**		**10.52**
												23% Reduction

*5% Reduction of Q
** Permitted withdrawal that will not drain reservoir

Intermed. Demand	Stage I Storage (110 days)	Stage II Storage (80 Days)	Stage III Storage (60 Days)
mgd	**MG**	**MG**	**MG**
13.728	1510.08	1098.24	823.68

An analysis of the results show that the ration target range of 20-25% has been attained. The days of available storage at various reservoir stages have direct correlation to the drought contingency plan, which will be discussed in a later section. Intermediate values of storage volumes and days will be interpolated from the above model results.

We would expect that rationing (mandatory restrictions) would be imposed for no more than 30-60 days since the ration level (20-25%) is considered conservative and will result in a faster reservoir recovery.

ECONOMIC EVALUATION

General - This section will examine the cost of production and treatment for each reservoir system. The following costs are tabulated in annual operating budgets by the Authority for each reservoir treatment and supply system:

a. Operators/Technicians Wages and Benefits
b. Administrative Wages and Benefits
c. Consulting Engineering Services
d. Accounting Audit Services
e. Legal Services
f. Trustee Expenses
g. Other Professional Fees
h. Legal Advertisements
i. Continuing Education
j. Credentially Fees/Dues
k. Building Maintenance
l. Office Supplies
m. Postage
n. Human Resources
o. Safety Costs
p. Chemicals
q. Electrical Power
r. Utilities
s. Laboratory Equipment and Supplies
t. Sludge Disposal
u. Insurance
v. Vehicle Expense
w. Maintenance

Cost Sharing - Cost sharing arrangements are in effect at Plane Nine and Bellwood reservoirs since they serve the Hollidaysburg Borough and Bellwood Borough systems, respectively. Recent experience has shown that the cost sharing is about 48% for Hollidaysburg Borough at Plane Nine Reservoir and 12% for Bellwood Borough at Bellwood Reservoir. These factors are based on the proportional usage based on metered production records. This cost factor is applied to total annual operating costs for the facilities. Debt service costs are shared based on fixed proportions (45.5% - Hollidaysburg Borough and 31.25% - Bellwood Borough).

Debt Service - To operating costs must be added the debt service cost for original capital construction. Current debt service for improvements at the reservoir systems are as follows:

			Reservoir System/ Debt Instrument	Debt Ending	Average Annual Debt Service
1.	Bellwood Reservoir System				
	a.	Bellwood Water Treatment Facility			
		1)	PennVEST Loan No. 50018	2013	$350,928
		2)	1994 Water Revenue Bonds	2019	467,534
			Sub-Total		$818,462
		Note:	Bellwood Borough Share = $255,738		
2.	Plane Nine Reservoir System				
	a.	Plane Nine Water Treatment Facility			
		1)	PennVEST Loan No. 25024	2012	$319,204
		2)	1994 Water Revenue Bonds	2019	548,919
			Net Sub-Total		$863,123
		Note:	Hollidaysburg Borough Share = $394,996		
	b.	Plane Nine Dam Modifications		2010	$219,674
3.	Tipton Reservoir System				
	a.	Tipton Water Treatment Facility			
		1)	PennVEST Loan No. 25024	2012	$332,233
		2)	1994 Water Revenue Bonds	2029	571,323
			Sub-Total		$903,556
4.	Kettle Reservoir System				
	a.	Kettle Water Treatment Facility			
		1)	PennVEST Loan No. 50035 (Est.)	2024	$81,813
		2)	1994 Water Revenue Bonds (Est).	2029	451,586
			Sub-Total		$533,399
	b.	Kettle Dam Modifications			
		1)	PennVEST Loan No. 30022	2009	$181,098
5.	Horseshoe Curve Reservoir System				
	a.	Horseshoe Curve Water Treatment Facility			
		1)	PennVEST Loan No. 50035	2024	$182,156
		2)	1994 Water Revenue Bonds	2029	1,005,450
			Sub-Total		$1,187,606
	b.	Lake Altoona Dam Modifications			
		1)	PennVEST Loan No. 50035 (Est.)	2024	$96,160
		2)	1994 Water Revenue Bonds (Est.)	2029	530,777
			Sub-Total		$626,937
6.	Homer Gap Reservoir System				
	a.	Homer Gap Water Treatment Facility			
		1)	PennVEST Loan No. 50035 (Est.)	2024	$66,647
		2)	1994 Water Revenue Bonds (Est.)	2029	367,870
			Sub-Total		$434,517
7.	Mill Run Reservoir System				
	a.	Mill Run Water Treatment Facility			
		1)	PennVEST Loan No. 50035	2024	$65,289
		2)	1994 Water Revenue Bonds	2029	360,375
			Sub-Total		$425,664

Cost Analysis - Operation, maintenance and administrative expenses, along with capital debt service costs for each reservoir system, have been compiled in Table 38. This data was developed by the Controller's Office of the Authority and represents the true cost of reservoir supply, treatment and transmission. It serves as a basis of comparison among systems and spans the period (2004 - 2010) when reservoir operations were consolidated and reservoirs decommissioned in some cases. Each cost component will be discussed in the following sections.

O&M Costs - This cost component includes lab supplies, electrical power, chemicals, maintenance, sludge disposal, utilities and insurance for each treatment system. Electrical power has proven to be the major cost factor averaging about 43% of the total O&M cost for all plants. Principally, power cost consists of finish water pumping and ozone generation. Chemical cost is the next highest component (25%), although it has risen significantly in recent years due to cost escalation. Maintenance and utility costs run about 10% each. Overall, O&M costs have been very consistent averaging $218/mg ($0.22/1,000 gal) or about $850,000 annually for all systems. In terms of the total cost of operation, O&M costs account for 48% of the total. After consolidation of operations (due to decline in production and economics), the total annual O&M cost is the same as it was in 2004. This despite a 19% rise in the consumer price index (CPI) for that time period.

Labor and Administrative Costs - The cost of labor to operate the plants includes administrative-related items listed under the General part of this section. They have been allocated to each reservoir system based on plant capacity. This proportioning is how these costs are allocated in the intermunicipal agreements. In terms of total cost of operation, labor and administrative expenses comprise the remaining 52% of the cost. Overall, labor and administrative have averaged $236/mg ($0.238/1,000 gal) or about $921,000 annually. As expected, labor costs rose in a manner commensurate with the consumer price index from 2004 to 2008 (13.5%). After consolidation of operations, the total annual labor and administrative costs are lower than labor costs in 2004 despite a 19% rise in the CPI for that time.

Total Operating Costs - Operating costs are comprised of operation, maintenance, labor and administrative costs to treat and transmit water to the service area from individual reservoir sources. The total operating cost has averaged $454/mg ($0,458/1,000 gallons). Due to rising costs and lower demand, operations were fully consolidated in 2006 - 2008 with the result that the total operating cost is less now than in 2004. From a practical standpoint, the consolidation of operations has produced tangible savings, currently on the order of $325,000 per year. The reduction in demand and efficiency of operations has produced savings over $500,000 since 2007.

An evaluation of individual reservoir performance has shown that the Mill Run and Bellwood systems have unit operating costs lower than average while Horseshoe Curve (Pappas) and Plane Nine are about average. Tipton is generally higher principally because of historically lower production. Certain fixed costs (utilities, bulk plant chemical purchases, general maintenance) become more pronounced at lower production levels.

At the high end of the scale are the Homer Gap and Kettle Plants ranging from $600 - $1,800 per MG. Operating costs alone would tend to justify the decommissioning of these plants. After consolidation of operations, the Horseshoe Curve (Pappas) plant appears to be the most cost effective facility. It benefits from treating good quality Mill Run water while operating at a higher production rate. However, recent analysis shows that the remaining plants (Tipton, Plane Nine and Bellwood) all are operating at about $490/MG.

It is clear that consolidation of plant operations has resulted in significant savings. If production stabilizes at 8-9 mgd, it is possible that decommissioning of the Tipton or Bellwood plants could result in further savings. The transfer of water from the Bellwood to the Tipton system (or vice versa) would occur at the Bellwood booster station.

Debt Service Costs - Inclusion of capital recovery costs (in the form of annual debt service payments) are recognized factors in the cost of production. The cost of discrete capital improvements at each reservoir system are shown in Table 38 and detailed earlier in this section.

Recent reservoir system projects include dam safety improvements, water treatment plants and storage/transmission lines. Many of these projects were financed through PennVEST loans and several have been defeased or paid off (Kettle and Plane Nine dams). Several PennVEST water treatment and storage/transmission projects (Plane Nine, Bellwood and Tipton) will expire in 2012 and 2013. The remaining PennVEST and Water Revenue Bond funded projects (Homer Gap, Kettle, Horseshoe Curve and Lake Altoona) will expire in 2024 and 2029, respectively. Debt service costs are now about $100,000 less than in 2004.

Based on the historical record, Mill Run was clearly the lowest cost reservoir system from a debt service perspective. No dam improvements were mandated and half the cost of the treatment plant was funded by a grant. Given the current configuration, Mill Run debt service should always be considered a part of the Horseshoe Curve system because of their common City service areas. The most expensive reservoir systems are clearly the Kettle and Homer Gap systems. Relative to Tipton, the debt service cost is elevated ($2,500 - 3,000/mg) because of the lower production rate. The intermunicipal plants, Bellwood and Plane Nine, are an interesting contrast. Because Bellwood operates at a 33% higher production rate (843 mg/year) than Plane Nine (634 mg/year), the unit debt service cost is corresponding lower for Bellwood.

After system consolidation, the debt service cost from individual reservoir sources has gone down, but debt service costs on decommissioned plants must still be paid. The annual debt service cost for the Mill Run, Homer Gap and Kettle plants is $1.5 million. This is several times the cost of any savings resulting from consolidation of operations. Under standard economic analysis and accounting practice, these plants would be classified as "stand by" facilities that can be readily used in the event of demand. This would be similar to the classification of stand-by fire protection facilities (hydrants, fire storage, residual pipeline capacity). Although rarely used, they need to be immediately available on demand. A similar analogy can be made for the decommissioned plants since the system, in order to maximize its permitted yield, has facilities available to meet increased demand. When viewed in this context, the debt service cost for decommissioned plants can be justified.

Total Production Cost - Total production costs are the sum of operating and debt service costs. Based on consolidation of operations and a decline in demand, the total cost of production is less now than it was in 2004. Conversely, the current annual unit cost is $2,290/mg ($2.29/1,000 gallons) as opposed to the $1,730/mg ($1.73/1,000 gallons) in 2004; a 32% increase compared to the CPI increase of 19% over that time period. The increase reflects the economics of scale associated with higher 2004 production rates. Fixed costs, especially debt service costs, are incurred regardless of the rate of production. This has been abundantly demonstrated by the Mill Run, Kettle and Homer Gap examples. Therefore, we have the paradoxical result of lower, overall costs but higher unit costs since 2004. It should be mentioned that the annual debt service cost is lower than what is shown in Table 36 because of the intermunicipal contributions ($650,000) from Bellwood and Hollidaysburg Borough. However, these payments do not change the unit cost of production.

It should be noted that debt service costs change over time reflecting changes in existing amortization schedules and new project financing. For instance, Mill Run and Bellwood dams will likely need to be upgraded in the next 5-10 years. Also, future water treatment standards may require upgrades. Improved treatment technologies (membrane filtration, etc.) will replace aging treatment equipment. Therefore, debt service required to finance these improvements will change over time. It is important that total production costs take this factor into account in the future.

Summary - Concerning the current mode of consolidated operations, if one concludes that the decommissioned plants serve as useful "standby" facilities, it stands to reason that limiting production to a number of key plants will result in cost savings. This is obvious when considering Kettle and Homer Gap. Concerning Mill Run, it must be kept in mind that Mill Run has always served as an auxiliary of the Horseshoe Curve system as they supply the same service districts. Whether water is treated at Mill Run or Horseshoe Curve is not significant in the larger scheme of things based on current demand.

The Pappas Treatment plant has served as a base of system operation in terms of supervisory personnel, overall process control and system monitoring. At this time, better control can be exercised from this location than operating another satellite treatment plant. The Bellwood and Plane Nine plants have to operate because of their intermunicipal functions, while the Tipton plant serves as a production center for maximum day demand in the northern service areas. Taken together, the operational plan that has evolved makes sense economically, given current production levels.

However, given the investment of the Authority in its supply system, the availability of water for future economic development must be a priority. The Authority is faced with a shrinking customer base and aging infrastructure. Recent years have shown a decrease in metered consumption because of water conservation and the economic downturn. But with a decrease in unaccounted-for-water, a sizeable capacity surplus has become available for sale to future customers. In this event, we expect operating personnel to fully utilize this system capacity in a prudent and responsible manner.

Production cost and revenue considerations will continue to be major factors in future reservoir management. This operating plan will provide a sound technical basis for insuring adequate capacity under all supply and demand conditions.

TABLE 38 - RESERVOIR SYSTEM PRODUCTION COST COMPARISON

	Treatment Facility Name	Average Production (MGD)	Annual Production (MGY)	Annual O&M Cost	Annual Labor Cost	Total Cost of Operation	Operating Cost (per MGY)	Rank	Total Debt Service Cost	Debt Service Cost (per MGY)	Rank	Total O&M and Debt Service Cost	Total Production Cost (per MGY)	Rank
Year 2004	Mill Run	3.1	1132	$ 120,179.00	$ 219,017.49	$ 339,196.49	$ 299.64	1	$ 425,664.00	$ 376.03	1	$ 764,860.00	$ 675.67	1
	Horseshoe Curve	2.7	986	$ 201,228.00	$ 190,769.65	$ 391,997.65	$ 397.56	4	$ 1,814,543.00	$ 1,840.31	5	$ 2,206,541.00	$ 2,237.87	5
	Homers Gap	0.7	256	$ 57,671.00	$ 49,530.46	$ 107,201.46	$ 418.76	5	$ 434,517.00	$ 1,697.33	4	$ 541,719.00	$ 2,116.09	4
	Plane Nine	2.0	730	$ 148,001.00	$ 141,239.19	$ 289,240.19	$ 396.22	3	$ 1,082,797.00	$ 1,483.28	3	$ 1,372,037.00	$ 1,879.50	3
	Kettle	0.8	292	$ 70,377.00	$ 56,495.68	$ 126,872.68	$ 434.50	7	$ 714,497.00	$ 2,446.91	7	$ 841,370.00	$ 2,881.40	6
	Bellwood	2.2	803	$ 131,057.00	$ 155,363.11	$ 286,420.11	$ 356.69	2	$ 818,462.00	$ 1,019.26	2	$ 1,104,882.00	$ 1,375.94	2
	Tipton	1.0	350	$ 79,519.00	$ 67,717.42	$ 147,236.42	$ 420.68	6	$ 903,566.00	$ 2,581.62	6	$ 1,050,802.00	$ 3,002.30	7
	Total	12.5	4549	$ 808,032.00	$ 880,133.00	$ 1,688,165.00			$ 6,194,046.00			$ 7,882,211.00		
Year 2005	Mill Run	2.3	840	$ 133,889.00	$ 174,654.23	$ 308,543.23	$ 367.31	1	$ 425,664.00	$ 506.74	1	$ 734,207.00	$ 874.06	1
	Horseshoe Curve	3.4	1250	$ 203,370.00	$ 259,902.12	$ 463,272.12	$ 370.62	2	$ 1,814,543.00	$ 1,451.64	3	$ 2,277,815.00	$ 1,822.25	3
	Homers Gap	0.2	65	$ 26,860.00	$ 13,514.91	$ 40,374.91	$ 621.15	6	$ 434,517.00	$ 6,684.88	7	$ 474,892.00	$ 7,306.03	7
	Plane Nine	1.8	660	$ 149,948.00	$ 137,228.32	$ 287,176.32	$ 435.12	4	$ 1,082,797.00	$ 1,640.60	4	$ 1,369,973.00	$ 2,075.72	4
	Kettle	0.3	120	$ 62,507.00	$ 24,950.60	$ 87,457.60	$ 728.81	7	$ 714,497.00	$ 5,954.14	6	$ 801,955.00	$ 6,682.96	6
	Bellwood	2.5	930	$ 160,982.00	$ 193,367.18	$ 354,349.18	$ 381.02	3	$ 818,462.00	$ 880.07	2	$ 1,172,811.00	$ 1,261.09	2
	Tipton	1.0	375	$ 88,561.00	$ 77,970.64	$ 166,531.64	$ 444.08	5	$ 903,566.00	$ 2,409.51	5	$ 1,070,098.00	$ 2,853.59	5
	Total	11.5	4240	$ 826,117.00	$ 881,588.00	$ 1,707,705.00			$ 6,194,046.00			$ 7,901,751.00		
Year 2006	Mill Run	2.6	955	$ 145,529.00	$ 216,668.65	$ 362,197.65	$ 379.26	1	$ 425,664.00	$ 445.72	1	$ 787,862.00	$ 824.99	1
	Horseshoe Curve	2.9	1051	$ 222,638.00	$ 238,448.95	$ 461,086.95	$ 438.71	3	$ 1,814,543.00	$ 1,726.50	4	$ 2,275,630.00	$ 2,165.20	5
	Homers Gap	0.0	0	$ 11,163.00	$ 0.00	$ 11,163.00	$ 0.00		$ 434,517.00	$ 0.00	-	$ 445,680.00	$ 0.00	-
	Plane Nine	1.8	662	$ 144,798.00	$ 150,193.34	$ 294,991.34	$ 445.61	4	$ 1,082,797.00	$ 1,635.64	3	$ 1,377,788.00	$ 1,169.24	3
	Kettle	0.3	95	$ 44,028.00	$ 21,553.43	$ 65,581.43	$ 690.33	6	$ 714,497.00	$ 7,521.02	6	$ 780,078.00	$ 8,211.35	6
	Bellwood	2.5	929	$ 147,163.00	$ 210,769.81	$ 357,932.81	$ 385.29	2	$ 818,462.00	$ 881.02	2	$ 1,176,395.00	$ 1,266.30	4
	Tipton	0.9	338	$ 89,862.00	$ 76,684.82	$ 166,546.82	$ 492.74	5	$ 903,566.00	$ 2,673.27	5	$ 1,070,113.00	$ 1,151.90	2
	Total	11.0	4030	$ 805,181.00	$ 914,319.00	$ 1,719,500.00			$ 6,194,046.00			$ 7,913,546.00		
Year 2007	Mill Run	2.6	957	$ 149,477.00	$ 217,827.62	$ 367,304.62	$ 383.81	1	$ 425,664.00	$ 444.79	1	$ 792,969.00	$ 828.60	1
	Horseshoe Curve	3.5	1269	$ 229,701.00	$ 288,843.52	$ 518,544.52	$ 408.62	2	$ 1,814,543.00	$ 1,429.90	3	$ 2,333,088.00	$ 1,838.52	3
	Homers Gap	0.0	0	$ 15,457.00	$ 0.00	$ 15,457.00	$ 0.00	-	$ 434,517.00	$ 0.00	-	$ 449,974.00	$ 0.00	-
	Plane Nine	1.8	650	$ 155,304.00	$ 147,949.79	$ 303,253.79	$ 466.54	4	$ 1,082,797.00	$ 1,665.84	4	$ 1,386,051.00	$ 2,132.39	4
	Kettle	0.0	0	$ 15,627.00	$ 0.00	$ 15,627.00	$ 0.00	-	$ 714,497.00	$ 0.00	-	$ 730,124.00	$ 0.00	-
	Bellwood	2.4	857	$ 172,334.00	$ 195,066.11	$ 367,400.11	$ 428.70	3	$ 818,462.00	$ 955.03	2	$ 1,185,862.00	$ 1,383.74	2
	Tipton	1.1	382	$ 102,621.00	$ 86,948.96	$ 189,569.96	$ 496.26	5	$ 903,566.00	$ 2,673.27	5	$ 1,093,136.00	$ 2,861.61	5
	Total	11.4	4115	$ 840,521.00	$ 936,636.00	$ 1,777,157.00			$ 6,194,046.00			$ 7,971,204.00		
Year 2008	Mill Run	2.6	937	$ 179,917.00	$ 298,987.78	$ 478,904.78	$ 511.10	1	$ 425,664.00	$ 454.28	1	$ 904,569.00	$ 965,39	1
	Horseshoe Curve	2.1	782	$ 228,393.00	$ 249,528.76	$ 477,921.76	$ 611.15	4	$ 1,814,543.00	$ 2,320.39	4	$ 2,292,465.00	$ 2,931.54	4
	Homers Gap	0.0	0	$ 16,641.00	$ 0.00	$ 16,641.00	$ 0.00	-	$ 434,517.00	$ 0.00	-	$ 451,158.00	$ 0.00	-
	Plane Nine	1.7	640	$ 174,505.00	$ 204,217.91	$ 378,722.91	$ 591.75	3	$ 1,082,797.00	$ 1,691.87	3	$ 1,461,520.00	$ 2,283.62	3
	Kettle	0.3	97	$ 52,532.00	$ 30,951.78	$ 83,483.78	$ 860.66	6	$ 714,497.00	$ 7,365.95	6	$ 797,981.00	$ 8,226.61	6
	Bellwood	2.4	874	$ 185,057.00	$ 278,885.08	$ 463,942.08	$ 530.83	2	$ 818,462.00	$ 936.46	2	$ 1,282,404.00	$ 1,467.28	2
	Tipton	0.8	295	$ 102,316.00	$ 94,131.69	$ 196,447.69	$ 665.92	5	$ 903,566.00	$ 3,062.94	5	$ 1,100,014.00	$ 3,728.86	5
	Total	9.9	3625	$ 939,361.00	$ 1,156,703.00	$ 2,096,064.00			$ 6,194,046.00			$ 8,290,111.00		
Year 2009	Mill Run	2.4	895	$ 158,531.00	$ 218,023.96	$ 376,554.96	$ 420.73	1	$ 425,664.00	$ 475.60	1	$ 802,219.00	$ 896.33	1
	Horseshoe Curve	2.7	1002	$ 275,128.00	$ 244,089.40	$ 519,217.40	$ 518.18	3	$ 1,814,543.00	$ 1,810.92	3	$ 2,333,761.00	$ 2,329.10	3
	Homers Gap	0.0	0	$ 13,997.00	$ 0.00	$ 13,997.00	$ 0.00	-	$ 434,517.00	$ 0.00	-	$ 448,514.00	$ 0.00	-
	Plane Nine	1.4	502	$ 174,248.00	$ 122,288.30	$ 296,536.30	$ 590.71	5	$ 1,082,797.00	$ 2,156.97	4	$ 1,379,333.00	$ 2,747.68	4
	Kettle	0.0	0	$ 15,459.00	$ 0.00	$ 15,459.00	$ 0.00	-	$ 608,857.00	$ 0.00	-	$ 624,316.00	$ 0.00	-
	Bellwood	2.1	755	$ 195,629.00	$ 183,919.65	$ 379,548.65	$ 502.71	2	$ 818,462.00	$ 1,084.06	2	$ 1,198,011.00	$ 1,586.77	2
	Tipton	0.9	315	$ 105,169.00	$ 76,734.69	$ 181,903.69	$ 577.47	4	$ 903,566.00	$ 2,868.46	5	$ 1,085,470.00	$ 3,445.94	5
	Total	9.5	3469	$ 938,161.00	$ 845,056.00	$ 1,783,217.00			$ 6,088,406.00			$ 7,871,624.00		
Year 2010	Mill Run	0.0	0	$ 27,001.05	$ 0.00	$ 27,001.05	$ 0.00	-	$ 425,664.00	$ 0.00	-	$ 452,665.00	$ 0.00	-
	Horseshoe Curve	4.4	1591	$ 294,451.14	$ 400,119.25	$ 694,570.39	$ 436.56	1	$ 1,814,543.00	$ 1,140,51	2	$ 2,509,114.00	$ 1,577.07	1
	Homers Gap	0.0	0	$ 11,385.93	$ 0.00	$ 11,385.93	$ 0.00	-	$ 434,517.00	$ 0.00	-	$ 445,903.00	$ 0.00	-
	Plane Nine	1.6	593	$ 159,059.37	$ 149,133.07	$ 308,192.44	$ 519.72	4	$ 1,082,797.00	$ 1,825.97	3	$ 1,390,990.00	$ 2,345.68	3
	Kettle	0.0	0	$ 16,251.24	$ 0.00	$ 16,251.24	$ 0.00	-	$ 608,857.00	$ 0.00	-	$ 625,108.00	$ 0.00	-
	Bellwood	2.1	750	$ 197,125.63	$ 188,616.87	$ 385,742.50	$ 514.32	3	$ 818,462.00	$ 1,091.29	1	$ 1,204,205.00	$ 1,605.61	2
	Tipton	1.2	453	$ 114,919.84	$ 113,924.59	$ 228,844.43	$ 505.18	2	$ 903,566.00	$ 1,994.63	4	$ 1,132,410.00	$ 2,499.80	4
	Total	9.3	3387	$ 820,194.20	$ 851,793.78	$ 1,671,987.98			$ 6,088,406.00			$ 7,760,395.00		

RESERVOIR WATER QUALITY CONSIDERATIONS

General - In recent years, water quality has increasingly governed Authority reservoir operations. This is due, in part, to changes in raw "water" chemistry since the original plant design in the early 1990's. Also, regulatory standards have focused on new contaminants such as disinfection byproducts, precursors, pathogens and microorganisms.

These contaminants are typically manifested in raw water particles, biological debris and protozoa and "naturally present organic material" (NOM). Appropriate treatment techniques include higher particle removal, enhanced pretreatment and multiple process barriers.

Obviously, lower raw water turbidity, NOM and biological particle debris will reduce pass-through potential and treatment costs. The ability to optimize treatment operations is directly related to individual reservoir water quality. Naturally, Authority personnel desire to use the best quality reservoir sources available for these purposes.

Source Water Quality Constituents - GD&F examined 5-10 years of monthly water quality information for basic parameters such as turbidity, temperature, pH, manganese, alkalinity, total organic carbon (TOC) and conductivity.

Algae concentrations have been tabulated for each reservoir based on a 10-year study by the Authority. Samples were taken at various depths in each reservoir. For our purposes, maximum and average results were obtained for those samples taken at the reservoir intake level. Reported copper sulfate applications were also noted for each reservoir to control seasonal algae along with attendant TOC sampling.

Please refer to the following tables for reservoir water quality data.

Table 39 - Reservoir Raw Water Quality Data

Reservoir	Parameter	Years Tested	Average Value	Maximum Value	Minimum Value
Tipton	Turbidity	2006 - 2010	1.48 NTU	3.58 (Max. Mon.)	0.94 NTU
	Temperature	2006 - 2010	50.3° F	67.7° F	37.4° F
	pH	2006 - 2010	6.74	7.21	6.37
	Manganese	2008 - 2011	0.034 mg/l	0.133 mg/l	0.011 mg/l
	Alkalinity	2002 - 2011	5.0 mg/l	8.4 mg/l	2.6 mg/l
	T.O.C.	2002 - 2011	0.95 mg/l	1.64 mg/l	0.51 mg/l
	Conductivity	2004 - 2010	51.8 µs/cm	93.0 µs/cm	23.0 µs/cm
Bellwood	Turbidity	2006 - 2010	2.22 NTU	7.72 (Max. Mon.)	1.16 NTU
	Temperature	2006 - 2010	51.7° F	71.4° F	36.0° F
	pH	2006 - 2010	6.86	7.23	6.47
	Manganese	2008 - 2011	0.206 mg/l	1.01 mg/l	0.009 mg/l
	Alkalinity	2002 - 2011	6.2 mg/l	17.0 mg/l	2.8 mg/l
	T.O.C.	2002 - 2011	0.92 mg/l	1.62 mg/l	0.46 mg/l
	Conductivity	2004 - 2010	80.3 µs/cm	184 µs/cm	34 µs/cm
Plane Nine	Turbidity	2007 - 2010	1.34 NTU	2.62 (Max. Mon.)	0.64 NTU
	Temperature	2007 - 2010	51.5° F	73.4° F	36.0° F
	pH	2007 - 2010	7.04	7.60	6.75
	Manganese	2008 - 2011	0.124 mg/l	0.816 mg/l	0.01 mg/l
	Alkalinity	2002 - 2011	10.2 mg/l	29.4 mg/l	2.9 mg/l
	T.O.C.	2002 - 2011	0.89 mg/l	1.88 mg/l	0.47 mg/l
	Conductivity	2004 - 2010	136 µs/cm	278 µs/cm	25.0 µs/cm
Kettle	Turbidity	2008	1.22 NTU	1.85 (Max. Mon.)	0.82 NTU
	Temperature	2008	-	-	-
	pH	2008	7.02	7.33	6.60
	Manganese	2008	0.052 mg/l	0.109 mg/l	0.017 mg/l
	Alkalinity	2002 - 2011	7.6 mg/l	10.0 mg/l	5.3 mg/l
	T.O.C.	2002 - 2011	1.60 mg/l	2.14 mg/l	0.98 mg/l
	Conductivity	2004 - 2009	72.8 µs/cm	663 µs/cm	19 µs/cm
Homer Gap	Turbidity	2004 - 2008	1.70 NTU	7.92 (Max. Mon.)	0.33 NTU
	Temperature	-	-	-	-
	pH	2004- 2008	7.22	8.99	6.39
	Manganese	2002 - 2008	0.029 mg/l	0.507 mg/l	0.0006 mg/l
	Alkalinity	2002 - 2011	4.5 mg/l	8.4 mg/l	2.6 mg/l
	T.O.C.	2002 - 2011	0.95 mg/l	1.64 mg/l	0.51 mg/l
	Conductivity	2004 - 2008	38.4 µs/cm	51 µs/cm	25 µs/cm
Horseshoe Curve	Turbidity	2007 - 2010	1.38 NTU	2.78 (Max. Mon.)	0.89 NTU
	Temperature	2007 - 2010	50.94° F	72.2° F	35.3° F
	pH	2007 - 2010	7.21	7.68	6.55
	Manganese	2008 - 2011	0.084 mg/l	0.831 mg/l	0.019 mg/l
	Alkalinity	2002 - 2011	13.3 mg/l	21.4 mg/l	6.9 mg/l
	T.O.C.	2002 - 2011	1.14 mg/l	1.82 mg/l	0.62 mg/l
	Conductivity	2002 - 2010	153 µs/cm	210 µs/cm	130 µs/cm
Mill Run	Turbidity	2007 - 2009	1.79 NTU	7.17 (Max. Mon.)	0.98 NTU
	Temperature	2007 - 2009	51.0° F	69.3° F	33.7° F
	pH	2007 - 2009	7.22	7.91	6.85
	Manganese	2008 - 2009	0.071 mg/l	0.336 mg/l	0.014 mg/l
	Alkalinity	2002 - 2009	14.7 mg/l	24.2 mg/l	10.1 mg/l
	T.O.C.	2002 - 2009	1.27 mg/l	1.92 mg/l	0.72 mg/l
	Conductivity	2002 - 2010	114 µs/cm	146 µs/cm	92 µs/cm

Table 40 - Reservoir Algae Levels (org./ml) and TOC (mg/l)

Reservoir	Period	Data Points	Maximum Concentration	Average Concentration	Avg. TOC	Max TOC	$CuSO_4$ Appl.
Bellwood	2001-2010	16	2,300	400	0.81	1.07	2
Tipton	2001-2009	10	430	240	0.80	0.95	1
Kettle	2002-2010	22	9,600	2,400	1.29	1.70	6
Homer Gap	2001-2010	24	40,000	4,300	0.77	0.93	9
Mill Run	2001-2010	24	11,700	2,400	1.07	1.38	8
Allegheny	2001-2010	15	4,400	1,550	2.25	3.27	4
Plane Nine	2001-2010	24	1,600	530	0.91	1.25	3
Muleshoe	2002-2010	12	3,700	1,300	0.65	0.76	0
Blair Gap	2002-2009	7	500	160	1.04	1.34	0
Kittanning Pt.	2001-2010	27	12,900	1,950	0.83	1.17	3
Impounding Dam	2001-2010	31	9,200	1,050	1.01	1.33	2
Lake Altoona	2001-2010	22	700	370	1.17	1.58	1

Water Quality Considerations - As mentioned, USEPA has focused on microbiological contaminants and precursor removal. Treatment techniques include enhanced pretreatment, chlorine contact and filtration, preferably in multiple barriers.

These techniques and contaminants are discussed as follows:

Disinfection Byproducts (DBP) - According to the USEPA, these substances pose health risks if present in high concentrations. Based on USEPA toxicology studies, DBP's pose potential cancer risks. The substances include Total Trihalomethanes (TTHM's) and Haloacetic Acids (HAA5) and their subcategories. Chlorite, bromate, and total organic carbon are also sampled and tested under this category. TTHM's and HAA5's are the major focus of concern.

The types of DBP's that form depend on the type, dose and residual of disinfection applied. Obviously, the higher the chlorine dosage and residual, more DBP's are formed. The circumstances of disinfection are related to reaction time, pH and temperature.

- **Reaction Time and DBP** - When the reaction time is shorter, higher concentrations of trihalomethanes and halogenic acetic acids may be formed. When the reaction time is longer, some temporary forms of disinfection byproducts may become disinfection endproducts, such as tribromine acetic acid or bromoform. Haloacetonitrils (HAN) and haloketons (HK) are decomposed.

  When temperatures increase, reactions take place faster, causing a higher chlorine concentration to be required for a proper disinfection. This causes more halogenic disinfection byproducts to form. An increase in temperature also enhances the decomposition of tribromine acetic acids, HAN and HK.

- **pH and DBP** - When pH values are high, more hypochlorite ions are formed, causing the effectiveness of chlorine disinfection to decrease. At higher pH values, more TTHM is formed, whereas more HAA5 is formed when pH values are lower. At high values HAN and HK are decomposed by hydrolysis, because of an increase in hydrolysis reactions at higher pH values.

- **NOM** - The constituents of the raw water have an effect in DBP formulas, specifically, concentrations and properties of "naturally present organic matter" (NOM).

  NOM is the predecessor of a disinfection byproduct. The level of organic matter is usually registered as the "total organic carbon" concentration or the "dissolved organic carbon" concentration. The composition and concentration of naturally present organic matter determine the types and concentrations of disinfection byproducts that will be eventually formed. Naturally present organic matter contains compounds, such as humic acids, fulvine acids, hydrophobic acids, hydrophobic neutral substances, transfilic acids, transfilic neutral substances, hydrophilic acids and hydrophilic neutral substances. Seasons influence the naturally present organic carbon concentration, causing the concentrations of disinfection byproducts to vary.

- **DBP Regulations** - USEPA began regulating DBP's when the Stage 1 Disinfectants/ Disinfection Byproducts Rule was published. The rule regulated total trihalomethanes (TTHM) and halogenic acetic acids (HAA5) at maximum allowable annual average levels of 80 parts per billion and 60 parts per billion, respectively. The Stage 2 Rule became effective on December 15, 2005. It requires systems to meet maximum contaminant levels as an average at EACH compliance monitoring location, instead of on a system-wide average as specified under the Stage 1 Rule. Based on system-wide DBP monitoring, the Authority is in full compliance with both Stage 1 and Stage 2 Rules.

Total Organic Carbon (TOC) - TOC testing is a way of measuring levels of organic substances capable of DBP formation.

According to USEPA *"…water systems that use surface water…and use conventional filtration are required to remove specified percentages of organic materials, measured as TOC, that may react with disinfectants to form DBP's. Removal will be achieved through a treatment technique (enhanced coagulation or enhanced softening)…"* According to the Stage 1 criteria, for source water TOC from 2.0 to 4.0 mg/l and source water alkalinity under 60 mg/l, 35% of the TOC must be removed by enhanced coagulation.

Water treatment facilities must compute TOC removal ratios and maintain running annual averages above 1.0. Based on an evaluation of the TOC, alkalinity and TOC removal efficiency the last five years, the Authority is in compliance with the Stage 1 criteria.

Microscopic Particulate Analysis (MPA) - With the advent of the USEPA "Filter Rule" in the mid-1980's. PADEP initiated a statewide Filter Plant Performance Evaluation (FPPE) program. This study combined an on-site survey of water treatment plants with microscopic evaluation of influent and effluent samples.

The Microscopic Particulate Analysis (MPA) involves the identification, sizing and population estimation of microorganisms and organic/inorganic debris in raw water. This test helps identify pathogens such as *giardia* and *cryptosporidium*. Tests are typically performed on raw and filtered water samples. The categorization of debris is as follows:

a. Fine Particulate Debris (1 to 5 um size) - rust, silt, coagulant floc

b. *Giardia*/*Cryptosporidium*-Sized Debris (3 to 7 um size - *crypto*) (8 to 19 um size *giardia*) - waterborne microbial pathogens

c. Large Particulate Debris (20 to 100+ um size) - conglomerated masses

d. Cellular Plant Debris (larger than 20 um) - vegetative pieces and characteristic of fecal material for *giardia* hosts (beaver, muskrat)

e. Diatoms and Other Algae (less than 1 to 100+ um size) - organic matter

f. Protozoa (6 to 29+ um size) - unicellular organisms

g. Nomatodes - sediment dwelling organisms found in bottom of reservoirs

h. Insects/Crustaceans/Rotifers (50+ um size) - numerous in surface water supplies

The following table shows MPA testing as part of recent PADEP filter performance evaluations. We have tabulated the presence/absence of giardia-cryptosporidium in the reservoir systems. These microorganisms are observed periodically. Homer Gap Reservoir, in particular, shows particular vulnerability to pathogen contamination and likely results from upstream, malfunctioning sewage systems.

Table 41 - Source Water MPA Testing Results

Reservoir System Treatment Plant	Date	Particle Size Range (microns)	Verifiable Giardia Cysts	Verifiable Crypto Cysts	Remarks
Tipton	01-20-09	0-65	None Observed	1	Algae, Diatoms, Protozoa, Pollen, Hyphae, Spores
Bellwood	03-01-11	0-1000	1	None Observed	Algae, Diatoms, Protozoa, Pollen, Hyphae, Spores, Rotifers
Kettle	04-21-08	0-110	None Observed	None Observed	Algae, Diatoms, Protozoa, Pollen, Hyphae, Spores, Rotifers
Plane Nine	01-11-11	0-300	None Observed	2	Diatoms, Algae (Filamentous & Unicellular), Spores, Protozoa, Hyphae, Pollen
Homer Gap	02-22-04	0-180	110.6	15.8	Algae, Diatoms, Protozoa, Hyphae, Pollen, Insect Eggs
Mill Run	09-15-08	0-260	None Observed	None Observed	Rotifers, Nematodes, Hyphae, Spores, Algae, Insect Parts, Diatoms
Horseshoe Curve	10-19-09	0-402	None Observed	None Observed	Algae (Filamentous & Unicellular), Diatoms, Pollen, Crustaceans, Protozoa, Rotifers, Fungal Hyphae

Raw Water Bacteriological Testing - The Authority was required to begin 24 months of *E. coli* testing in April 2007. The average results, as shown in the following table, are well below the trigger level (50 MPN/100 ml).

In addition, the Authority performed twelve months of cryptosporidium testing for all reservoir systems from April 2007 to March 2008 to conform with the LT2 ESWTR. The results of this testing are: Bellwood - 0.015 oocysts/l; Homer Gap - 0.002 oocysts/l; Kettle - 0.007 oocysts/l; Mill Run/Allegheny - 0.007 oocysts/l; Horseshoe Curve - 0.000 oocysts/l; and Plane Nine - 0.000 oocysts/l. All test results are below 0.075 oocysts/l and fall under the "Bin Classification 1." This means the Authority does not need to provide additional treatment, although 3-log credits (at least) are available through the existing process treatment systems.

Table 42 - Source Water *E. coli* Test Results (2007 - 2009)

Reservoir System	Average *E. coli* (MPN/100 ml)	Max. Value
Tipton	1.42	8.0
Bellwood	7.81	62.0
Kettle	1.23	8.0
Plane Nine[1]	2.48	38.4
Mill Run[2]	2.20	19.0
Homer Gap	7.83	45.0
Horseshoe Curve[3]	1.79	15.0

Notes:

(1) Blending ranges from 60% Muleshoe Reservoir and 40% Plane Nine Reservoir water to 35% Muleshoe Reservoir and 65% Plane Nine Reservoir water.

(2) All samples reflect 100% Mill Run Reservoir water except Nov./Dec. 2008 with a blend of 50% Mill Run Reservoir and 50% Allegheny Reservoir.

(3) All samples reflect 100% Cochran-Impounding Reservoir.

Treatment Processes - The Authority treatment process consists of two systems. One system, the Andronic Pappas water treatment plant, is located at the Horseshoe Curve.

- Gravity raw water feed from Cochran-Impounding Reservoir
- Ozonation process consisting of ozone generators and contact chambers
- Chemical feed system for alum, polymer and alkaline addition
- Rapid mix and flocculation tanks
- Sedimentation process
- Post-sedimentation non-ionic polymer addition in a mixing chamber/surge tank for neutralization of highly charged particle spillover
- Filter backwash and sedimentation basin underflow to a solids separation, solids conditioning and plate-and-frame dewatering system
- Multi-media, rapid sand filtration system
- Chlorination system and chlorine contact basin with chemical addition of chlorine, fluoride, corrosion inhibitor
- Finish water pumping to Low and High Service areas of the City

The other treatment plants are "direct filtration-ozonation" processes that employ many of the same functions of the Horseshoe Curve plant. These treatment facilities are located at the Tipton, Bellwood, Kettle, Homer Gap and Plane Nine Reservoir systems. Unit processes include:

- Gravity raw water feed from upstream reservoirs
- Ozonation process consisting of ozone generators and contact chambers
- Chemical feed system for alum, polymer and alkaline addition
- Rapid mix and flocculation tanks
- Automatic backwash filtration system with traveling bridge, cell indexed multi-media filters
- Filter-to-waste discharge to solids separation tank and sludge drying beds
- Chlorination system and chlorine contact basin with chemical addition of chlorine and corrosion inhibitor
- Finish water pumping to respective distribution systems

The systems were designed in consideration of raw water chemistry at the respective reservoirs. The direct filtration plants were designed for low turbidity reservoir sources while eliminating the settling process, thus reducing chemical usage, sludge production and capital/operating expenses.

The Andronic Pappas WTP had to consider low pH/high acidity source water. This required a more sophisticated pretreatment and oxidation process in conjunction with a conventional multi-media filtration system. However, watershed and land restoration work, along with passive mine drainage treatment systems, have largely restored the source water since the original design.

Both plants use ozone as a pretreatment oxidant for inactivation of water borne pathogens, destruction of organics and algae, oxidation of iron and manganese and elimination of taste and odor problems.

Multiple treatment barriers are provided at all plants to achieve compliance with the USEPA Long Term 2 Surface Water Treatment Rule and Disinfection By-Products Rule. Various degrees of "log" credits for these barriers include ozonation, enhanced coagulation (Andronic Pappas WTP), filtration and disinfection/contact time. The Authority plants, by virtue of their design and performance, achieve USEPA Safe Drinking Water standards. The following table shows recent finish water turbidity performance.

Table 43 - Water Treatment Finish Water Turbidity (2011)

Water Treatment Plant	Average Turbidity Range	Max Turbidity
Tipton	0.06 - 0.07 NTU	0.07 NTU
Bellwood	0.06 - 0.12 NTU	0.22 NTU
Mill Run	0.05 - 0.07 NTU	0.07 NTU
Pappas	0.02 - 0.05 NTU	0.05 NTU
Plane Nine	0.03 - 0.05 NTU	0.07 NTU
Kettle (2008)	0.04 - 0.09 NTU	0.11 NTU
Homer Gap	offline	offline

Treatment Facility Performance - Since the Authority plants are in full regulatory compliance, optimization of operations and attendant cost effectiveness has become a priority. The following discussions will address individual reservoir water quality in relation to system operations.

- **Tipton Reservoir System** - Analytical results show Tipton Reservoir to have excellent drinking water quality. Tipton has the lowest concentrations of manganese and algae for the entire system. Only one application of copper sulfate condition was applied to the reservoir over the last 10 years. Turbidity, pH and alkalinity are considered to be excellent. Total organic carbon levels (both reservoir intake and plant raw water) are very low. As a result of ozone treatment, DBP levels are very low and well within regulatory limits. Operating personnel consider Tipton Reservoir to be one of its best quality sources and one of the most stable and consistent to treat.

- **Bellwood Reservoir System** - Results of the algae study show Bellwood Reservoir to have very low levels of algae and TOC. Only two applications of copper sulfate were noted from 2001 - 2011. Negatively, turbidity and manganese are the highest in the system. Average manganese levels (0.206 mg/l) are 4 times the secondary maximum contaminant level while turbidity levels are 50% higher than the average for all other reservoirs.

  Operating personnel report that Bellwood WTP produces a high level of manganese and iron sludge along with chemical coagulant solids necessary for Fe/Mn precipitation. This source is particularly difficult to treat in the early spring when water temperatures are low. Generally, Bellwood WTP is the most challenging plant to operate for these reasons. Operating personnel have suggested that Tipton Reservoir be utilized during these seasonal raw water conditions. This would provide a more consistent treatment process and also reduce operating costs.

- **Plane Nine Reservoir System** - Overall water quality at the Plane Nine Reservoir system is considered good. Turbidity, pH and alkalinity are within normal ranges. Manganese levels are above the SMCL (0.124 mg/l). But, they are about half those of Bellwood Reservoir and do not seriously inhibit the operation of the Plane Nine plant. Conductivity is higher for any other Authority system because of runoff from old US Route 22. This condition is particularly pronounced in the winter when road salt concentrations are high. High conductivity, in and of itself, does not affect treatment. Relative to summer algae conditions, Plane Nine Reservoir is among the lowest in the system. Copper sulfate applications totaled three over the last 10 years. It is interesting to note that Blair Gap Reservoir shows abnormally low algae levels, the best of any Authority reservoir. This is due to the physical location of the reservoir in a defile of Blair Gap. It is shaded by trees and mountains which limits direct sunlight on the reservoir and subsequent biological activity.

  Operating personnel report that water treatment at Plane Nine is consistent and stable with the normal solids generation. It is interesting to note that Plane Nine water treatment plant was the first "direct filtration" plant in the system and is approaching 20 years of virtually trouble-free operation.

- **Kettle Reservoir System** - Since Kettle Reservoir was taken off line several years ago, limited water quality information is available. Data for 2008 indicates very good water quality for pH, alkalinity and turbidity. Manganese levels are not a treatment concern. However, TOC levels are the highest in the system with the potential for DBP formation. Average summer algae concentrations are the second highest in the system. Copper sulfate applications numbered six times over the last 10 years, even when the Kettle WTP was shut down.

Operating personnel report that during non-summer operations, treatment conditions are stable at the plant. However, summer algae levels stress the oxidation system. In fact, the ozone generators must operate at capacity in order to fully oxidate these algae levels. The storage capacity of the reservoir in conjunction with low inflow from the small watershed produces excessive algae. Water quality conditions and attendant costs are one of the reasons for decommissioning of the Kettle water treatment plant.

- **Homer Gap Reservoir System** - Since Homer Gap Reservoir was taken off line several years ago, limited water quality information is available. Data for 2008 indicates very good water quality for pH, alkalinity and turbidity. Manganese levels were slightly elevated, but not a treatment concern. However, TOC levels are among the highest in the system with the potential for DBP formation. Average summer algae concentrations are the highest in the system. Copper sulfate applications numbered six times over the last 10 years, several times when Homer Gap WTP was shut down. Microbiological testing reveals evidence of pathogen contamination due to upstream, malfunctioning on-lot sewage systems.

  Operating personnel that during non-summer operations, treatment conditions are stable at the plant. Summer algae levels stress the oxidation system. In fact, the ozone generators operate at capacity in order to fully oxidate these algae levels. The storage capacity of the reservoir in conjunction with low inflow from the small watershed produce excessive algae. Water quality conditions and attendant costs are one of the reasons for decommissioning of Homer Gap water treatment plant.

- **Horseshoe Curve Reservoir System** - Raw water quality to the Andronic Pappas WTF has undergone a remarkable transformation the last ten years. This change has resulted from acid mine drainage abatement work in the Glen White Run watershed. Passive wetland treatment systems were installed by the Blair County Conservation District in 1999 - 2000. In the Kittanning Run watershed, strip mine reclamation (due to remining) has decreased soil erosion.

  Glen White Run flow is diverted into the Horseshoe Curve Reservoir system while Kittanning Run water is completely bypassed. Recent analytical testing shows Kittanning Run to be severely degraded by AMD. Please refer to the following table:

Table 44 - Kittanning Run Water Quality (1998 - 2010)

Constituent	Average	Range	Samples Tested
pH	3.23	2.88 - 3.23	47
Conductivity	1091 µs/cm	160 - 1091 µs/cm	41
Acidity	185 mg/l	54 - 652 mg/l	43
Iron	24.5 mg/l	1.16 - 54.0 mg/l	37
Manganese	13.4 mg/l	0.631 - 25.1 mg/l	37
Dissolved Solids	925 mg/l	106 - 1.647 mg/l	40
Aluminum	10.1 mg/l	0.92 - 20.7 mg/l	37
Calcium	63.0 mg/l	13.8 - 105 mg/l	29
Magnesium	62.0 mg/l	5.49 - 100 mg/l	29
Hardness*	412.0 mg/l	57 - 672 mg/l	29

*Computed (as $CaCO_3$)

Relative to summer algae levels, most seem to be concentrated in the upper (Kittanning Point) and lower (Lake Altoona) reservoirs. Cochran Impounding Reservoir concentrations have averages just over 1,000 org/ml which are readily treatable by ozonation facilities at the Pappas WTP. TOC levels are typically low, about 1.00 mg/l. Copper sulfate applications total six over the last 10 years for all three reservoirs.

Operators have indicated that the high level of raw water quality has provided predictable process chemistry and stable filtration results. When blended with Mill Run water, water treatment is further enhanced. Finish water turbidities are typically below 0.05 NTU with hardness levels between 50 and 100 mg/l. Water treatment efficiencies and solids generation at the Horseshoe Curve plant are comparable with any other plant in the system.

It should be mentioned that the Authority must rely on the continued effectiveness of the Glen White Run passive treatment systems. Also, the Kittanning Run watershed is bypassed around the reservoir system since its water quality continues to be poor. The Authority will not have the advantage of passing Kittanning Run during a severe drought. Assuming no passive treatment, water quality must unavoidably decline during these periods of shortage.

- **Mill Run Reservoir System** - Mill Run Reservoir is a high quality source which is borne out by the data. It is characterized by low turbidity, high alkalinity and pH and relatively low manganese levels. Whether treated directly at the Mill Run WTP or blended and treated at the Pappas WTP, Mill Run raw water is considered exceptional. Relative to the potential for DBP formation, TOC levels are elevated but offset to same extent by higher source water alkalinity. Elevated levels of conductance may reflect the presence of US Route 36 through the watershed and related effects of road salt. Summer algae levels are the second highest in the reservoir system. However, these do not seem to affect treatment operations at the Mill Run WTP or when blended at the Pappas WTP. Typically, copper sulfate is applied every year to control algae. It should be noted that Allegheny Reservoir high biological activity is due to its shallow reservoir depth and large surface area exposed to sunlight. TOC levels are considered the highest in the Authority system. It is no coincidence that Allegheny Reservoir is not used heavily during low flow periods, given the higher cost of oxidation required to reduce algae levels.

Assessment - As discussed, reservoir water quality considerations have become a critical factor in reservoir operation and planning. Based on the foregoing, we can draw the following conclusions:

- Authority reservoir water quality has improved over the last 30 years principally because of AMD improvements in the Horseshoe Curve watershed. In fact, raw water to the Pappas treatment plant is now among the best in the system. The best quality reservoir systems (are in descending order) are Tipton, Mill Run, Plane Nine, Bellwood, Kettle and Homer Gap.

- The Authority will have to rely on the continued performance of the passive AMD treatment systems on Glen While Run and, if necessary, assume the maintenance and cleaning tasks to ensure functionality. Kittanning Run is still a very poor quality stream and is largely bypassed. During severe droughts, water quality at Horseshoe Curve will decline when Kittanning Point is brought on-line for additional inflow.

- Overall, basic water quality is considered excellent. On average, the sources exhibit low turbidity (1.59 NTU), net alkalinity (8.8 mg/l), acceptable manganese levels (0.086 mg/l) and neutral pH (7.04).

- Summer algae levels in the larger reservoirs are not considered excessive. The ozonation process is effective in oxidizing this material. The periodic and judicious application of copper sulfate in the reservoirs has also controlled algae formation.

- In general, total organic carbon (TOC) levels are relatively low in the larger reservoirs. Net raw water alkalinity together with oxidation supplied by the ozone process (and alkaline chemical addition) is success in removing disinfection byproducts.

- The smaller watershed/lower inflow reservoirs have elevated levels of summer algae. These reservoirs are not currently operating including Allegheny, Kettle and Homer Gap Reservoirs because of operating costs associated with higher ozone generation costs.

- Treatment efficients at the plants are exceptional and meet regulatory requirements. Finish water turbidities are on the order of 0.05 NTU. This performance is indicative of optimized plant operations and generally stable water quality.

- The input of water quality on operations is reflected in the current reservoir operating mode. Generally, the best quality sources coincide with the best yielding reservoirs.

- Under normal circumstances, the Horseshoe Curve (including Mill Run Reservoir systems), Plane Nine, Bellwood and Tipton Reservoir systems are operated as much for quality as they are for quantity. As will be demonstrated, these water quality sources have lower operating costs due to lower chemical costs and waste solids production.

- Periodic and seasonal variation in treatment operations can dictate reservoir utilization. As noted, the Bellwood Reservoir can experience unstable water quality in the late winter-to-spring period, thus affecting coagulation chemistry. It is apparent that higher quality Tipton Reservoir can fully supplement or replace Bellwood Reservoir during these times. Coordination with Bellwood Borough officials should be done since a change in billing would result.

- During severe droughts, use of lower quality sources will be required. Fortunately, the treatment capacity exists. Operating personnel will need to closely monitor raw water quality and make the necessary process adjustments to maintain finish water quality. However, treatment costs will rise in terms of chemical consumption and solids generation.

RESERVOIR OPERATIONAL SEQUENCING

The Authority has a great deal of flexibility in the reservoir systems it uses for water supply. We have assembled a reservoir sequence schedule based on demand and economic factors involved in their operations. This should be used as a general guide since treatment plant capacity exceeds 2033 projected demand by 100%. Considerable latitude exists to vary day-to-day operations by either increasing or decreasing treatment rates (assuming an adequate reservoir supply).

As a general rule, withdrawal from reservoir systems should be sustainable (based on available, dependable flow) and allow sufficient reserve capacity at the treatment plant for peak demands. Assuming sufficient supply, the average treatment plant rate should allow for at least a 50% reserve for peak conditions. Therefore, the following sustainable withdrawals are proposed for individual reservoir systems.

Table 45 - Withdrawals for Normal Reservoir and Treatment Plant Operations

Reservoir System	Sustainable Withdrawal (mgd)
Horseshoe Curve	5.00
Mill Run	2.50
Homer Gap	0.35
Plane Nine	2.00
Kettle	0.75
Bellwood	2.50
Tipton	1.50
Total	14.60

Based on the foregoing, the following sequence of reservoir systems could be used in the following demand scenarios:

Table 46 - Reservoir Sequencing at Various Demands

Reservoir System	Demand (mgd)											
in Operation	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.25
Horseshoe Curve	•	•	•	•	•	•	•	•	•	•	•	•
Bellwood	•	•	•	•	•	•	•	•	•	•	•	•
Plane Nine	•	•	•	•	•	•	•	•	•	•	•	•
Tipton	•	•	•	•	•	•	•	•	•	•	•	•
Mill Run						•	•	•	•	•	•	•
Kettle											•	•
Homer Gap												•

We recommend that the current four reservoir operation plan continue to function up to a limit of 11.0 mgd. In our opinion, Mill Run, as an auxiliary component of the Horseshoe Curve system, could be run concurrently, making a total of five systems in operation. Mill Run is the most cost effective of all the reservoir systems and would result in only a marginal increase in cost when used with the other four systems.

Above 11.0 mgd, Mill Run Reservoir will definitely need to operate. At 13.5 mgd, Kettle Reservoir comes on line and at 14.25 mgd, Homer Gap Reservoir becomes operational. At this level, we recommend all reservoir systems be on-line and operating.

DROUGHT CONTINGENCY PLANNING

A primary goal of this study is to correlate the results of reservoir simulation and operation analysis with drought contingency planning. We have established several conclusions as a result of our analysis:

- Because of the fully integrated nature of the distribution system, the use of total system storage as a fundamental premise for drought planning is valid.
- The dependable flow of the reservoir system is 12.82 mgd. This has been fully documented by a standard simulation model (Res-Sim 3.0) using a significant 65-year period of record.
- Demands above the dependable flow (12.82 mgd) up to the projected 2033 withdrawal of 14.64 mgd will require varying levels of voluntary and mandatory restrictions.
- Because of the 65-year period of record used in this study, a 50-year drought event can reliably establish a safe yield (12.82 mgd) that will not drain the reservoir system.
- A study of ration simulations in the Res-Sim 3.0 model reveal that 5% for voluntary restrictions and 20-25% for mandatory restrictions can preserve the water supply.
- At the present time, the simultaneous occurrence of a 50-year drought event and 14.62 mgd demand is highly unlikely.

In reviewing the PADEP drought planning criteria within the context of this study, the question becomes what is the baseline for establishing reservoir monitoring over and above drought declarations of the state.

We contend that the safe yield of 12.82 mgd (or rounding to the lower figure of 12.0 mgd), is a valid baseline for reservoir monitoring. That is, for all demands less than 12.0 mgd, the Authority only needs to monitor reservoir storage levels and days remaining to February 28. It merely follows the drought instructions issued by state officials. Drought watches, drought warnings and drought emergencies will have their own regulating effect on customers in terms of water conservation. This self regulatory effect could produce up to 5-8% of conservation (0.6 to 1.0 mgd) from dependable flow. The Authority would need to monitor when individual reservoir systems may be in deficit with the discretion (or flexibility) to add sources (Kettle, Homer Gap or Mill Run) or transfer water (Westerly/Easterly/Bellwood booster stations) as needs dictate.

There may be some objection that dependable flow may not be based on the maximum drought event. In other words, a drought event more severe than any experienced since 1944 may produce a lower dependable flow (below 12.82 mgd). This is possible, but does not recognize other supply options of the Authority. The 31st well field has a yield of 1.0 - 2.0 mgd. This source has been removed from the Authority supply inventory and disconnected from the system due to water quality issues. However, PADEP has acknowledged that the 31st well field could be permitted as a temporary emergency source.

If a drought event of the magnitude described does not qualify as an emergency, then another definition is required. With this assumption, the 31st well field could be temporarily connected to the system and blended with reservoir water. It accounts for the "uncertainty factor" in this reservoir evaluation. This water could be sufficiently chlorinated (to comply with the 4-log removal standard) and air stripped to remove any residual volatile organics for emergency purposes. The 31st well field is the reason that a reservoir inventory baseline of 12.0 mgd can be adjusted.

Based on this criteria, the following drought contingency plan (with trigger points and stages corresponding to PADEP criteria) is shown in the following table. The trigger points for demands in excess of 12.0 mgd are tabulated in increments of 0.5 mgd and interpolated from ration simulation modeling. All mandatory restrictions shall be performed in accordance with the rationing plan of the Authority including the shedding of customers and imposition and monitoring of rationing measures.

Table 47 - Drought Contingency Plan
Based on Res-Sim 3.0 Model Ration Simulation

Stage I - Drought Watch

a. For total system demand below 12.0 mgd,
Trigger: State Declares Drought Watch for the Area

b. For total system demand above 12.0 mgd, Trigger:

Demand	System Storage (mg)	% Total	System Storage Days
12.0	1,080	41	90
12.5	1,200	45	96
12.8	1,269	48	99
13.0	1,319	50	101
13.5	1,446	55	107
13.75	1,510	57	110
14.0	1,697	64	121
14.5	2,084	79	144
14.64	2,196	83	150

Note: All reservoir systems brought on-line in the intervening period between Stage I and Stage II.

Monitor storage levels and days remaining until February 28.

Stage II - Drought Warning

a. For total system demand below 12.0 mgd,
Trigger: State Declares Drought Warning for the Area

b. For total system demand above 12.0 mgd, Trigger:

Demand	System Storage (mg)	% Total	System Storage Days
12.0	720	27	60
12.5	821	31	66
12.8	885	33	69
13.0	928	35	71
13.5	1,042	39	77
13.75	1,098	41	80
14.0	1,199	45	86
14.5	1,404	53	97
14.64	1,464	55	100

Note: Monitor storage levels and days remaining until February 28.

Stage III - Drought Emergency

a. For total system demand below 12.0 mgd,
Trigger: Governor Declares a Drought Emergency for the Area

b. For total system demand above 12.0 mgd, Trigger:

Demand	System Storage (mg)	% Total	System Storage Days
12.0	480	18	40
12.5	571	22	46
12.8	629	24	49
13.0	669	25	51
13.5	771	29	57
13.75	824	31	60
14.0	919	35	66
14.5	1,114	42	77
14.64	1,171	44	80

Utilization of 31st Street Well Field (1.0 - 2.0 mgd capacity)

Emergency Considerations - While not a focus on this reservoir operations plan, the effect of non-drought related emergencies is an operational consideration. Such emergencies would include the contamination of a water supply, dam safety problems or shutdown of a water treatment facility. The emergencies may be of a short or long term duration.

The 2003 Source Water Assessment and Watershed Protection Plan addressed various contingencies and risks associated with emergencies. Also, the Authority has prepared a Critical Incident Response Manual, USEPA Vulnerability Assessment, Dam Emergency Action Plan, Plant Preparedness, Prevention and Contingency Plan (PPC) and USEPA Emergency Response Plan to address security concerns. These documents fully provide emergency response efforts and the necessary protocols to be observed.

Relative to the reservoir system, the emergency shutdown of a reservoir system could have various effects. For instance, if an individual reservoir system other than the Horseshoe Curve system was effected, the practical affect would be nominal. The yield of these individual systems is 10-15% of the total system yield. Distribution system transfers (principally from the Horseshoe Curve system) would easily provide water supply to the affected service area. This has been amply demonstrated in our study.

However, the Horseshoe Curve is a different story. If all three reservoirs were disabled by a contamination event (for instance, a hazardous waste railroad spill on the Horseshoe Curve), 5.1 mgd of safe yield would be removed from the system. The dependable flow would be reduced to 7.72 mgd. For average hydrological conditions, the current demand of 9.0 mgd could be met without restrictions. However, during severe shortages, mandatory restrictions would be necessary.

An evaluation of the necessary rationing and hydraulic reconfiguration is beyond the scope of this report. Suffice to say that a menu of mandatory restrictions (on the order of 20 - 30%), prohibition of non-essential metered consumption, leak detection and hydraulic pressure reduction would be considered. Without the Horseshoe Curve, a total production rate of 7.5 mgd is a likely demand target for the remaining reservoir system.

RECOMMENDATIONS

The following recommendations are offered to enhance the operation of the Altoona Water Authority reservoir system.

- As a result of this study, the Authority can supply water up to 12.0 mgd as the safe yield of the system. Total reservoir storage should be used for drought planning triggers.

- For production less than 12.0 mgd, the Authority can safely deliver water during shortages within the parameters of drought declarations of the state while monitoring total shortage capacity and days remaining to February 28.

- For production levels above 12.0 mgd and when drought storage levels dictate, voluntary and mandatory restrictions should be implemented according to the revised drought contingency plan.

- Based on production levels under 11.0 mgd, the current four reservoir system operational plan is adequate. These include the Horseshoe Curve, Bellwood, Plane Nine and Tipton Systems. The Mill Run plant could be run concurrently since it is a functional component of the Horseshoe Curve service area.

- From 11.0 to 13.5 mgd, Mill Run Reservoir will need to operate. At 13.5 mgd, Kettle Reservoir system comes on line while at 14.25 mgd, all reservoir systems are operational with the addition of Homer Gap reservoir.

- If production continues to decline to 8 mgd, further economies could be realized by operating Horseshoe Curve, Bellwood or Tipton and Plane Nine and taking Tipton or Bellwood Reservoir temporarily off-line.

- The Plane Nine Reservoir system should be operated as a true multiple reservoir system to maximize watershed yield. Both upstream reservoirs (Muleshoe and Blair Gap) should remain full at all times with Plane Nine Reservoir operated as the primary raw water source to the plant. When Plane Nine Reservoir is drawdown 13 feet (El. 1395 msl), Muleshoe and Blair Gap should be drawdown to supplement Plane Nine. The release from Muleshoe Reservoir is limited to 2.0 mgd.

- When Mill Run Reservoir is drawn down 43-feet, Allegheny Reservoir should be pumped back to Mill Run at a rate of 2.0 cfs, which is the maximum capacity of the pump station.

- Loup Run intake should continue to supplement Tipton Reservoir at all flows up to the Loup Run conservation release.

- As an integral component of the City service gradient, Mill Run Reservoir is considered an auxiliary component of the Horseshoe Curve Reservoir system. The operation (or non operation) of the Mill Run plant is purely an economic consideration based on current demand (9-11 mgd). The transfer of water from Mill Run to the Horseshoe Curve is limited to 5.0 mgd.

RECOMMENDATIONS (Continued)…

- When the Cochran-Impounding Reservoir is drawn down to 28.5 feet, Lake Altoona should be pumped back to the Cochran-Impounding Reservoir at a maximum rate of 5.0 mgd, until it reaches a level of 29 feet below spillway, then flow from Kittanning Point Reservoir can be released at a rate of 3.0 mgd.

- Reservoir water quality has taken on increased importance in system operations. The Authority has very good-to-exceptional quality sources. Despite increased regulation, the Authority treatment plants operate at a high level of efficiency and meet all regulatory guidelines. Accordingly, reservoir management and cost effectiveness must be taken into account.

- Generally, the highest yielding reservoirs also have the best water quality. The best quality reservoir systems are (in descending order): Tipton, Horseshoe Curve, Mill Run, Plane Nine, Bellwood, Kettle and Homer Gap.

- Tipton Reservoir can fully supplement or replace Bellwood Reservoir during periods of unstable water quality. This will result in lower operating costs for chemical consumption and waste solids production.

- Reservoir water quality will decline during severe droughts. Operating personnel will need to closely monitor raw water quality and make necessary process adjustments to maintain quality.

- For normal operating conditions, individual treatment plants should be operated at sustainable treatment rates to ensure 50% reserve capacity for peak demand conditions.

- Continue to operate the reservoir system as a fully integrated whole with individual reservoirs in deficit supplemented with those reservoirs in surplus by distribution systems transfers (pump stations, tanks).

- Retain all reservoirs and treatment plants for use as supplemental supplies in the event of scheduled maintenance, severe drought shortages, increased demand and emergencies (dam safety, water quality, hydraulic failure, fire safety, system outages, etc.).

- Submit the Reservoir Operation and Management Plan to PADEP along with the revised drought contingency plan for final review and approval.

- Responses and protocols for non-drought emergencies (reservoir contamination, dam safety problems, treatment plant outages) are addressed by previous emergency response planning. Generally, the loss of an individual reservoir has a negligible effect. However, if the Horseshoe Curve reservoirs were removed from service, safe yield would be reduced to 7.72 mgd. Additional studies, beyond the scope of this study, are necessary to define drought measures and hydraulic restrictions for this condition.

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APPENDIX A

USGS GAGING STATION DATA
(01557500 BALD EAGLE CREEK AT TYRONE, PA)

01557500 BALD EAGLE CREEK AT TYRONE, PA

Lower Susquehanna Basin
Upper Juniata Subbasin

LOCATION.--Lat 40°41'01", long 78°14'02" referenced to North American Datum of 1927, Blair County, PA, Hydrologic Unit 02050302, on left bank 0.2 mi upstream from highway bridge on SR 220 at Tyrone, 0.2 mi upstream from Laurel Run, and 1.3 mi upstream from mouth.

DRAINAGE AREA.--44.1 mi^2.

SURFACE-WATER RECORDS

PERIOD OF RECORD.--October 1944 to current year. Prior to October 1967, published as South Bald Eagle Creek at Tyrone.

REVISED RECORDS.--WSP 1903: 1954(M). WDR PA-75-2: 1974.

GAGE.--Water-stage recorder. Datum of gage is 921.80 ft above National Geodetic Vertical Datum of 1929. Oct 1, 1944, to Nov 15, 1950, water-stage recorder, and Nov 16, 1950, to Nov 30, 1952, nonrecording gage at site 0.5 mi downstream at datum 17.99 ft lower. Satellite telemetry at station.

COOPERATION.--Station established and maintained by the U.S. Geological Survey in cooperation with the Pennsylvania Department of Environmental Protection.

REMARKS.--Records fair except those for estimated daily discharges, which are poor. Prior to Nov 30, 1952, daily discharges were affected by West Virginia Pulp and Paper Company diversion. Several measurements of water temperature were made during the year.

EXTREMES OUTSIDE PERIOD OF RECORD.--Maximum stage known, about 15 ft, Mar 17 or 18, 1936, site and datum in use prior to Dec 1, 1952.

EXTREMES FOR CURRENT YEAR.--Peak discharges greater than base discharge of 940 ft^3/s and (or) maximum (*):

Date	Time	Discharge (ft^3/s)	Gage height (ft)
Jun 20	1045	*680	*2.70
No peaks above base discharge			

Minimum discharge, 5.1 ft^3/s, Oct. 20, 21, gage height, 0.20 ft.

01557500 BALD EAGLE CREEK AT TYRONE, PA—Continued

DISCHARGE, CUBIC FEET PER SECOND
WATER YEAR OCTOBER 2008 TO SEPTEMBER 2009
DAILY MEAN VALUES
[e, estimated]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	9.2	12	32	126	e58	94	68	64	28	48	50	9.5
2	8.5	12	29	108	e68	90	71	65	27	46	34	9.0
3	8.0	11	23	94	e62	e83	178	60	28	43	29	8.9
4	8.0	11	22	77	e58	e78	230	89	30	39	26	8.7
5	7.7	11	22	73	54	e71	183	91	28	33	24	8.5
6	7.2	12	e20	67	77	70	160	110	28	31	22	8.2
7	6.7	12	19	72	93	72	135	326	24	29	20	8.4
8	6.6	12	e17	75	e370	97	115	222	22	26	19	8.6
9	7.0	12	e16	59	e300	196	98	180	21	25	19	8.6
10	7.0	12	47	53	141	147	88	144	19	23	18	8.3
11	6.3	12	89	50	184	141	83	122	19	25	18	8.3
12	6.1	12	195	46	428	128	71	104	30	28	18	9.6
13	6.0	16	109	e42	310	112	66	92	21	21	17	9.2
14	5.9	22	83	e38	223	102	67	88	18	19	14	8.2
15	5.8	36	75	e35	174	95	103	80	17	18	13	e7.6
16	5.6	36	77	e30	143	89	89	71	16	18	12	e7.5
17	5.6	23	97	e34	120	86	75	69	39	18	12	e7.8
18	5.4	19	111	e42	109	77	73	60	83	23	12	e7.6
19	5.4	18	297	e39	118	71	71	55	44	18	12	e7.4
20	5.2	17	295	e37	98	66	94	50	348	17	12	e7.3
21	5.6	17	175	e35	e83	62	120	46	302	15	12	e7.1
22	5.9	17	137	e34	76	59	106	43	192	15	11	e7.3
23	5.9	17	147	e37	69	54	104	41	139	20	11	e7.5
24	5.9	20	217	e42	e61	50	97	39	107	25	10	e7.2
25	28	20	378	e38	e59	48	91	37	88	17	9.9	e7.0
26	25	18	200	e36	65	67	83	36	76	17	9.6	e8.5
27	15	18	190	e38	84	83	77	37	68	15	9.6	e42
28	12	19	192	e44	102	67	72	36	60	12	12	e22
29	12	18	208	e52	---	68	69	64	55	13	19	e13
30	13	19	190	e46	---	69	65	37	51	16	12	e10
31	12	---	160	e42	---	63	---	31	---	61	10	---
Total	273.5	511	3,869	1,641	3,787	2,655	3,002	2,589	2,028	774	527.1	298.8
Mean	8.82	17.0	125	52.9	135	85.6	100	83.5	67.6	25.0	17.0	9.96
Max	28	36	378	126	428	196	230	326	348	61	50	42
Min	5.2	11	16	30	54	48	65	31	16	12	9.6	7.0
Cfsm	0.20	0.39	2.83	1.20	3.07	1.94	2.27	1.89	1.53	0.57	0.39	0.23
In.	0.23	0.43	3.26	1.38	3.19	2.24	2.53	2.18	1.71	0.65	0.44	0.25

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1945 - 2009, BY WATER YEAR (WY)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean	33.5	58.0	77.5	84.0	102	165	142	105	61.7	30.9	22.2	29.8
Max	178	216	217	226	251	364	399	304	377	138	140	289
(WY)	(1991)	(1951)	(1973)	(1952)	(1981)	(1945)	(1993)	(1978)	(1972)	(1956)	(2003)	(2004)
Min	4.10	5.95	6.43	10.9	15.9	48.1	34.0	23.8	11.9	5.41	4.15	3.59
(WY)	(1964)	(1954)	(1966)	(1981)	(1963)	(1990)	(1946)	(1976)	(1999)	(1965)	(1966)	(1965)

01557500 BALD EAGLE CREEK AT TYRONE, PA—Continued

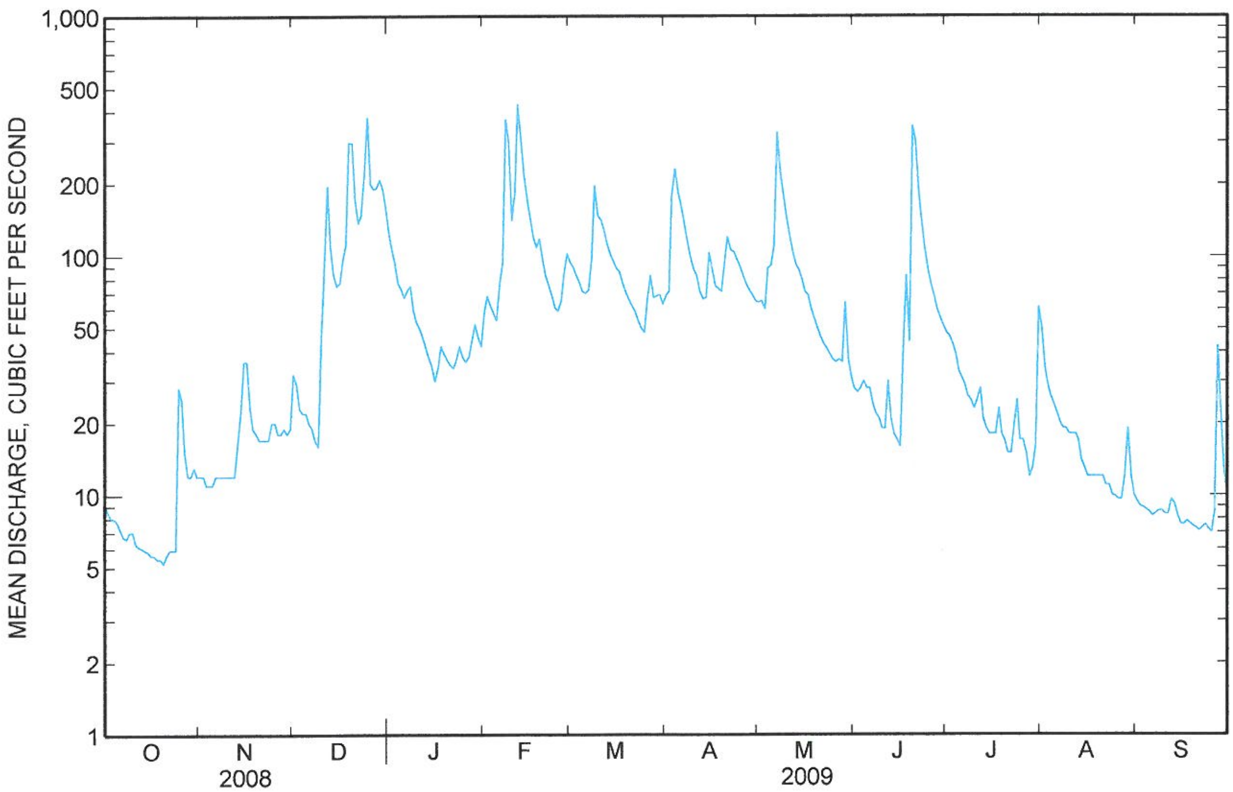
SUMMARY STATISTICS

	Calendar Year 2008		Water Year 2009		Water Years 1945 - 2009	
Annual total	26,996.2		21,955.4			
Annual mean	73.8		60.2		75.8	
Highest annual mean					133	1951
Lowest annual mean					42.8	1999
Highest daily mean	954	Mar 5	428	Feb 12	2,800	Jun 23, 1972
Lowest daily mean	5.2	Oct 20	5.2	Oct 20	1.4	Sep 13, 1973
Annual seven-day minimum	5.5	Oct 15	5.5	Oct 15	1.7	Sep 7, 1973
Maximum peak flow			680	Jun 20	[a]5,140	Nov 25, 1950
Maximum peak stage			2.70	Jun 20	[b]7.50	Nov 25, 1950
Instantaneous low flow			5.1	Oct 20[c]	1.4	Sep 12, 1973
Annual runoff (cfsm)	1.67		1.36		1.72	
Annual runoff (inches)	22.77		18.52		23.34	
10 percent exceeds	185		140		173	
50 percent exceeds	32		37		41	
90 percent exceeds	7.6		8.3		7.5	

[a] From rating curve extended above 2,100 ft^3/s on basis of contracted-opening measurement of peak flow.

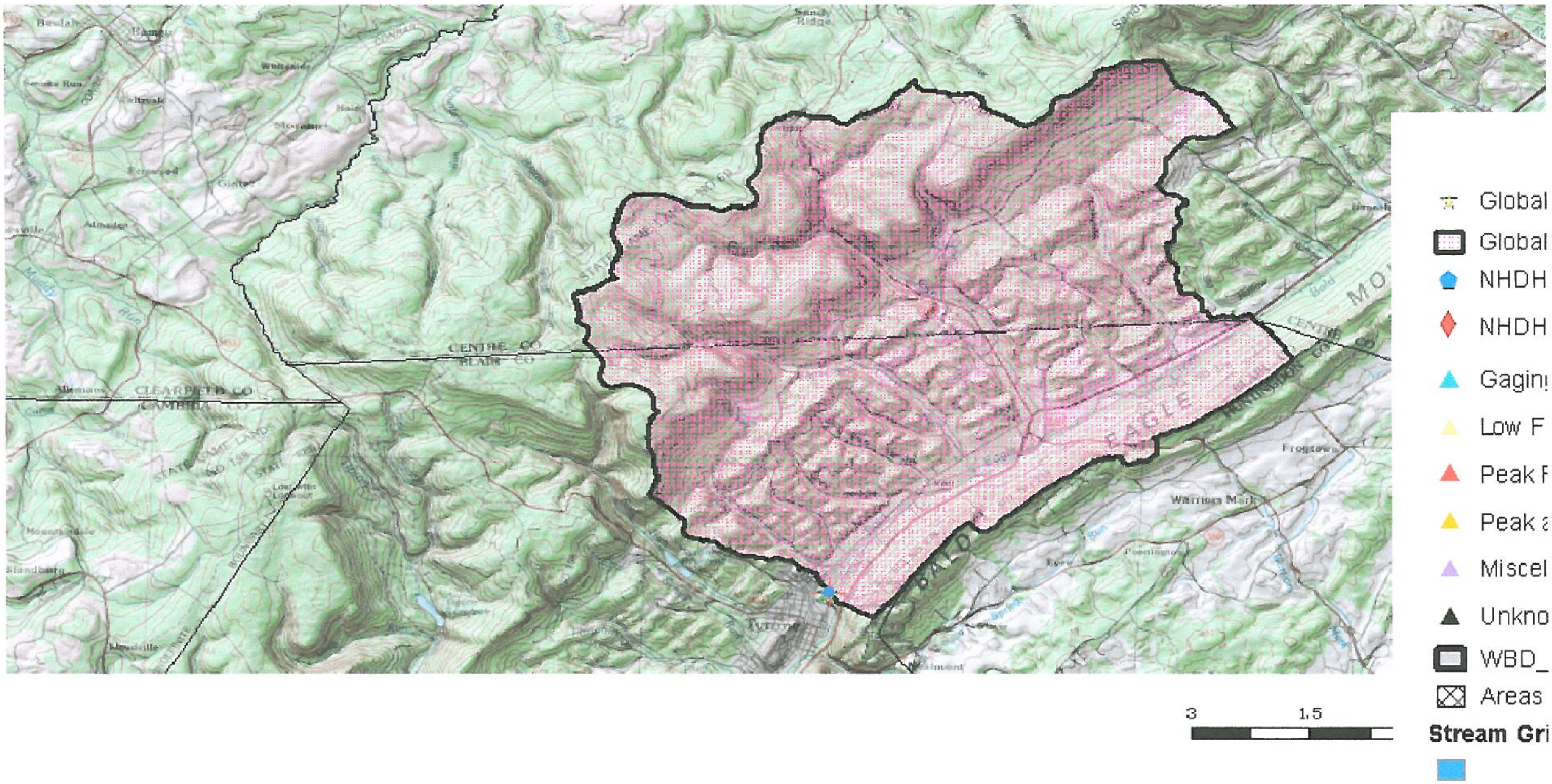
[b] From floodmark, site and datum then in use.

[c] Also Oct 21.



USGS
Pennsylvania StreamStats

StreamStats Print Page



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Appendix B

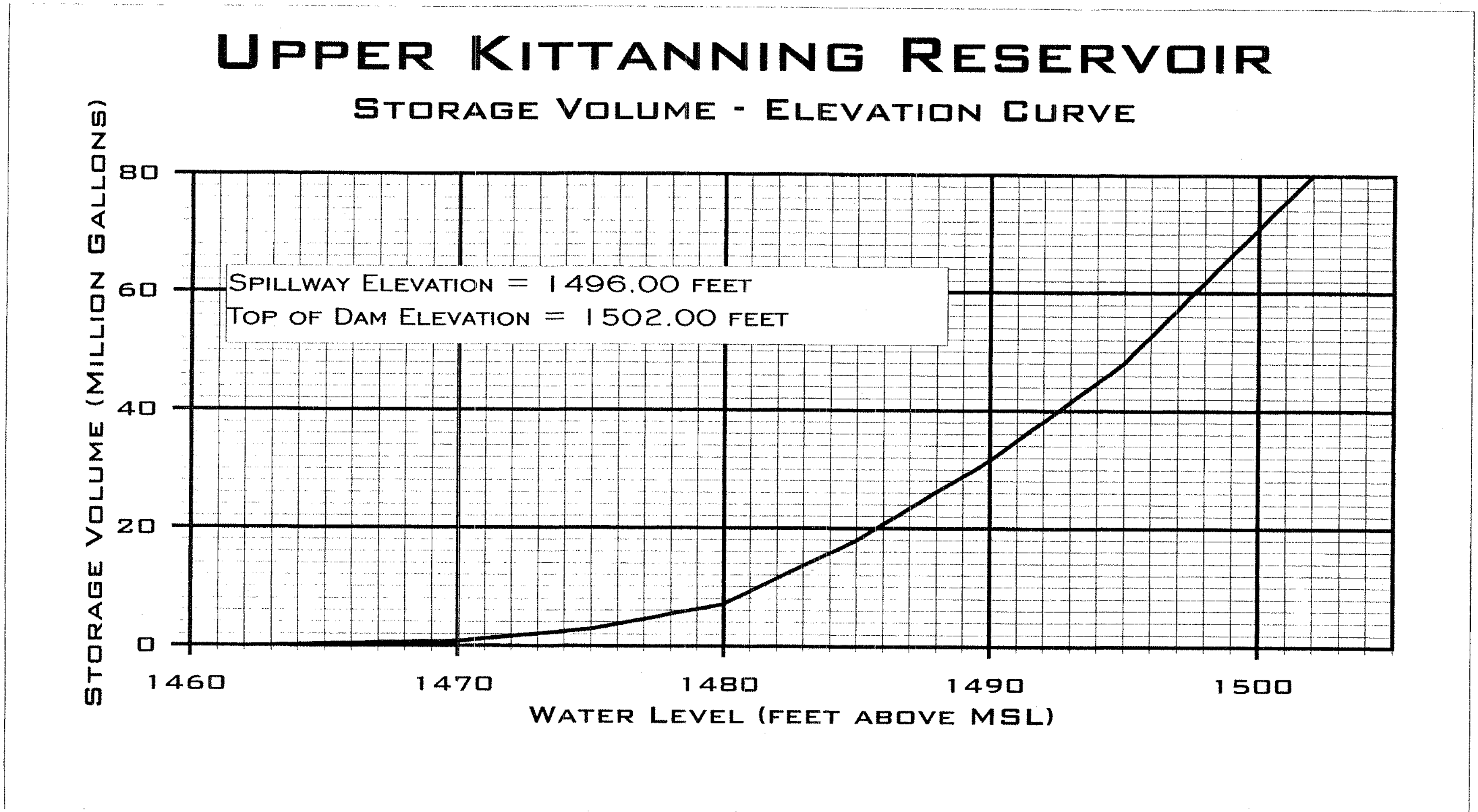
Reservoir Storage - Elevation Curves and Rating Tables

Upper Kittanning Reservoir

Storage - Elevation Table

Spillway Elevation: 1496.00 feet
Crest Elevation: 1502.00 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1463.00	-33.00	0.00	1476.50	-19.50	4.06	1490.00	-6.00	31.50
1463.50	-32.50	0.08	1477.00	-19.00	4.48	1490.50	-5.50	33.15
1464.00	-32.00	0.15	1477.50	-18.50	4.90	1491.00	-5.00	34.80
1464.50	-31.50	0.23	1478.00	-18.00	5.32	1491.50	-4.50	36.45
1465.00	-31.00	0.30	1478.50	-17.50	5.74	1492.00	-4.00	38.10
1465.50	-30.50	0.35	1479.00	-17.00	6.16	1492.50	-3.50	39.75
1466.00	-30.00	0.40	1479.50	-16.50	6.58	1493.00	-3.00	41.40
1466.50	-29.50	0.45	1480.00	-16.00	7.00	1493.50	-2.50	43.05
1467.00	-29.00	0.50	1480.50	-15.50	8.09	1494.00	-2.00	44.70
1467.50	-28.50	0.55	1481.00	-15.00	9.18	1494.50	-1.50	46.35
1468.00	-28.00	0.60	1481.50	-14.50	10.27	1495.00	-1.00	48.00
1468.50	-27.50	0.65	1482.00	-14.00	11.36	1495.50	-0.50	50.29
1469.00	-27.00	0.70	1482.50	-13.50	12.45	1496.00	0.00	52.57
1469.50	-26.50	0.75	1483.00	-13.00	13.54	1496.50	0.50	54.86
1470.00	-26.00	0.80	1483.50	-12.50	14.63	1497.00	1.00	57.14
1470.50	-25.50	1.00	1484.00	-12.00	15.72	1497.50	1.50	59.43
1471.00	-25.00	1.20	1484.50	-11.50	16.81	1498.00	2.00	61.71
1471.50	-24.50	1.40	1485.00	-11.00	17.90	1498.50	2.50	64.00
1472.00	-24.00	1.60	1485.50	-10.50	19.26	1499.00	3.00	66.29
1472.50	-23.50	1.80	1486.00	-10.00	20.62	1499.50	3.50	68.57
1473.00	-23.00	2.00	1486.50	-9.50	21.98	1500.00	4.00	70.86
1473.50	-22.50	2.20	1487.00	-9.00	23.34	1500.50	4.50	73.14
1474.00	-22.00	2.40	1487.50	-8.50	24.70	1501.00	5.00	75.43
1474.50	-21.50	2.60	1488.00	-8.00	26.06	1501.50	5.50	77.71
1475.00	-21.00	2.80	1488.50	-7.50	27.42	1502.00	6.00	80.00
1475.50	-20.50	3.22	1489.00	-7.00	28.78			
1476.00	-20.00	3.64	1489.50	-6.50	30.14			

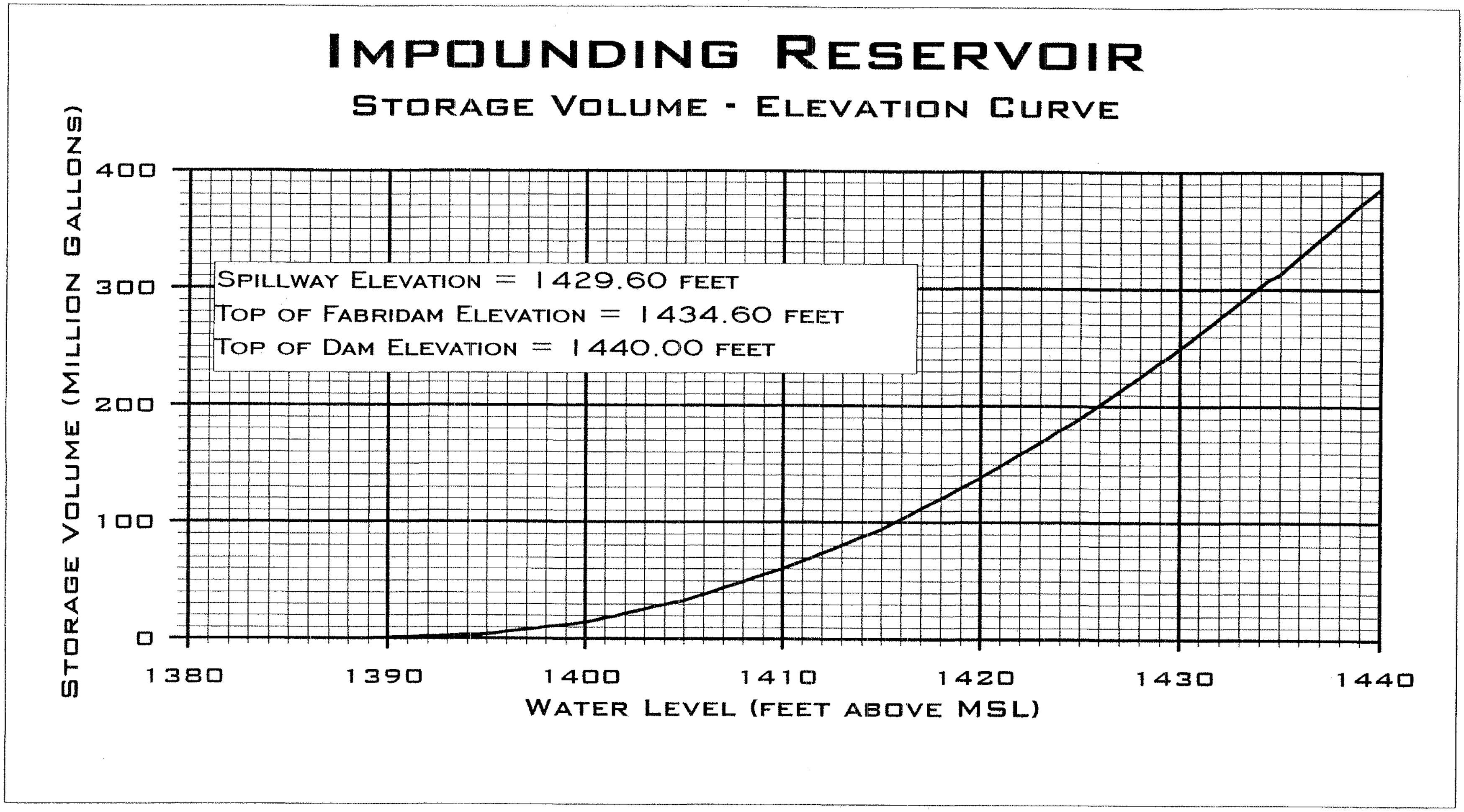


Upper Kittanning Reservoir
Storage Volume - Elevation Curve
Spillway Elevation = 1496.00 feet
Top of Dam Elevation = 1502.00 feet
Storage Volume (Million Gallons)
80
60
40
20
0
1460
1470
1480
1490
1500
Water Level (feet above MSL)

IMPOUNDING RESERVOIR
STORAGE - ELEVATION TABLE

Spillway Elevation: 1429.60 feet
Fabridam Top: 1434.60 feet
Crest Elevation: 1440.00 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1388.00	-41.60	0.00	1406.00	-23.60	38.40	1424.00	-5.60	178.80
1388.50	-41.10	0.13	1406.50	-23.10	41.10	1424.50	-5.10	183.90
1389.00	-40.60	0.25	1407.00	-22.60	43.80	1425.00	-4.60	189.00
1389.50	-40.10	0.38	1407.50	-22.10	46.50	1425.50	-4.10	195.00
1390.00	-39.60	0.50	1408.00	-21.60	49.20	1426.00	-3.60	201.00
1390.50	-39.10	0.85	1408.50	-21.10	51.90	1426.50	-3.10	207.00
1391.00	-38.60	1.20	1409.00	-20.60	54.60	1427.00	-2.60	213.00
1391.50	-38.10	1.55	1409.50	-20.10	57.30	1427.50	-2.10	219.00
1392.00	-37.60	1.90	1410.00	-19.60	60.00	1428.00	-1.60	225.00
1392.50	-37.10	2.25	1410.50	-19.10	63.40	1428.50	-1.10	231.00
1393.00	-36.60	2.60	1411.00	-18.60	66.80	1429.00	-0.60	237.00
1393.50	-36.10	2.95	1411.50	-18.10	70.20	1429.50	-0.10	243.00
1394.00	-35.60	3.30	1412.00	-17.60	73.60	1429.60	0.00	244.20
1394.50	-35.10	3.65	1412.50	-17.10	77.00	1430.00	0.40	249.00
1395.00	-34.60	4.00	1413.00	-16.60	80.40	1430.50	0.90	255.64
1395.50	-34.10	5.00	1413.50	-16.10	83.80	1431.00	1.40	262.29
1396.00	-33.60	6.00	1414.00	-15.60	87.20	1431.50	1.90	268.93
1396.50	-33.10	7.00	1414.50	-15.10	90.60	1432.00	2.40	275.58
1397.00	-32.60	8.00	1415.00	-14.60	94.00	1432.50	2.90	282.22
1397.50	-32.10	9.00	1415.50	-14.10	98.40	1433.00	3.40	288.87
1398.00	-31.60	10.00	1416.00	-13.60	102.80	1433.50	3.90	295.51
1398.50	-31.10	11.00	1416.50	-13.10	107.20	1434.00	4.40	302.16
1399.00	-30.60	12.00	1417.00	-12.60	111.60	1434.50	4.90	308.80
1399.50	-30.10	13.00	1417.50	-12.10	116.00	1434.60	5.00	309.00
1400.00	-29.60	14.00	1418.00	-11.60	120.40	1435.00	5.40	313.00
1400.50	-29.10	15.90	1418.50	-11.10	124.80	1435.50	5.90	320.30
1401.00	-28.60	17.80	1419.00	-10.60	129.20	1436.00	6.40	327.60
1401.50	-28.10	19.70	1419.50	-10.10	133.60	1436.50	6.90	334.90
1402.00	-27.60	21.60	1420.00	-9.60	138.00	1437.00	7.40	342.20
1402.50	-27.10	23.50	1420.50	-9.10	143.10	1437.50	7.90	349.50
1403.00	-26.60	25.40	1421.00	-8.60	148.20	1438.00	8.40	356.80
1403.50	-26.10	27.30	1421.50	-8.10	153.30	1438.50	8.90	364.10
1404.00	-25.60	29.20	1422.00	-7.60	158.40	1439.00	9.40	371.40
1404.50	-25.10	31.10	1422.50	-7.10	163.50	1439.50	9.90	378.70
1405.00	-24.60	33.00	1423.00	-6.60	168.60	1440.00	10.40	386.00
1405.50	-24.10	35.70	1423.50	-6.10	173.70			

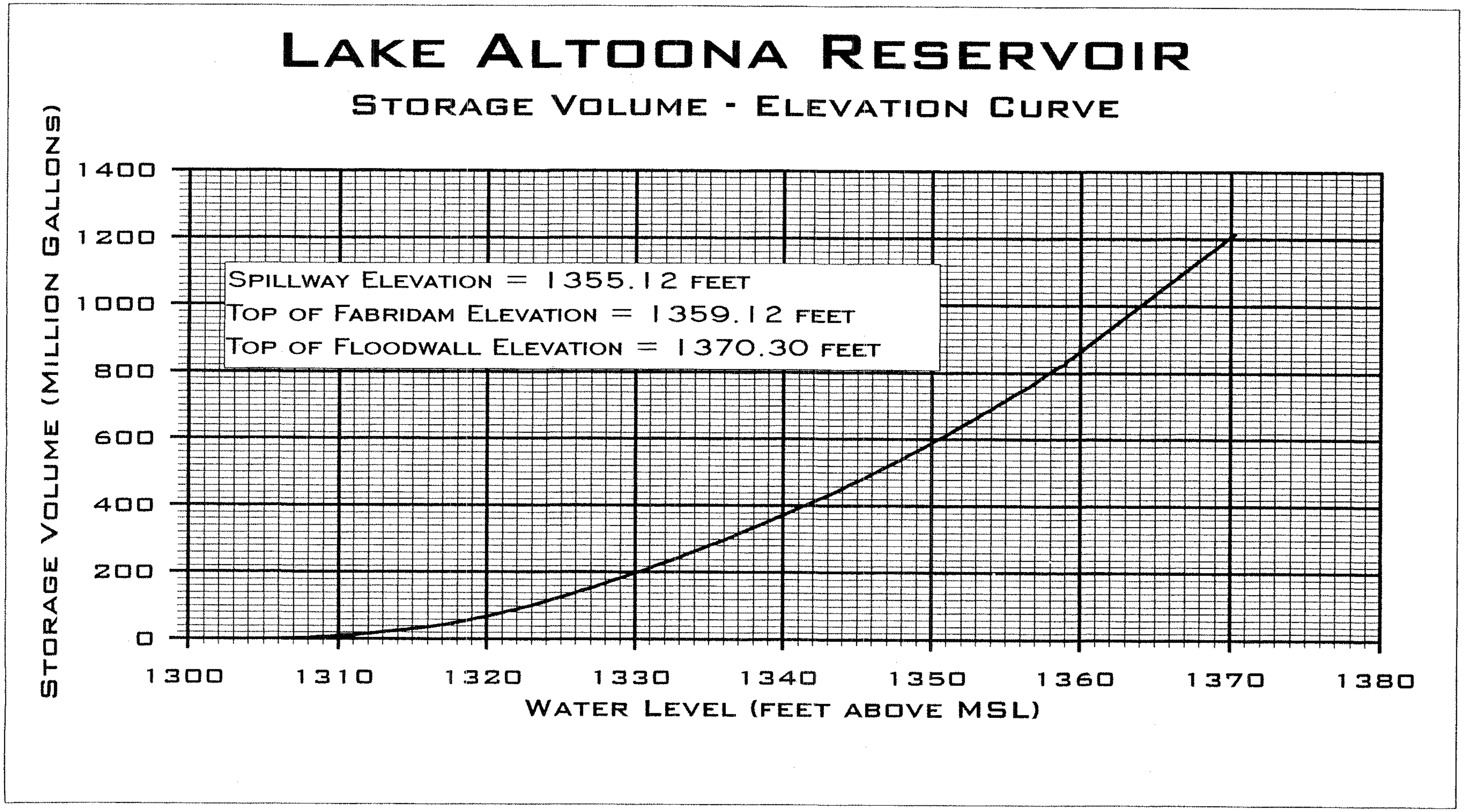

IMPOUNDING RESERVOIR
STORAGE VOLUME - ELEVATION CURVE
SPILLWAY ELEVATION = 1429.60 FEET
TOP OF FABRIDAM ELEVATION = 1434.60 FEET
TOP OF DAM ELEVATION = 1440.00 FEET
STORAGE VOLUME (MILLION GALLONS)
400
300
200
100
0
1380
1390
1400
1410
1420
1430
1440
WATER LEVEL (FEET ABOVE MSL)

Lake Altoona Reservoir

Storage - Elevation Table

Spillway Elevation:	1355.12	feet
Fabridam Top:	1359.12	feet
Crest Elevation:	1370.30	feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1305.00	-50.12	0.00		1324.00	-31.12	112.79		1343.00	-12.12	430.99
1305.50	-49.62	0.29		1324.50	-30.62	119.14		1343.50	-11.62	441.44
1306.00	-49.12	0.57		1325.00	-30.12	125.48		1344.00	-11.12	451.89
1306.50	-48.62	1.33		1325.50	-29.62	132.14		1344.50	-10.62	462.58
1307.00	-48.12	2.09		1326.00	-29.12	138.79		1345.00	-10.12	473.27
1307.50	-47.62	3.14		1326.50	-28.62	145.75		1345.50	-9.62	484.22
1308.00	-47.12	4.19		1327.00	-28.12	152.70		1346.00	-9.12	495.17
1308.50	-46.62	5.44		1327.50	-27.62	159.92		1346.50	-8.62	506.39
1309.00	-46.12	6.69		1328.00	-27.12	167.13		1347.00	-8.12	517.61
1309.50	-45.62	8.13		1328.50	-26.62	174.56		1347.50	-7.62	529.12
1310.00	-45.12	9.57		1329.00	-26.12	181.99		1348.00	-7.12	540.62
1310.50	-44.62	11.22		1329.50	-25.62	189.63		1348.50	-6.62	552.41
1311.00	-44.12	12.86		1330.00	-25.12	197.26		1349.00	-6.12	564.19
1311.50	-43.62	14.71		1330.50	-24.62	205.10		1349.50	-5.62	576.25
1312.00	-43.12	16.56		1331.00	-24.12	212.94		1350.00	-5.12	588.31
1312.50	-42.62	18.62		1331.50	-23.62	220.96		1350.50	-4.62	600.63
1313.00	-42.12	20.67		1332.00	-23.12	228.97		1351.00	-4.12	612.94
1313.50	-41.62	22.92		1332.50	-22.62	237.18		1351.50	-3.62	625.50
1314.00	-41.12	25.17		1333.00	-22.12	245.39		1352.00	-3.12	638.06
1314.50	-40.62	27.64		1333.50	-21.62	253.81		1352.50	-2.62	650.87
1315.00	-40.12	30.11		1334.00	-21.12	262.23		1353.00	-2.12	663.68
1315.50	-39.62	32.93		1334.50	-20.62	270.84		1353.50	-1.62	676.76
1316.00	-39.12	35.74		1335.00	-20.12	279.45		1354.00	-1.12	689.83
1316.50	-38.62	39.07		1335.50	-19.62	288.26		1354.50	-0.62	703.19
1317.00	-38.12	42.39		1336.00	-19.12	297.06		1355.00	-0.12	716.55
1317.50	-37.62	46.27		1336.50	-18.62	306.04		1355.12	0.00	719.36
1318.00	-37.12	50.14		1337.00	-18.12	315.02		1355.50	0.38	730.85
1318.50	-36.62	54.48		1337.50	-17.62	324.19		1356.00	0.88	743.44
1319.00	-36.12	58.81		1338.00	-17.12	333.35		1356.50	1.38	757.70
1319.50	-35.62	63.53		1338.50	-16.62	342.70		1357.00	1.88	771.95
1320.00	-35.12	68.25		1339.00	-16.12	352.05		1357.50	2.38	786.68
1320.50	-34.62	73.33		1339.50	-15.62	361.60		1358.00	2.88	801.40
1321.00	-34.12	78.41		1340.00	-15.12	371.14		1358.50	3.38	816.80
1321.50	-33.62	83.83		1340.50	-14.62	380.89		1359.00	3.88	825.10
1322.00	-33.12	89.24		1341.00	-14.12	390.64		1359.12	4.00	835.40
1322.50	-32.62	94.97		1341.50	-13.62	400.61		1359.50	4.38	845.00
1323.00	-32.12	100.70		1342.00	-13.12	410.58		1370.30	15.18	1215.00
1323.50	-31.62	106.75		1342.50	-12.62	420.79				


LAKE ALTOONA RESERVOIR
STORAGE VOLUME - ELEVATION CURVE
SPILLWAY ELEVATION = 1355.12 FEET
TOP OF FABRIDAM ELEVATION = 1359.12 FEET
TOP OF FLOODWALL ELEVATION = 1370.30 FEET
STORAGE VOLUME (MILLION GALLONS)
0
200
400
600
800
1000
1200
1400
1300
1310
1320
1330
1340
1350
1360
1370
1380
WATER LEVEL (FEET ABOVE MSL)

Mill Run Reservoir

Storage - Elevation Table

Spillway Elevation: 1502.00 feet
Fabridam Top: 1508.00 feet
Crest Elevation: 1515.00 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1425.00	-77.00	0.00	1455.50	-46.50	39.70	1486.00	-16.00	233.80
1425.50	-76.50	0.16	1456.00	-46.00	41.40	1486.50	-15.50	238.70
1426.00	-76.00	0.33	1456.50	-45.50	43.10	1487.00	-15.00	243.60
1426.50	-75.50	0.50	1457.00	-45.00	44.80	1487.50	-14.50	248.50
1427.00	-75.00	0.66	1457.50	-44.50	46.50	1488.00	-14.00	253.40
1427.50	-74.50	0.83	1458.00	-44.00	48.20	1488.50	-13.50	258.30
1428.00	-74.00	1.00	1458.50	-43.50	49.90	1489.00	-13.00	263.20
1428.50	-73.50	1.16	1459.00	-43.00	51.60	1489.50	-12.50	268.10
1429.00	-73.00	1.33	1459.50	-42.50	53.30	1490.00	-12.00	273.00
1429.50	-72.50	1.50	1460.00	-42.00	55.00	1490.50	-11.50	278.70
1430.00	-72.00	1.66	1460.50	-41.50	57.50	1491.00	-11.00	284.40
1430.50	-71.50	1.83	1461.00	-41.00	60.00	1491.50	-10.50	290.10
1431.00	-71.00	2.00	1461.50	-40.50	62.50	1492.00	-10.00	295.80
1431.50	-70.50	2.16	1462.00	-40.00	65.00	1492.50	-9.50	301.50
1432.00	-70.00	2.33	1462.50	-39.50	67.50	1493.00	-9.00	307.20
1432.50	-69.50	2.50	1463.00	-39.00	70.00	1493.50	-8.50	312.90
1433.00	-69.00	2.66	1463.50	-38.50	72.50	1494.00	-8.00	318.60
1433.50	-68.50	2.83	1464.00	-38.00	75.00	1494.50	-7.50	324.30
1434.00	-68.00	3.00	1464.50	-37.50	77.50	1495.00	-7.00	330.00
1434.50	-67.50	3.16	1465.00	-37.00	80.00	1495.50	-6.50	336.50
1435.00	-67.00	3.33	1465.50	-36.50	82.50	1496.00	-6.00	343.00
1435.50	-66.50	3.50	1466.00	-36.00	85.00	1496.50	-5.50	349.50
1436.00	-66.00	3.66	1466.50	-35.50	87.50	1497.00	-5.00	356.00
1436.50	-65.50	3.83	1467.00	-35.00	90.00	1497.50	-4.50	362.50
1437.00	-65.00	4.00	1467.50	-34.50	92.50	1498.00	-4.00	369.00
1437.50	-64.50	4.16	1468.00	-34.00	95.00	1498.50	-3.50	375.50
1438.00	-64.00	4.33	1468.50	-33.50	97.50	1499.00	-3.00	382.00
1438.50	-63.50	4.50	1469.00	-33.00	100.00	1499.50	-2.50	388.50
1439.00	-63.00	4.66	1469.50	-32.50	102.50	1500.00	-2.00	395.00
1439.50	-62.50	4.83	1470.00	-32.00	105.00	1500.50	-1.50	402.65
1440.00	-62.00	5.00	1470.50	-31.50	108.40	1501.00	-1.00	410.30
1440.50	-61.50	5.50	1471.00	-31.00	111.80	1501.50	-0.50	417.95
1441.00	-61.00	6.00	1471.50	-30.50	115.20	1502.00	0.00	425.60
1441.50	-60.50	6.50	1472.00	-30.00	118.60	1502.50	0.50	433.00
1442.00	-60.00	7.00	1472.50	-29.50	122.00	1503.00	1.00	440.40
1442.50	-59.50	7.50	1473.00	-29.00	125.40	1503.50	1.50	447.80
1443.00	-59.00	8.00	1473.50	-28.50	128.80	1504.00	2.00	455.20
1443.50	-58.50	8.50	1474.00	-28.00	132.20	1504.50	2.50	462.60

Mill Run Reservoir

Storage - Elevation Table

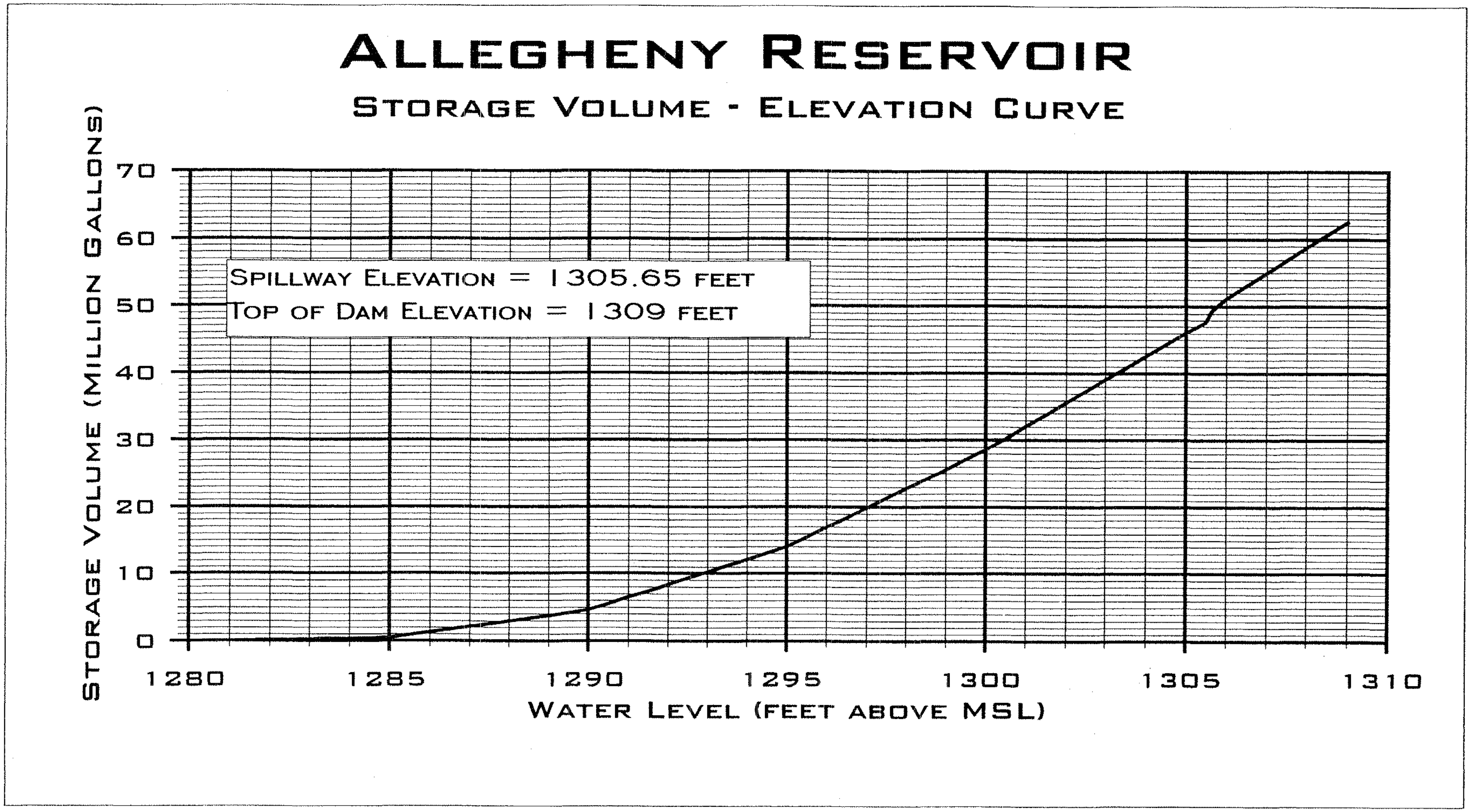
Spillway Elevation: 1502.00 feet
Fabridam Top: 1508.00 feet
Crest Elevation: 1515.00 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1444.00	-58.00	9.00		1474.50	-27.50	135.60		1505.00	3.00	470.00
1444.50	-57.50	9.50		1475.00	-27.00	139.00		1505.50	3.50	478.10
1445.00	-57.00	10.00		1475.50	-26.50	142.80		1506.00	4.00	486.20
1445.50	-56.50	11.25		1476.00	-26.00	146.60		1506.50	4.50	494.30
1446.00	-56.00	12.50		1476.50	-25.50	150.40		1507.00	5.00	502.40
1446.50	-55.50	13.75		1477.00	-25.00	154.20		1507.50	5.50	510.50
1447.00	-55.00	15.00		1477.50	-24.50	158.00		1508.00	6.00	518.60
1447.50	-54.50	16.25		1478.00	-24.00	161.80		1508.50	6.50	526.70
1448.00	-54.00	17.50		1478.50	-23.50	165.60		1509.00	7.00	534.80
1448.50	-53.50	18.75		1479.00	-23.00	169.40		1509.50	7.50	542.90
1449.00	-53.00	20.00		1479.50	-22.50	173.20		1510.00	8.00	551.00
1449.50	-52.50	21.25		1480.00	-22.00	177.00		1510.50	8.50	559.90
1450.00	-52.00	22.50		1480.50	-21.50	181.70		1511.00	9.00	568.80
1450.50	-51.50	24.05		1481.00	-21.00	186.40		1511.50	9.50	577.70
1451.00	-51.00	25.60		1481.50	-20.50	191.10		1512.00	10.00	586.60
1451.50	-50.50	27.15		1482.00	-20.00	195.80		1512.50	10.50	595.50
1452.00	-50.00	28.70		1482.50	-19.50	200.50		1513.00	11.00	604.40
1452.50	-49.50	30.25		1483.00	-19.00	205.20		1513.50	11.50	613.30
1453.00	-49.00	31.80		1483.50	-18.50	209.90		1514.00	12.00	622.20
1453.50	-48.50	33.35		1484.00	-18.00	214.60		1514.50	12.50	631.10
1454.00	-48.00	34.90		1484.50	-17.50	219.30		1515.00	13.00	640.00
1454.50	-47.50	36.45		1485.00	-17.00	224.00				
1455.00	-47.00	38.00		1485.50	-16.50	228.90				

ALLEGHENY RESERVOIR
STORAGE - ELEVATION TABLE

Spillway Elevation: 1305.65 feet
Crest Elevation: 1309.00 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1281.00	-24.65	0.00		1291.00	-14.65	6.44		1301.00	-4.65	32.00
1281.00	-24.65	0.00		1291.00	-14.65	6.44		1301.00	-4.65	32.00
1281.50	-24.15	0.06		1291.50	-14.15	7.39		1301.50	-4.15	33.75
1282.00	-23.65	0.13		1292.00	-13.65	8.33		1302.00	-3.65	35.50
1282.50	-23.15	0.19		1292.50	-13.15	9.28		1302.50	-3.15	37.25
1283.00	-22.65	0.25		1293.00	-12.65	10.22		1303.00	-2.65	39.00
1283.50	-22.15	0.31		1293.50	-12.15	11.17		1303.50	-2.15	40.75
1284.00	-21.65	0.38		1294.00	-11.65	12.11		1304.00	-1.65	42.50
1284.50	-21.15	0.44		1294.50	-11.15	13.06		1304.50	-1.15	44.25
1285.00	-20.65	0.50		1295.00	-10.65	14.00		1305.00	-0.65	46.00
1285.50	-20.15	0.91		1295.50	-10.15	15.45		1305.50	-0.15	47.65
1286.00	-19.65	1.31		1296.00	-9.65	16.90		1305.65	0.00	49.30
1286.50	-19.15	1.72		1296.50	-9.15	18.35		1306.00	0.35	51.19
1287.00	-18.65	2.12		1297.00	-8.65	19.80		1306.50	0.85	53.07
1287.50	-18.15	2.53		1297.50	-8.15	21.25		1307.00	1.35	54.96
1288.00	-17.65	2.93		1298.00	-7.65	22.70		1307.50	1.85	56.84
1288.50	-17.15	3.33		1298.50	-7.15	24.15		1308.00	2.35	58.73
1289.00	-16.65	3.74		1299.00	-6.65	25.60		1308.50	2.85	60.61
1289.50	-16.15	4.15		1299.50	-6.15	27.05		1309.00	3.35	62.50
1290.00	-15.65	4.55		1300.00	-5.65	28.50				
1290.50	-15.15	5.50		1300.50	-5.15	30.25				

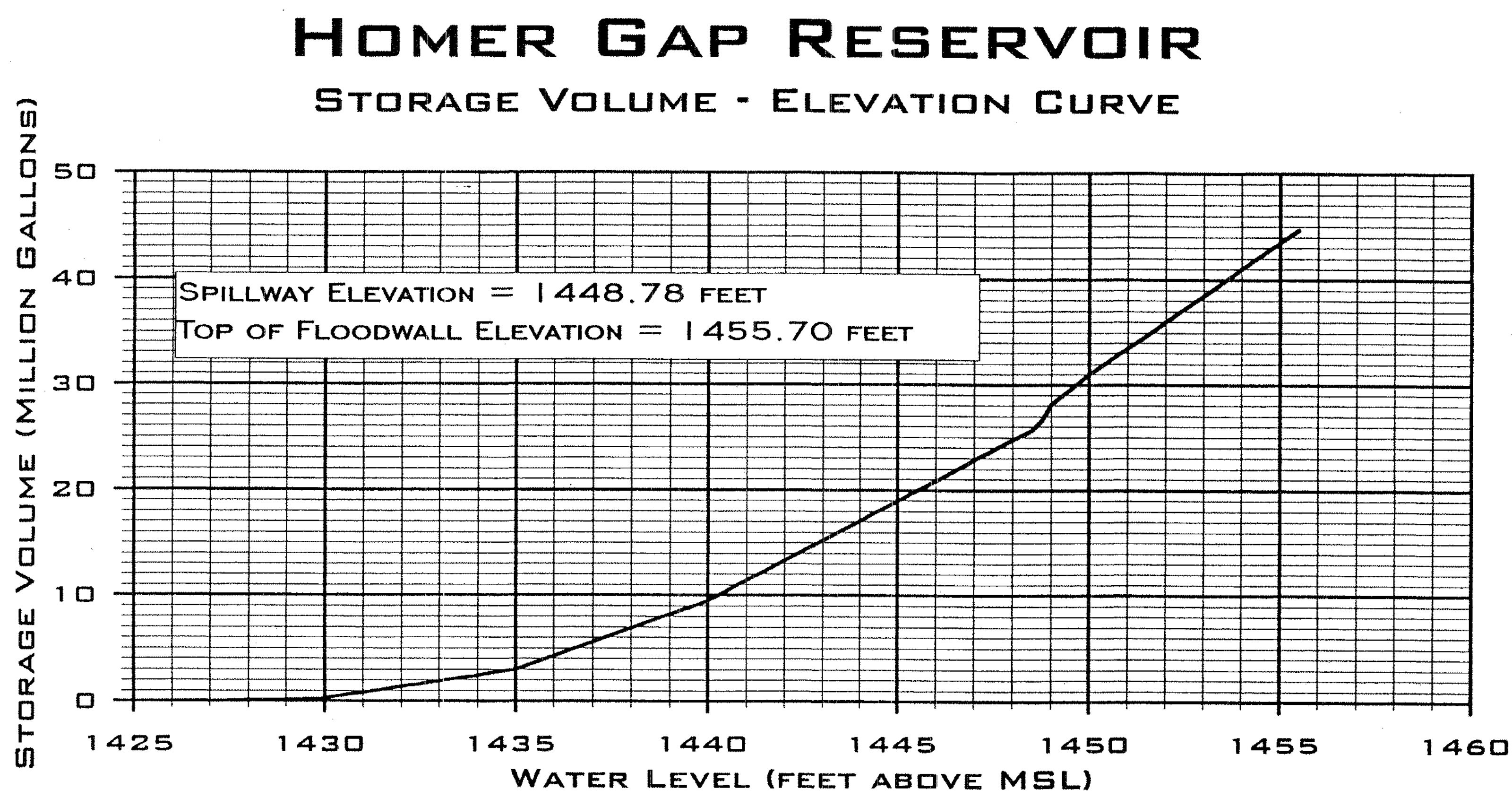

ALLEGHENY RESERVOIR
STORAGE VOLUME - ELEVATION CURVE
SPILLWAY ELEVATION = 1305.65 FEET
TOP OF DAM ELEVATION = 1309 FEET
STORAGE VOLUME (MILLION GALLONS)
0
10
20
30
40
50
60
70
1280
1285
1290
1295
1300
1305
1310
WATER LEVEL (FEET ABOVE MSL)

Homer Gap Reservoir

Storage - Elevation Table

Spillway Elevation: 1448.78 feet
Crest Elevation: 1455.70 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1427.00	-21.78	0.00	1437.00	-11.78	5.60	1447.00	-1.78	22.85
1427.00	-21.78	0.00	1437.00	-11.78	5.60	1447.00	-1.78	22.85
1427.50	-21.28	0.05	1437.50	-11.28	6.25	1447.50	-1.28	23.81
1428.00	-20.78	0.10	1438.00	-10.78	6.90	1448.00	-0.78	24.77
1428.50	-20.28	0.15	1438.50	-10.28	7.55	1448.50	-0.28	25.74
1429.00	-19.78	0.20	1439.00	-9.78	8.20	1448.78	0.00	26.70
1429.50	-19.28	0.25	1439.50	-9.28	8.85	1449.00	0.22	28.13
1430.00	-18.78	0.30	1440.00	-8.78	9.50	1449.50	0.72	29.57
1430.50	-18.28	0.57	1440.50	-8.28	10.45	1450.00	1.22	31.00
1431.00	-17.78	0.84	1441.00	-7.78	11.40	1450.50	1.72	32.25
1431.50	-17.28	1.11	1441.50	-7.28	12.35	1451.00	2.22	33.49
1432.00	-16.78	1.38	1442.00	-6.78	13.30	1451.50	2.72	34.74
1432.50	-16.28	1.65	1442.50	-6.28	14.25	1452.00	3.22	35.98
1433.00	-15.78	1.92	1443.00	-5.78	15.20	1452.50	3.72	37.23
1433.50	-15.28	2.19	1443.50	-5.28	16.15	1453.00	4.22	38.47
1434.00	-14.78	2.46	1444.00	-4.78	17.10	1453.50	4.72	39.72
1434.50	-14.28	2.73	1444.50	-4.28	18.05	1454.00	5.22	40.96
1435.00	-13.78	3.00	1445.00	-3.78	19.00	1454.50	5.72	42.21
1435.50	-13.28	3.65	1445.50	-3.28	19.96	1455.00	6.22	43.45
1436.00	-12.78	4.30	1446.00	-2.78	20.93	1455.50	6.72	44.70
1436.50	-12.28	4.95	1446.50	-2.28	21.89			

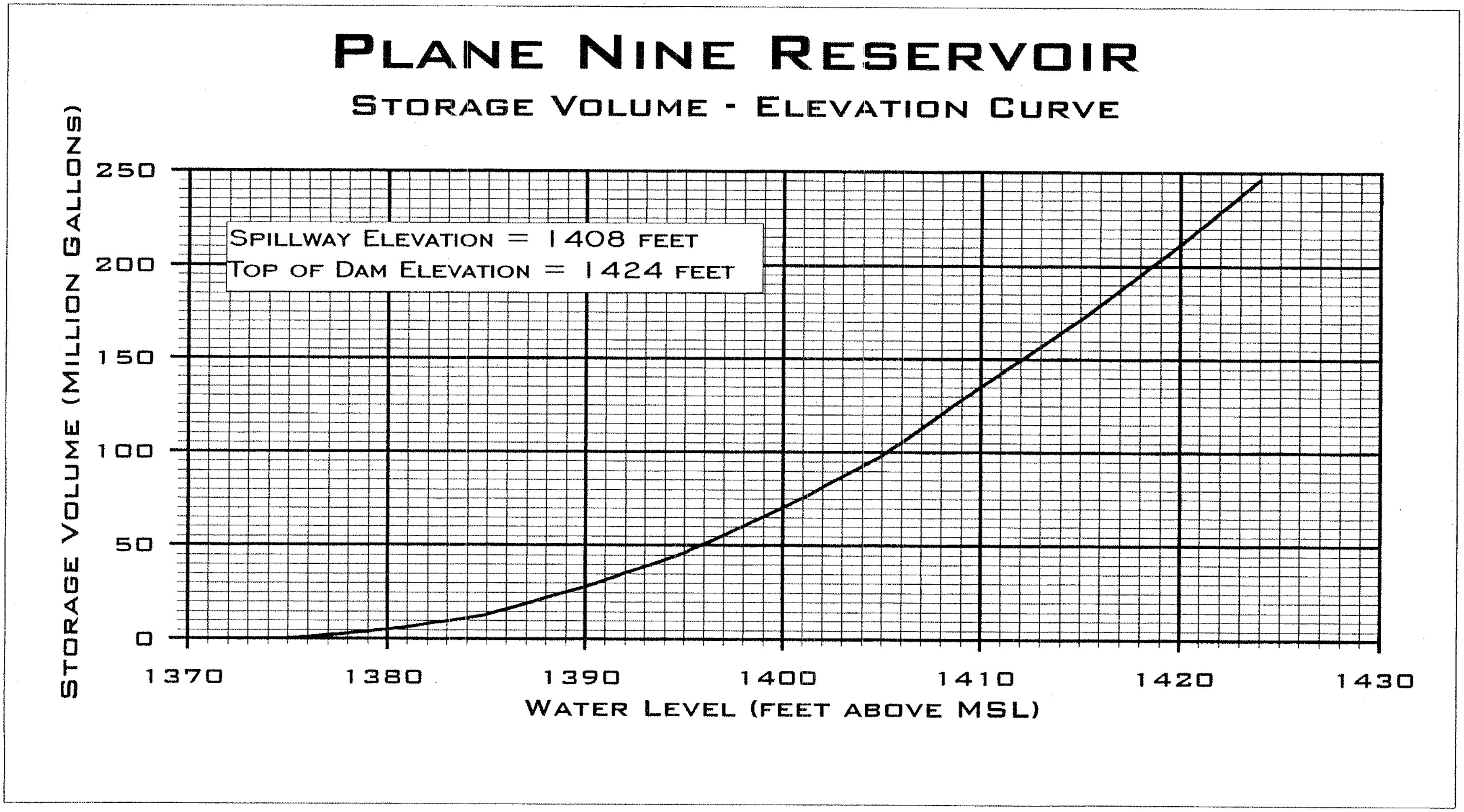

HOMER GAP RESERVOIR
STORAGE VOLUME - ELEVATION CURVE
SPILLWAY ELEVATION = 1448.78 FEET
TOP OF FLOODWALL ELEVATION = 1455.70 FEET
STORAGE VOLUME (MILLION GALLONS)
0
10
20
30
40
50
1425
1430
1435
1440
1445
1450
1455
1460
WATER LEVEL (FEET ABOVE MSL)

Plane Nine Reservoir

Storage - Elevation Table

Spillway Elevation: 1408 feet
Crest Elevation: 1424 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1375.00	-33.00	0.00	1391.50	-16.50	33.40	1408.00	0.00	120.20
1375.50	-32.50	0.50	1392.00	-16.00	35.20	1408.50	0.50	123.90
1376.00	-32.00	1.00	1392.50	-15.50	37.00	1409.00	1.00	127.60
1376.50	-31.50	1.50	1393.00	-15.00	38.80	1409.50	1.50	131.30
1377.00	-31.00	2.00	1393.50	-14.50	40.60	1410.00	2.00	135.00
1377.50	-30.50	2.50	1394.00	-14.00	42.40	1410.50	2.50	138.60
1378.00	-30.00	3.00	1394.50	-13.50	44.20	1411.00	3.00	142.20
1378.50	-29.50	3.50	1395.00	-13.00	46.00	1411.50	3.50	145.80
1379.00	-29.00	4.00	1395.50	-12.50	48.40	1412.00	4.00	149.40
1379.50	-28.50	4.50	1396.00	-12.00	50.80	1412.50	4.50	153.00
1380.00	-28.00	5.00	1396.50	-11.50	53.20	1413.00	5.00	156.60
1380.50	-27.50	5.80	1397.00	-11.00	55.60	1413.50	5.50	160.20
1381.00	-27.00	6.60	1397.50	-10.50	58.00	1414.00	6.00	163.80
1381.50	-26.50	7.40	1398.00	-10.00	60.40	1414.50	6.50	167.40
1382.00	-26.00	8.20	1398.50	-9.50	62.80	1415.00	7.00	171.00
1382.50	-25.50	9.00	1399.00	-9.00	65.20	1415.50	7.50	175.00
1383.00	-25.00	9.80	1399.50	-8.50	67.60	1416.00	8.00	179.00
1383.50	-24.50	10.60	1400.00	-8.00	70.00	1416.50	8.50	183.00
1384.00	-24.00	11.40	1400.50	-7.50	72.80	1417.00	9.00	187.00
1384.50	-23.50	12.20	1401.00	-7.00	75.60	1417.50	9.50	191.00
1385.00	-23.00	13.00	1401.50	-6.50	78.40	1418.00	10.00	195.00
1385.50	-22.50	14.50	1402.00	-6.00	81.20	1418.50	10.50	199.00
1386.00	-22.00	16.00	1402.50	-5.50	84.00	1419.00	11.00	203.00
1386.50	-21.50	17.50	1403.00	-5.00	86.80	1419.50	11.50	207.00
1387.00	-21.00	19.00	1403.50	-4.50	89.60	1420.00	12.00	211.00
1387.50	-20.50	20.50	1404.00	-4.00	92.40	1420.50	12.50	215.38
1388.00	-20.00	22.00	1404.50	-3.50	95.20	1421.00	13.00	219.75
1388.50	-19.50	23.50	1405.00	-3.00	98.00	1421.50	13.50	224.13
1389.00	-19.00	25.00	1405.50	-2.50	101.70	1422.00	14.00	228.50
1389.50	-18.50	26.50	1406.00	-2.00	105.40	1422.50	14.50	232.88
1390.00	-18.00	28.00	1406.50	-1.50	109.10	1423.00	15.00	237.25
1390.50	-17.50	29.80	1407.00	-1.00	112.80	1423.50	15.50	241.63
1391.00	-17.00	31.60	1407.50	-0.50	116.50	1424.00	16.00	246.00



PLANE NINE RESERVOIR
STORAGE VOLUME - ELEVATION CURVE
SPILLWAY ELEVATION = 1408 FEET
TOP OF DAM ELEVATION = 1424 FEET
STORAGE VOLUME (MILLION GALLONS)
250
200
150
100
50
0
1370
1380
1390
1400
1410
1420
1430
WATER LEVEL (FEET ABOVE MSL)

Muleshoe Reservoir

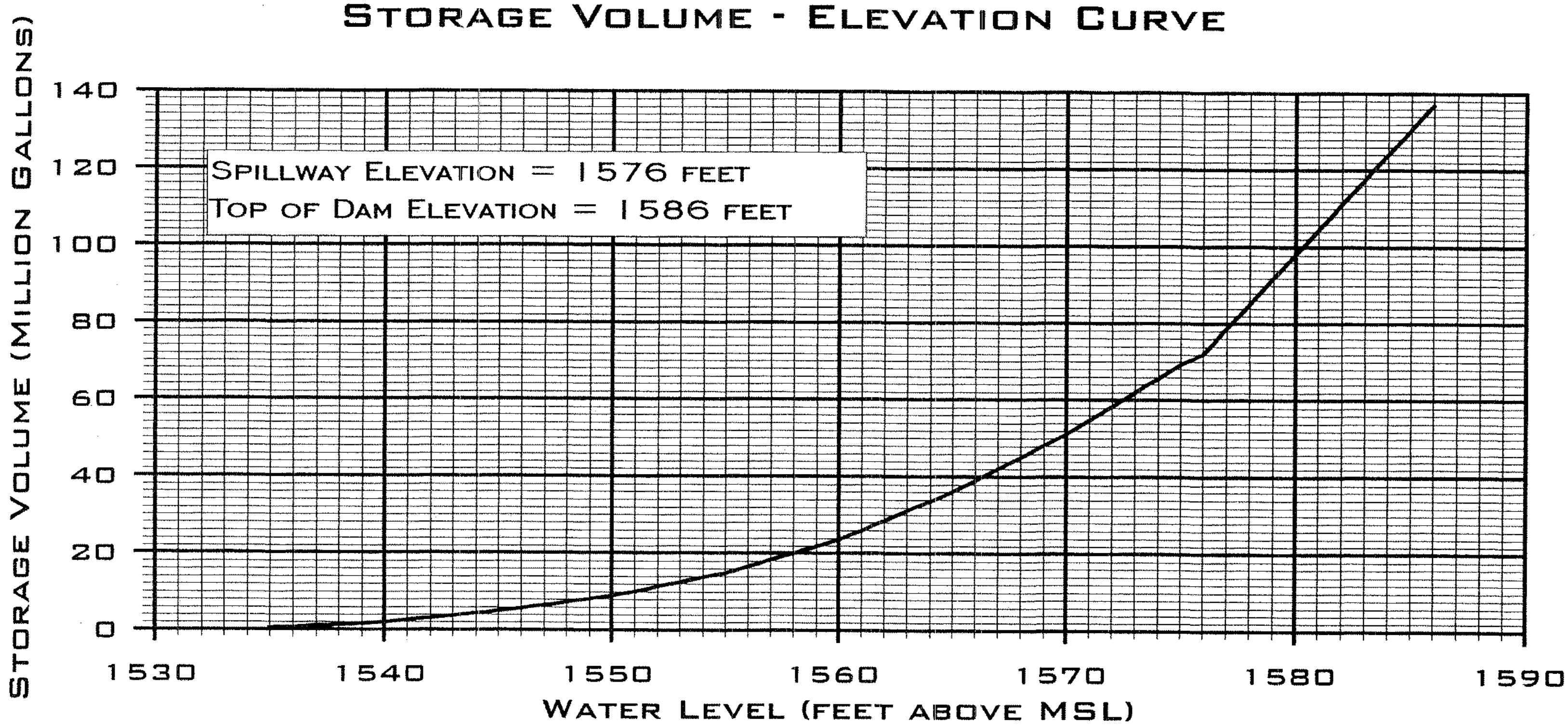
Storage - Elevation Table

Spillway Elevation: 1576 feet
Crest Elevation: 1586 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1535.00	-41.00	0.50		1552.50	-23.50	11.85		1570.00	-6.00	51.00
1535.50	-40.50	0.65		1553.00	-23.00	12.44		1570.50	-5.50	52.81
1536.00	-40.00	0.80		1553.50	-22.50	13.03		1571.00	-5.00	54.62
1536.50	-39.50	0.95		1554.00	-22.00	13.62		1571.50	-4.50	56.43
1537.00	-39.00	1.10		1554.50	-21.50	14.21		1572.00	-4.00	58.24
1537.50	-38.50	1.25		1555.00	-21.00	14.80		1572.50	-3.50	60.05
1538.00	-38.00	1.40		1555.50	-20.50	15.67		1573.00	-3.00	61.86
1538.50	-37.50	1.55		1556.00	-20.00	16.54		1573.50	-2.50	63.67
1539.00	-37.00	1.70		1556.50	-19.50	17.41		1574.00	-2.00	65.48
1539.50	-36.50	1.85		1557.00	-19.00	18.28		1574.50	-1.50	67.29
1540.00	-36.00	2.00		1557.50	-18.50	19.15		1575.00	-1.00	69.10
1540.50	-35.50	2.29		1558.00	-18.00	20.02		1575.50	-0.50	70.55
1541.00	-35.00	2.58		1558.50	-17.50	20.89		1576.00	0.00	72.00
1541.50	-34.50	2.87		1559.00	-17.00	21.76		1576.50	0.50	75.24
1542.00	-34.00	3.16		1559.50	-16.50	22.63		1577.00	1.00	78.48
1542.50	-33.50	3.45		1560.00	-16.00	23.50		1577.50	1.50	81.72
1543.00	-33.00	3.74		1560.50	-15.50	24.75		1578.00	2.00	84.96
1543.50	-32.50	4.03		1561.00	-15.00	26.00		1578.50	2.50	88.20
1544.00	-32.00	4.32		1561.50	-14.50	27.25		1579.00	3.00	91.44
1544.50	-31.50	4.61		1562.00	-14.00	28.50		1579.50	3.50	94.68
1545.00	-31.00	4.90		1562.50	-13.50	29.75		1580.00	4.00	97.92
1545.50	-30.50	5.30		1563.00	-13.00	31.00		1580.50	4.50	101.16
1546.00	-30.00	5.70		1563.50	-12.50	32.25		1581.00	5.00	104.40
1546.50	-29.50	6.10		1564.00	-12.00	33.50		1581.50	5.50	107.64
1547.00	-29.00	6.50		1564.50	-11.50	34.75		1582.00	6.00	110.88
1547.50	-28.50	6.90		1565.00	-11.00	36.00		1582.50	6.50	114.12
1548.00	-28.00	7.30		1565.50	-10.50	37.50		1583.00	7.00	117.36
1548.50	-27.50	7.70		1566.00	-10.00	39.00		1583.50	7.50	120.60
1549.00	-27.00	8.10		1566.50	-9.50	40.50		1584.00	8.00	123.84
1549.50	-26.50	8.50		1567.00	-9.00	42.00		1584.50	8.50	127.08
1550.00	-26.00	8.90		1567.50	-8.50	43.50		1585.00	9.00	130.32
1550.50	-25.50	9.49		1568.00	-8.00	45.00		1585.50	9.50	133.56
1551.00	-25.00	10.08		1568.50	-7.50	46.50		1586.00	10.00	136.80
1551.50	-24.50	10.67		1569.00	-7.00	48.00				
1552.00	-24.00	11.26		1569.50	-6.50	49.50				

MULESHOE RESERVOIR

STORAGE VOLUME - ELEVATION CURVE

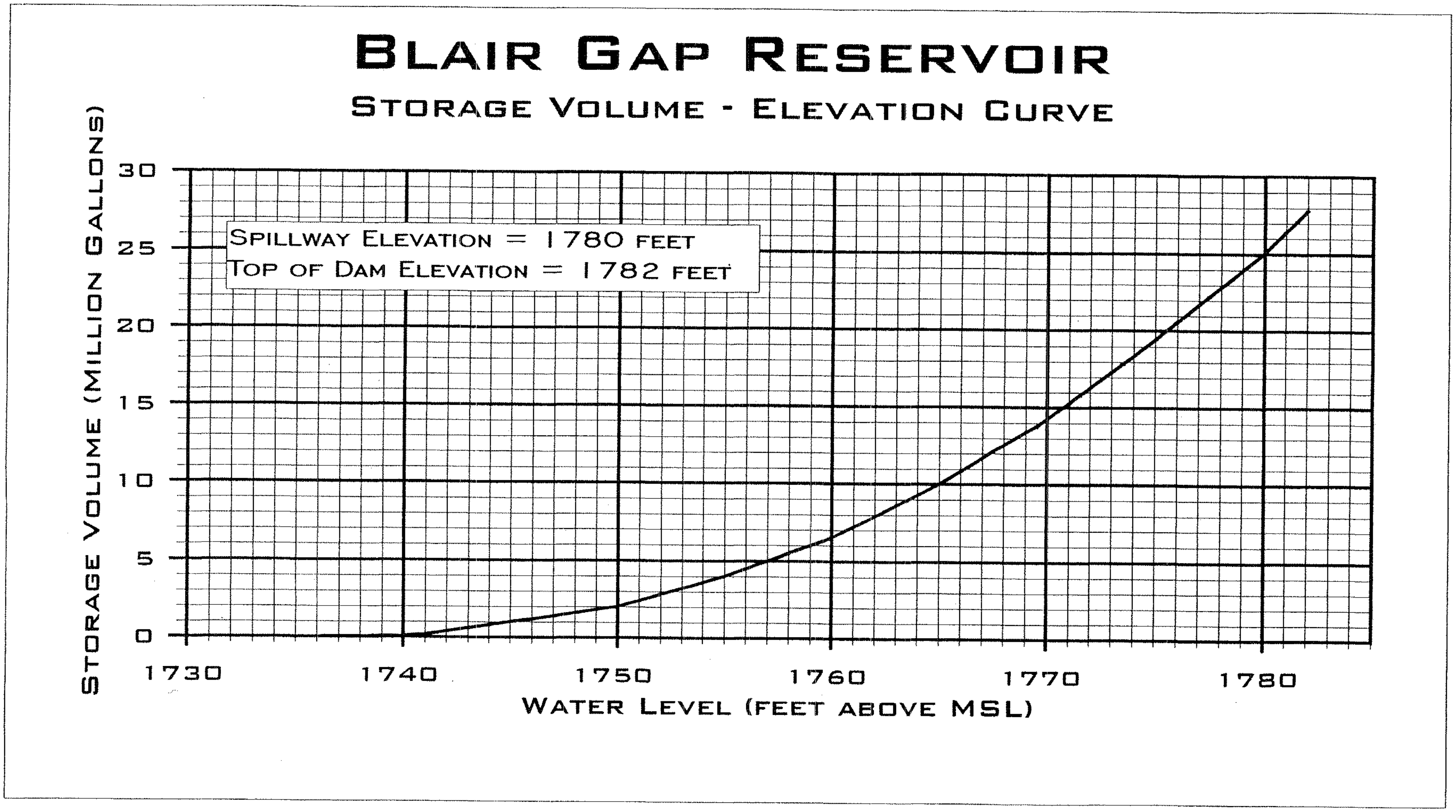


Blair Gap Reservoir

Storage - Elevation Table

Spillway Elevation: 1780 feet
Crest Elevation: 1782 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1735.00	-45.00	0.00		1753.50	-26.50	3.40		1768.00	-12.00	12.52
1735.50	-44.50	0.01		1754.00	-26.00	3.60		1768.50	-11.50	12.94
1740.00	-40.00	0.10		1754.50	-25.50	3.80		1769.00	-11.00	13.36
1740.50	-39.50	0.15		1755.00	-25.00	4.00		1769.50	-10.50	13.72
1741.00	-39.00	0.20		1755.50	-24.50	4.25		1770.00	-10.00	14.20
1741.50	-38.50	0.30		1756.00	-24.00	4.50		1770.50	-9.50	14.72
1742.00	-38.00	0.40		1756.50	-23.50	4.75		1771.00	-9.00	15.24
1742.50	-37.50	0.50		1757.00	-23.00	5.00		1771.50	-8.50	15.76
1743.00	-37.00	0.60		1757.50	-22.50	5.25		1772.00	-8.00	16.28
1743.50	-36.50	0.70		1758.00	-22.00	5.50		1772.50	-7.50	16.80
1744.00	-36.00	0.80		1758.50	-21.50	5.75		1773.00	-7.00	17.32
1744.50	-35.50	0.90		1759.00	-21.00	6.00		1773.50	-6.50	17.84
1745.00	-35.00	1.00		1759.50	-20.50	6.25		1774.00	-6.00	18.36
1745.50	-34.50	1.10		1760.00	-20.00	6.50		1774.50	-5.50	18.88
1746.00	-34.00	1.20		1760.50	-19.50	6.85		1775.00	-5.00	19.40
1746.50	-33.50	1.30		1761.00	-19.00	7.20		1775.50	-4.50	19.96
1747.00	-33.00	1.40		1761.50	-18.50	7.55		1776.00	-4.00	20.52
1747.50	-32.50	1.50		1762.00	-18.00	7.90		1776.50	-3.50	21.08
1748.00	-32.00	1.60		1762.50	-17.50	8.25		1777.00	-3.00	21.64
1748.50	-31.50	1.70		1763.00	-17.00	8.60		1777.50	-2.50	22.20
1749.00	-31.00	1.80		1763.50	-16.50	8.95		1778.00	-2.00	22.76
1749.50	-30.50	1.90		1764.00	-16.00	9.30		1778.50	-1.50	23.32
1750.00	-30.00	2.00		1764.50	-15.50	9.65		1779.00	-1.00	23.88
1750.50	-29.50	2.20		1765.00	-15.00	10.00		1779.50	-0.50	24.44
1751.00	-29.00	2.40		1765.50	-14.50	10.42		1780.00	0.00	25.00
1751.50	-28.50	2.60		1766.00	-14.00	10.84		1780.50	0.50	25.70
1752.00	-28.00	2.80		1766.50	-13.50	11.26		1781.00	1.00	26.40
1752.50	-27.50	3.00		1767.00	-13.00	11.68		1781.50	1.50	27.10
1753.00	-27.00	3.20		1767.50	-12.50	12.10		1782.00	2.00	27.80



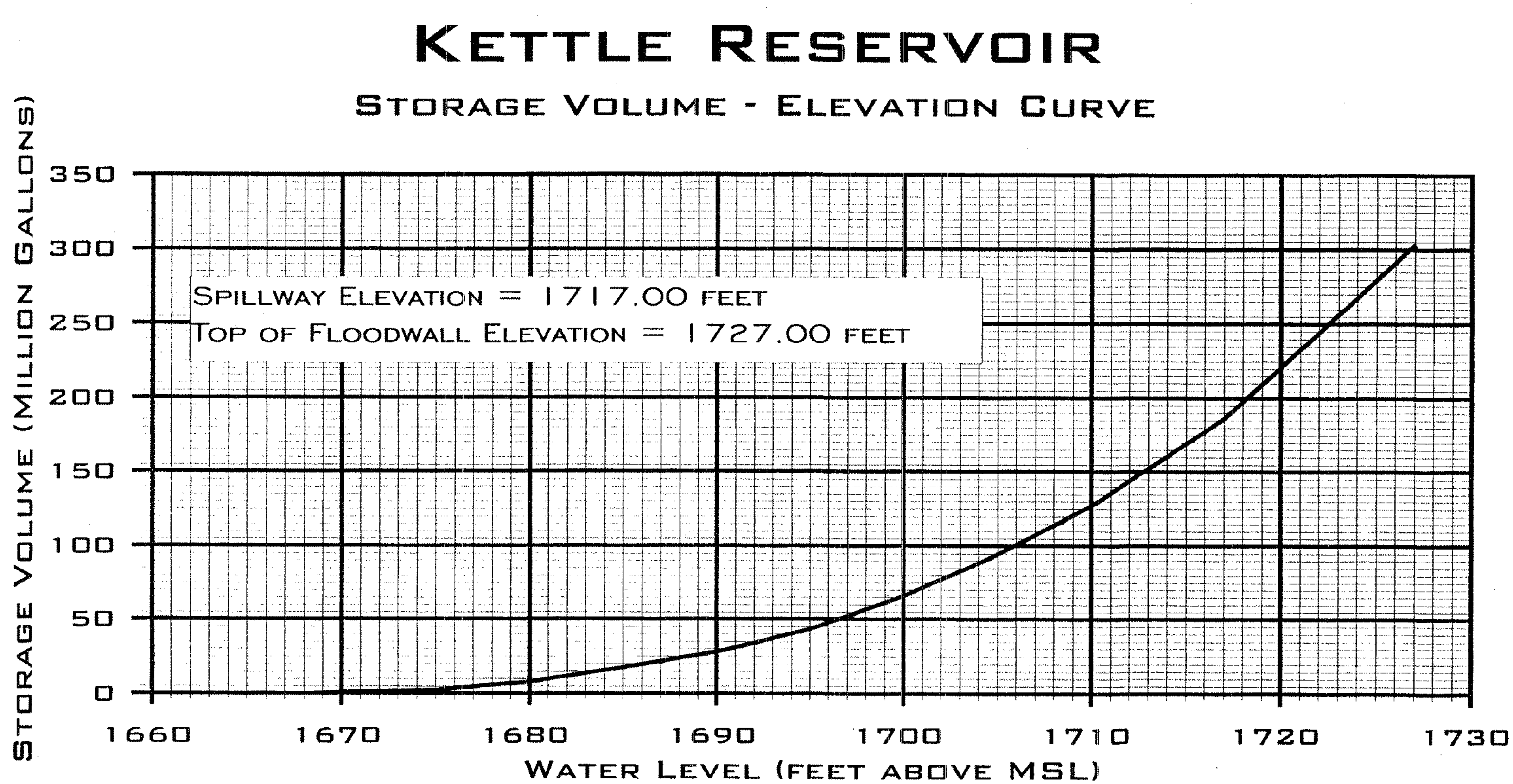
Blair Gap Reservoir
Storage Volume - Elevation Curve
Spillway Elevation = 1780 feet
Top of Dam Elevation = 1782 feet
Storage Volume (Million Gallons)
30
25
20
15
10
5
0
1730
1740
1750
1760
1770
1780
Water Level (feet above MSL)

KETTLE RESERVOIR

STORAGE - ELEVATION TABLE

Spillway Elevation: 1717.00 feet
Crest Elevation: 1727.00 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)	Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1668.00	-49.00	0.00	1688.00	-29.00	23.80	1708.00	-9.00	113.80
1668.50	-48.50	0.25	1688.50	-28.50	24.85	1708.50	-8.50	117.10
1669.00	-48.00	0.50	1689.00	-28.00	25.90	1709.00	-8.00	120.40
1669.50	-47.50	0.75	1689.50	-27.50	26.95	1709.50	-7.50	123.70
1670.00	-47.00	1.00	1690.00	-27.00	28.00	1710.00	-7.00	127.00
1670.50	-46.50	1.15	1690.50	-26.50	29.50	1710.50	-6.50	131.19
1671.00	-46.00	1.30	1691.00	-26.00	31.00	1711.00	-6.00	135.37
1671.50	-45.50	1.45	1691.50	-25.50	32.50	1711.50	-5.50	139.56
1672.00	-45.00	1.60	1692.00	-25.00	34.00	1712.00	-5.00	143.74
1672.50	-44.50	1.75	1692.50	-24.50	35.50	1712.50	-4.50	147.93
1673.00	-44.00	1.90	1693.00	-24.00	37.00	1713.00	-4.00	152.11
1673.50	-43.50	2.05	1693.50	-23.50	38.50	1713.50	-3.50	156.30
1674.00	-43.00	2.20	1694.00	-23.00	40.00	1714.00	-3.00	160.49
1674.50	-42.50	2.35	1694.50	-22.50	41.50	1714.50	-2.50	164.67
1675.00	-42.00	2.50	1695.00	-22.00	43.00	1715.00	-2.00	168.86
1675.50	-41.50	3.05	1695.50	-21.50	45.30	1715.50	-1.50	173.04
1676.00	-41.00	3.60	1696.00	-21.00	47.60	1716.00	-1.00	177.23
1676.50	-40.50	4.15	1696.50	-20.50	49.90	1716.50	-0.50	181.41
1677.00	-40.00	4.70	1697.00	-20.00	52.20	1717.00	0.00	185.60
1677.50	-39.50	5.25	1697.50	-19.50	54.50	1717.50	0.50	191.45
1678.00	-39.00	5.80	1698.00	-19.00	56.80	1718.00	1.00	197.29
1678.50	-38.50	6.35	1698.50	-18.50	59.10	1718.50	1.50	203.14
1679.00	-38.00	6.90	1699.00	-18.00	61.40	1719.00	2.00	208.98
1679.50	-37.50	7.45	1699.50	-17.50	63.70	1719.50	2.50	214.83
1680.00	-37.00	8.00	1700.00	-17.00	66.00	1720.00	3.00	220.67
1680.50	-36.50	8.95	1700.50	-16.50	68.80	1720.50	3.50	226.52
1681.00	-36.00	9.90	1701.00	-16.00	71.60	1721.00	4.00	232.36
1681.50	-35.50	10.85	1701.50	-15.50	74.40	1721.50	4.50	238.21
1682.00	-35.00	11.80	1702.00	-15.00	77.20	1722.00	5.00	244.05
1682.50	-34.50	12.75	1702.50	-14.50	80.00	1722.50	5.50	249.90
1683.00	-34.00	13.70	1703.00	-14.00	82.80	1723.00	6.00	255.74
1683.50	-33.50	14.65	1703.50	-13.50	85.60	1723.50	6.50	261.59
1684.00	-33.00	15.60	1704.00	-13.00	88.40	1724.00	7.00	267.43
1684.50	-32.50	16.55	1704.50	-12.50	91.20	1724.50	7.50	273.28
1685.00	-32.00	17.50	1705.00	-12.00	94.00	1725.00	8.00	279.12
1685.50	-31.50	18.55	1705.50	-11.50	97.30	1725.50	8.50	284.97
1686.00	-31.00	19.60	1706.00	-11.00	100.60	1726.00	9.00	290.81
1686.50	-30.50	20.65	1706.50	-10.50	103.90	1726.50	9.50	296.66
1687.00	-30.00	21.70	1707.00	-10.00	107.20	1727.00	10.00	302.50
1687.50	-29.50	22.75	1707.50	-9.50	110.50			



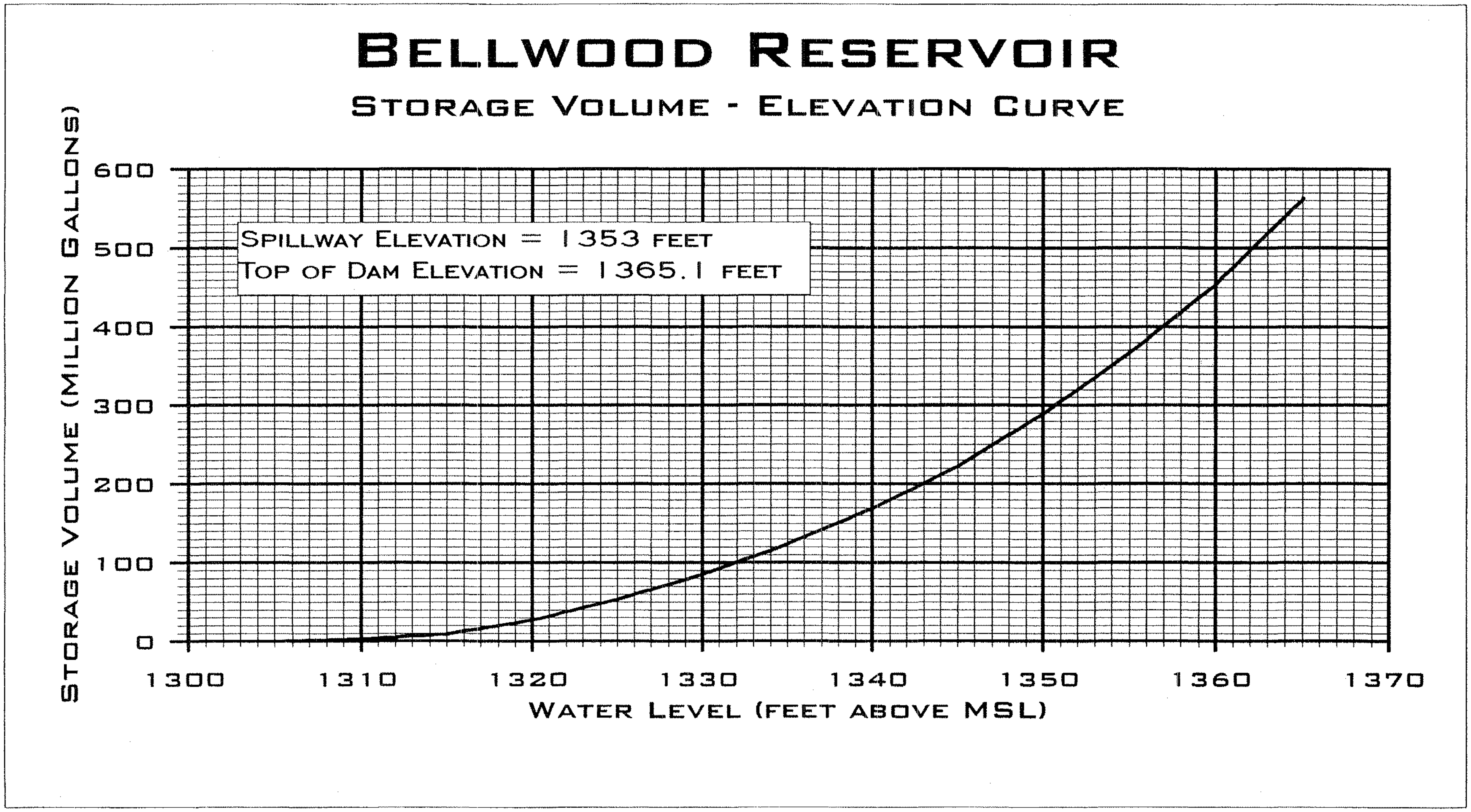
KETTLE RESERVOIR
STORAGE VOLUME - ELEVATION CURVE
SPILLWAY ELEVATION = 1717.00 FEET
TOP OF FLOODWALL ELEVATION = 1727.00 FEET
STORAGE VOLUME (MILLION GALLONS)
350
300
250
200
150
100
50
0
1660
1670
1680
1690
1700
1710
1720
1730
WATER LEVEL (FEET ABOVE MSL)

Bellwood Reservoir

Storage - Elevation Table

Spillway Elevation: 1353.00 feet
Crest Elevation: 1365.10 feet

Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)		Water Surface Elevation	Feet Below Spillway	Stored Volume (MG)
1305.00	-48.00	0.00		1325.50	-27.50	56.23		1346.00	-7.00	235.32
1305.50	-47.50	0.31		1326.00	-27.00	59.36		1346.50	-6.50	242.03
1306.00	-47.00	0.62		1326.50	-26.50	62.49		1347.00	-6.00	248.74
1306.50	-46.50	0.93		1327.00	-26.00	65.62		1347.50	-5.50	255.45
1307.00	-46.00	1.24		1327.50	-25.50	68.75		1348.00	-5.00	262.16
1307.50	-45.50	1.55		1328.00	-25.00	71.88		1348.50	-4.50	268.87
1308.00	-45.00	1.86		1328.50	-24.50	75.01		1349.00	-4.00	275.58
1308.50	-44.50	2.17		1329.00	-24.00	78.14		1349.50	-3.50	282.29
1309.00	-44.00	2.48		1329.50	-23.50	81.27		1350.00	-3.00	289.00
1309.50	-43.50	2.79		1330.00	-23.00	84.40		1350.50	-2.50	296.66
1310.00	-43.00	3.10		1330.50	-22.50	88.30		1351.00	-2.00	304.32
1310.50	-42.50	3.73		1331.00	-22.00	92.20		1351.50	-1.50	311.98
1311.00	-42.00	4.36		1331.50	-21.50	96.10		1352.00	-1.00	319.64
1311.50	-41.50	4.99		1332.00	-21.00	100.00		1352.50	-0.50	327.30
1312.00	-41.00	5.62		1332.50	-20.50	103.90		1353.00	0.00	334.96
1312.50	-40.50	6.25		1333.00	-20.00	107.80		1353.50	0.50	342.62
1313.00	-40.00	6.88		1333.50	-19.50	111.70		1354.00	1.00	350.28
1313.50	-39.50	7.51		1334.00	-19.00	115.60		1354.50	1.50	357.94
1314.00	-39.00	8.14		1334.50	-18.50	119.50		1355.00	2.00	365.60
1314.50	-38.50	8.77		1335.00	-18.00	123.40		1355.50	2.50	374.35
1315.00	-38.00	9.40		1335.50	-17.50	127.94		1356.00	3.00	383.10
1315.50	-37.50	11.12		1336.00	-17.00	132.48		1356.50	3.50	391.85
1316.00	-37.00	12.84		1336.50	-16.50	137.02		1357.00	4.00	400.60
1316.50	-36.50	14.56		1337.00	-16.00	141.56		1357.50	4.50	409.35
1317.00	-36.00	16.28		1337.50	-15.50	146.10		1358.00	5.00	418.10
1317.50	-35.50	18.00		1338.00	-15.00	150.64		1358.50	5.50	426.85
1318.00	-35.00	19.72		1338.50	-14.50	155.18		1359.00	6.00	435.60
1318.50	-34.50	21.44		1339.00	-14.00	159.72		1359.50	6.50	444.35
1319.00	-34.00	23.16		1339.50	-13.50	164.26		1360.00	7.00	453.10
1319.50	-33.50	24.88		1340.00	-13.00	168.80		1360.50	7.50	463.79
1320.00	-33.00	26.60		1340.50	-12.50	174.11		1361.00	8.00	474.48
1320.50	-32.50	29.25		1341.00	-12.00	179.42		1361.50	8.50	485.17
1321.00	-32.00	31.90		1341.50	-11.50	184.73		1362.00	9.00	495.86
1321.50	-31.50	34.55		1342.00	-11.00	190.04		1362.50	9.50	506.55
1322.00	-31.00	37.20		1342.50	-10.50	195.35		1363.00	10.00	517.24
1322.50	-30.50	39.85		1343.00	-10.00	200.66		1363.50	10.50	527.93
1323.00	-30.00	42.50		1343.50	-9.50	205.97		1364.00	11.00	538.62
1323.50	-29.50	45.15		1344.00	-9.00	211.28		1364.50	11.50	549.31
1324.00	-29.00	47.80		1344.50	-8.50	216.59		1365.00	12.00	560.00
1324.50	-28.50	50.45		1345.00	-8.00	221.90		1365.10	12.10	562.20
1325.00	-28.00	53.10		1345.50	-7.50	228.61				


BELLWOOD RESERVOIR
STORAGE VOLUME - ELEVATION CURVE
SPILLWAY ELEVATION = 1353 FEET
TOP OF DAM ELEVATION = 1365.1 FEET
STORAGE VOLUME (MILLION GALLONS)
0
100
200
300
400
500
600
1300
1310
1320
1330
1340
1350
1360
1370
WATER LEVEL (FEET ABOVE MSL)

APPENDIX C

EVAPORATION RATE DETERMINATION FOR INDIVIDUAL RESERVOIR SYSTEMS

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Kittanning Point	52.6	12.6

Drainage Area at Intake = 8.89 (sq. mi.) Date of Reservoir = 1884 Age of Reservoir = 127 (years)

2. Compute Depth of Storage

Reservoir Capacity = 52.6 (mg)

$$52.6 \text{ (mg)} \times \frac{1 \text{ (ac. - ft.)}}{0.326 \text{ (mg)}} \times \frac{1 \text{ (in. - sq. mi.)}}{53.3 \text{ (ac.-ft.)}} = 3.03 \text{ (in.-sq. mi.) (unit depth of storage)}$$

3.03 (in. - sq. mi.) ÷ 8.89 (sq. mi.) = 0.341 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (50% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

3 Month Critical Duration Mean Flow = 1.76 (in./mo.)

8 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

$$\text{Storage as \% of runoff} = \frac{0.341 \text{ (in. storage)}}{21.12 \text{ (in. runoff)}} \times 100\% = 1.6\%$$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 7 (in.) (Critical Duration = 3 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 3 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 7 (in. E_{DM}) x 0.083 (ft./in.) = 0.59 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

12.6 (ac.) x .65 = 8.19 (ac.) effective surface evaporation area

0.59 (ft.) x 8.19 (ac.) = 4.83 (ac. ft.) x 0.326 (mg/ac.ft.) = 1.575 (mg) (Evaporation Loss)

1.575 (mg) evap. loss ÷ 3 mo. duration ÷ 30.4 (day/mo.) = 0.017 mgd (Evaporation Rate)
0.027 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority   Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Impounding (Cochran)	309 mg (w/5' Rubber Dam)	42.8

Drainage Area at Intake = 9.57 (sq. mi.)   Date of Reservoir = 1894 Age of Reservoir = 107 (years)

2. Compute Depth of Storage

Reservoir Capacity = 309 (mg)

$$309\ (\text{mg}) \times \frac{1\ (\text{ac.-ft.})}{0.326\ (\text{mg})} \times \frac{1\ (\text{in.-sq. mi.})}{53.3\ (\text{ac.-ft.})} = 17.78\ (\text{in.-sq. mi.})\ (\text{unit depth of storage})$$

17.78 (in. - sq. mi.) ÷ 9.57 (sq. mi.) = 1.858 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (50% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

5 Month Critical Duration Mean Flow = 1.76 (in./mo.)

21 % of Mean Flow   1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

$$\text{Storage as \% of runoff} = \frac{1.858\ (\text{in. storage})}{21.12\ (\text{in. runoff})} \times 100\% = 8.8\%$$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 8.75 (in.) (Critical Duration = 5 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 5 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 8.75 (in. E_{DM}) x 0.083 (ft./in.) = 0.74 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

42.8 (ac.) x .65 = 27.82 (ac.) effective surface evaporation area

0.74 (ft.) x 27.82 (ac.) = 20.59 (ac. ft.) x 0.326 (mg/ac.ft.) = 6.71 (mg) (Evaporation Loss)

6.71 (mg) evap. loss ÷ 5 mo. duration ÷ 30.4 (day/mo.) = 0.044 mgd (Evaporation Rate)
0.068 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Lake Altoona	835 mg w/4 ft. Rubber Dam	89.1

Drainage Area at Intake = 12.42 (sq. mi.) Date of Reservoir = 1908 Age of Reservoir = 103 (years)

2. Compute Depth of Storage

Reservoir Capacity = 835 (mg)

$$835\ (\text{mg}) \times \frac{1\ (\text{ac. - ft.})}{0.326\ (\text{mg})} \times \frac{1\ (\text{in. - sq. mi.})}{53.3\ (\text{ac.-ft.})} = 48.06\ (\text{in.-sq. mi.})$$ (unit depth of storage)

48.06 (in. - sq. mi.) ÷ 12.42 (sq. mi.) = 3.87 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (50% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

6 Month Critical Duration Mean Flow = 1.76 (in./mo.)

39 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

$$\text{Storage as \% of runoff} = \frac{3.87\ (\text{in. storage})}{21.12\ (\text{in. runoff})} \times 100\% = 18.3\%$$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 9.25 (in.) (Critical Duration = 6 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 6 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 9.25 (in. E_{DM}) x 0.083 (ft./in.) = 0.783 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

89.1 (ac.) x .65 = 57.92 (ac.) effective surface evaporation area

0.783 (ft.) x 57.92 (ac.) = 45.35 (ac. ft.) x 0.326 (mg/ac.ft.) = 14.79 (mg) (Evaporation Loss)

14.79 (mg) evap. loss ÷ 6 mo. duration ÷ 30.4 (day/mo.) = 0.08 mgd (Evaporation Rate)
0.125 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Mill Run	519 mg w/6' Rubber Dam	50.3

Drainage Area at Intake = 4.25 (sq. mi.) Date of Reservoir = 1958 Age of Reservoir = 53 (years)

2. Compute Depth of Storage

Reservoir Capacity = 519 (mg)

$519 \text{ (mg)} \times \frac{1 \text{ (ac. - ft.)}}{0.326 \text{ (mg)}} \times \frac{1 \text{ (in. - sq. mi.)}}{53.3 \text{ (ac.-ft.)}} = 29.87$ (in.-sq. mi.) (unit depth of storage)

29.87 (in. - sq. mi.) ÷ 4.25 (sq. mi.) = 7.03 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (12.5% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

8 Month Critical Duration Mean Flow = 1.76 (in./mo.)

62 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 13.09 (in. runoff)

Storage as % of runoff = $\frac{7.03 \text{ (in. storage)}}{21.12 \text{ (in. runoff)}} \times 100\% = 33.29\%$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 10.25 (in.) (Critical Duration = 8 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 5 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 10.25 (in. E_{DM}) x 0.083 (ft./in.) = 0.878 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

50.3 (ac.) x .65 = 32.70 (ac.) effective surface evaporation area

0.878 (ft.) x 32.70 (ac.) = 28.7 (ac. ft.) x 0.326 (mg/ac.ft.) = 9.36 (mg) (Evaporation Loss)

9.36 (mg) evap. loss ÷ 8 mo. duration ÷ 30.4 (day/mo.) = 0.039 mgd (Evaporation Rate)
0.060 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Allegheny	49.3	11.4

Drainage Area at Intake = 6.25 (sq. mi.) Date of Reservoir = 1905 Age of Reservoir = 106 (years)

2. Compute Depth of Storage

Reservoir Capacity = 49.3 (mg)

$$49.3 \text{ (mg)} \times \frac{1 \text{ (ac. - ft.)}}{0.326 \text{ (mg)}} \times \frac{1 \text{ (in. - sq. mi.)}}{53.3 \text{ (ac.-ft.)}} = 2.83 \text{ (in.-sq. mi.) (unit depth of storage)}$$

2.83 (in. - sq. mi.) ÷ 6.25 (sq. mi.) = 0.453 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (50% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

3 Month Critical Duration Mean Flow = 1.76 (in./mo.)

10 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

$$\text{Storage as \% of runoff} = \frac{0.453 \text{ (in. storage)}}{21.12 \text{ (in. runoff)}} \times 100\% = 2.15\%$$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 7 (in.) (Critical Duration = 3 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 3 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 7 (in. E_{DM}) x 0.083 (ft./in.) = 0.59 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

11.4 (ac.) x .65 = 7.41 (ac.) effective surface evaporation area

0.59 (ft.) x 7.41 (ac.) = 4.37 (ac. ft.) x 0.326 (mg/ac.ft.) = 1.425 (mg) (Evaporation Loss)

1.425 (mg) evap. loss ÷ 3 mo. duration ÷ 30.4 (day/mo.) = 0.016 mgd (Evaporation Rate)
0.024 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Homer Gap	26.7	7.1

Drainage Area at Intake = 2.47 (sq. mi.) Date of Reservoir = 1914 Age of Reservoir = 97 (years)

2. Compute Depth of Storage

Reservoir Capacity = 26.7 (mg)

$$26.7 \text{ (mg)} \times \frac{1 \text{ (ac. - ft.)}}{0.326 \text{ (mg)}} \times \frac{1 \text{ (in. - sq. mi.)}}{53.3 \text{ (ac.-ft.)}} = 1.536 \text{ (in.-sq. mi.) (unit depth of storage)}$$

1.536 (in. - sq. mi.) ÷ 2.47 (sq. mi.) = 0.622 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (12.5 Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

4 Month Critical Duration Mean Flow = 1.76 (in./mo.)

11 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

$$\text{Storage as \% of runoff} = \frac{0.622 \text{ (in. storage)}}{21.12 \text{ (in. runoff)}} \times 100\% = 2.95\%$$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 8.25 (in.) (Critical Duration = 4 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 5 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 8.25 (in. E_{DM}) x 0.083 (ft./in.) = 0.70 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

7.1 (ac.) x .65 = 4.615 (ac.) effective surface evaporation area

0.70 (ft.) x 4.615 (ac.) = 3.23 (ac. ft.) x 0.326 (mg/ac.ft.) = 1.617 (mg) (Evaporation Loss)

1.617 (mg) evap. loss ÷ 4 mo. duration ÷ 30.4 (day/mo.) = 0.013 mgd (Evaporation Rate)
0.021 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Plane Nine	120	30

Drainage Area at Intake = 12.6 (sq. mi.) Date of Reservoir = 1907 Age of Reservoir = 104 (years)

2. Compute Depth of Storage

Reservoir Capacity = 120 (mg)

120 (mg) x $\frac{\text{1 (ac. - ft.)}}{\text{0.326 (mg)}}$ x $\frac{\text{1 (in. - sq. mi.)}}{\text{53.3 (ac.-ft.)}}$ = 6.906 (in.-sq. mi.) (unit depth of storage)

6.906 (in. - sq. mi.) ÷ 12.6 (sq. mi.) = 0.576 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (50% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

4 Month Critical Duration Mean Flow = 1.76 (in./mo.)

11 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

Storage as % of runoff = $\frac{\text{0.526 (in. storage)}}{\text{21.12 (in. runoff)}}$ x 100% = 2.73%

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 8.25 (in.) (Critical Duration = 4 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 4 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 8.25 (in. E_{DM}) x 0.083 (ft./in.) = 0.70 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

4.30 (ac.) x .65 = 19.5 (ac.) effective surface evaporation area

0.70 (ft.) x 19.5 (ac.) = 13.65 (ac. ft.) x 0.326 (mg/ac.ft.) = 4.45 (mg) (Evaporation Loss)

4.45 (mg) evap. loss ÷ 4 mo. duration ÷ 30.4 (day/mo.) = 0.036 mgd (Evaporation Rate)
0.057 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Muleshoe	72	13

Drainage Area at Intake = 7.2 (sq. mi.) Date of Reservoir = 1956 Age of Reservoir = 55 (years)

2. Compute Depth of Storage

Reservoir Capacity = 72 (mg)

$$72 \text{ (mg)} \times \frac{1 \text{ (ac. - ft.)}}{0.326 \text{ (mg)}} \times \frac{1 \text{ (in. - sq. mi.)}}{53.3 \text{ (ac.-ft.)}} = 4.14 \text{ (in.-sq. mi.) (unit depth of storage)}$$

4.14 (in. - sq. mi.) ÷ 7.2 (sq. mi.) = 0.576 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (50% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

4 Month Critical Duration Mean Flow = 1.76 (in./mo.)

11 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

$$\text{Storage as \% of runoff} = \frac{0.576 \text{ (in. storage)}}{21.12 \text{ (in. runoff)}} \times 100\% = 2.72\%$$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 8.75 (in.) (Critical Duration = 4 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 4 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 8.75 (in. E_{DM}) x 0.083 (ft./in.) = 0.70 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

13 (ac.) x .65 = 8.25 (ac.) effective surface evaporation area

0.70 (ft.) x 8.45 (ac.) = 5.915 (ac. ft.) x 0.326 (mg/ac.ft.) = 1.93 (mg) (Evaporation Loss)

1.93 (mg) evap. loss ÷ 4 mo. duration ÷ 30.4 (day/mo.) = 0.016 mgd (Evaporation Rate)
0.025 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority   Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Blair Gap	25	4

Drainage Area at Intake = 3.40 (sq. mi.) Date of Reservoir = 1905 Age of Reservoir = 106 (years)

2. Compute Depth of Storage

Reservoir Capacity = 25 (mg)

$$25 \text{ (mg)} \times \frac{1 \text{ (ac. - ft.)}}{0.326 \text{ (mg)}} \times \frac{1 \text{ (in. - sq. mi.)}}{53.3 \text{ (ac.-ft.)}} = 1.439 \text{ (in.-sq. mi.) (unit depth of storage)}$$

1.439 (in. - sq. mi.) ÷ 3.40 (sq. mi.) = 0.423 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (50% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

3 Month Critical Duration Mean Flow = 1.76 (in./mo.)

9 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

$$\text{Storage as \% of runoff} = \frac{0.423 \text{ (in. storage)}}{21.12 \text{ (in. runoff)}} \times 100\% = 2.0\%$$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 7 (in.) (Critical Duration = 3 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 3 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 7 (in. E_{DM}) x 0.083 (ft./in.) = 0.59 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

4 (ac.) x .65 = 2.6 (ac.) effective surface evaporation area

0.59 (ft.) x 2.6 (ac.) = 1.534 (ac. ft.) x 0.326 (mg/ac.ft.) = 0.50 (mg) (Evaporation Loss)

0.50 (mg) evap. loss ÷ 3 mo. duration ÷ 30.4 (day/mo.) = 0.0055 mgd (Evaporation Rate)
0.0085 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Kettle	185	29.9

Drainage Area at Intake = 2.5 (sq. mi.) Date of Reservoir = 1888 Age of Reservoir = 123 (years)

2. Compute Depth of Storage

Reservoir Capacity = 185 (mg)

$185 \text{ (mg)} \times \frac{1 \text{ (ac. - ft.)}}{0.326 \text{ (mg)}} \times \frac{1 \text{ (in. - sq. mi.)}}{53.3 \text{ (ac.-ft.)}} = 10.65$ (in.-sq. mi.) (unit depth of storage)

10.65 (in. - sq. mi.) ÷ 2.5 (sq. mi.) = 4.26 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (12.5% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

7 Month Critical Duration Mean Flow = 1.76 (in./mo.)

38.5 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

Storage as % of runoff = $\frac{4.276 \text{ (in. storage)}}{21.12 \text{ (in. runoff)}} \times 100\% = 20.23\%$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 9.75 (in.) (Critical Duration = 7 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 7 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 9.75 (in. E_{DM}) x 0.083 (ft./in.) = 0.825 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

29.9 (ac.) x .65 = 19.435 (ac.) effective surface evaporation area

0.825 (ft.) x 19.435 (ac.) = 16.04 (ac. ft.) x 0.326 (mg/ac.ft.) = 5.23 (mg) (Evaporation Loss)

5.23 (mg) evap. loss ÷ 7 mo. duration ÷ 30.4 (day/mo.) = 0.0246 mgd (Evaporation Rate)
0.0381 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Bellwood	335.0	53

Drainage Area at Intake = 18.2 (sq. mi.) Date of Reservoir = 1946 Age of Reservoir = 65 (years)

2. Compute Depth of Storage

Reservoir Capacity = 309 (mg)

$335 \text{ (mg)} \times \frac{1 \text{ (ac. - ft.)}}{0.326 \text{ (mg)}} \times \frac{1 \text{ (in. - sq. mi.)}}{53.3 \text{ (ac.-ft.)}} = 19.280$ (in.-sq. mi.) (unit depth of storage)

19.280 (in. - sq. mi.) ÷ 18.2 (sq. mi.) = 1.059 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (12.5% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

5 Month Critical Duration Mean Flow = 1.76 (in./mo.)

17.5 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

Storage as % of runoff $= \frac{1.059 \text{ (in. storage)}}{21.12 \text{ (in. runoff)}} \times 100\% = 5.01\%$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 8.75 (in.) (Critical Duration = 5 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 5 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 8.75 (in. E_{DM}) x 0.083 (ft./in.) = 0.74 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

53 (ac.) x .65 = 34.45 (ac.) effective surface evaporation area

6.74 (ft.) x 34.45 (ac.) = 25.49 (ac. ft.) x 0.326 (mg/ac.ft.) = 8.31 (mg) (Evaporation Loss)

8.31 (mg) evap. loss ÷ 5 mo. duration ÷ 30.4 (day/mo.) = 0.055 mgd (Evaporation Rate)
0.085 cfs

EVAPORATION EVALUATION OF INDIVIDUAL RESERVOIR SOURCE

Water Supplier: Altoona Water Authority Date: April 2011

1. Reservoir Data

Reservoir Name	Capacity (mg)	Surface Area (ac.)
Tipton	320	42.3

Drainage Area at Intake = 8.57 (sq. mi.) Date of Reservoir = 1924 Age of Reservoir = 87 (years)

2. Compute Depth of Storage

Reservoir Capacity = 320.0 (mg)

$$320.0 \text{ (mg)} \times \frac{1 \text{ (ac. - ft.)}}{0.326 \text{ (mg)}} \times \frac{1 \text{ (in. - sq. mi.)}}{53.3 \text{ (ac.-ft.)}} = 18.416 \text{ (in.-sq. mi.) (unit depth of storage)}$$

18.416 (in. - sq. mi.) ÷ 8.7 (sq. mi.) = 2.117 (in. storage) (total depth of storage)

3. Gaging Station Correlation with Reservoir

Station 5575 (Bald Eagle Cr. @ Tyrone) Yield-Storage-Frequency Curves (Ref: DEP Bulletin No. 7)

8 Year Return Period (12.5% Percent of Time (Mean) - Limit of Freq. Curve)

44.1 (sq. mi.) Drainage Area at Station

6 Month Critical Duration Mean Flow = 1.76 (in./mo.)

25 % of Mean Flow 1.76 (in./mo.) x (12 mo.) = 21.12 (in. runoff)

$$\text{Storage as \% of runoff} = \frac{2.117 \text{ (in. storage)}}{21.12 \text{ (in. runoff)}} \times 100\% = 10.02\%$$

4. Expected Net Lake Evaporation Rate & Loss

Pittsburgh Station E_{DM} = 9.25 (in.) (Critical Duration = 7 mo., Recurrence Int. = 2 yr. (50% Mean))

1.02 (C) (Adj. for Evaporation Recurrence Interval (Duration = 7 mo., Recurrence Interval = 8 yr.))

1.02 (C) x 9.25 (in. E_{DM}) x 0.083 (ft./in.) = 0.783 (ft.)

65% Surface Area Reservoir Elevation Where Storage Above & Below is Equal

42.3 (ac.) x .65 = 27.5 (ac.) effective surface evaporation area

0.783 (ft.) x 27.5 (ac.) = 21.53 (ac. ft.) x 0.326 (mg/ac.ft.) = 7.02 (mg) (Evaporation Loss)

7.02 (mg) evap. loss ÷ 6 mo. duration ÷ 30.4 (day/mo.) = 0.0385 mgd (Evaporation Rate)
0.060 cfs

Appendix D

Hydraulic Analysis of Selected System Components

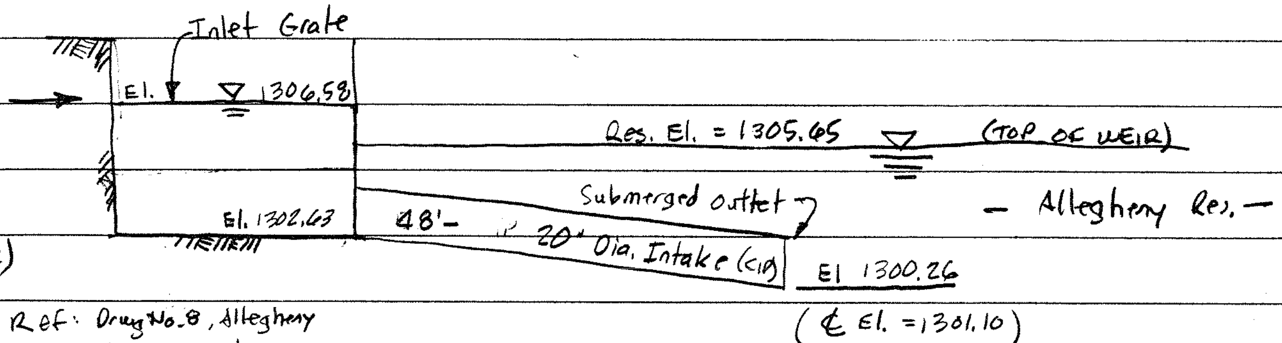
AWA ROP No. 10057

BY: NG

DATE: MAY 4, 2010

"Allegheny Reservoir Intake Hydraulic Analysis"

NOTE! Assume Inlet Grates are Clogged At High Flows (Conservative) Therefore, H_1 = 1306.58 ft (max)



Ref: Drwg No. 8, Allegheny Reservoir Hyd. Eval., 07/06/79

— Allegheny Reservoir Intake Sketch —

1. Compute Capacity – Inlet Control (Ref. "Handbook of Hydraulics", 6th Ed Prater & King)

$$Q = C_d A (2gh)^{1/2}$$

$$Q = 0.62(2.18)\left[(2(g)(0.93))\right]^{1/2}$$

Q = 10.46 cfs (6.76 mgd) {Inlet Control}

h = Channel El. – Res El.

h = 1306.58 – 1305.65 = 0.93 ft

C_d = 0.62 (Sharp-Edged Entrance)

$A = \pi d^2/4 = \pi (20/12)^2/4 = 2.18$

2. Compute Capacity – Outlet Control (Ref. "Water Resources Eng'r", 3rd Ed., Linsley, et al)

$$h_L = \left(K_e + K_o + \frac{29 n^2 (L)}{R^{4/3}}\right)\frac{v^2}{2g}$$

$$0.93 = \left(0.5 + 1.0 + \frac{29(.015)^2(48)}{(0.417)^{4/3}}\right)\frac{v^2}{2(g)}$$

h_L = 1306.58 – 1305.65 = 0.93 ft

K_e = 0.50 (Sharp Edge, flush inlet)

n = 0.015 (old cast iron pipe)

L = 48 ft

R = A/wp = 2.18/5.23 = 0.417 ft.

v = 4.89 ft/sec

Q = VA = 4.89 (2.18) = **10.66 cfs** (6.89 mgd)

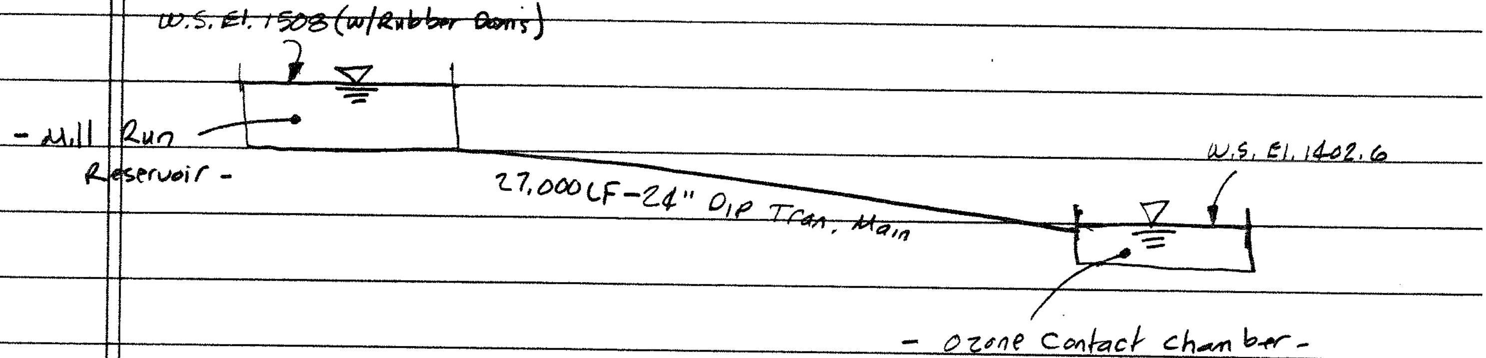
3. Capacity of Intake = **10.46 cfs (6.76 mgd)**

AWA ROP No. 10057

BY: WG

DATE: MAY 4, 2011

"Mill Run Water Transmission Main Capacity"



- Mill Run Transmission Main Sketch - Horseshoe Curve WTP -

1. Compute Gravity Hydraulic Capacity of Mill Run Water Tran. Main

a. $Q = 0.279\ C\ D^{2.63}\ S^{0.54}$

$C = 100$ to 130 (40 year old pipe)

$S = \frac{h}{L}$

$h = 1508 - 1402.60 = 105.4$

$L = 27{,}000$ ft (Mill Run Dam to WTP)

$S = h/L = 105.4 / 27{,}000$

$S = 0.0039$ ft/ft

$Q = 0.279(100)(2)^{2.63}(0.0039)^{0.54}$

$Q =$ **8.64 mgd** (5.58 cfs) @ C=100

b. $Q = 0.279\ C\ D^{2.63}\ S^{0.54}$ (C=110)

$Q = 0.279(110)(2)^{2.63}(0.0039)^{0.54} =$ **9.5 mgd** (6.13 cfs) (C=110)

c. $Q = 0.279\ C\ D^{2.63}\ S^{0.54}$ (C=120)

$Q = 0.279(120)(2)^{2.63}(0.0039)^{0.54} =$ **10.36 mgd** (6.70 cfs) (C=120)

d. $Q = 0.279(130)(2)^{2.63}(0.0039)^{0.54} =$ **11.23 mgd** (7.25 cfs) (C=130)

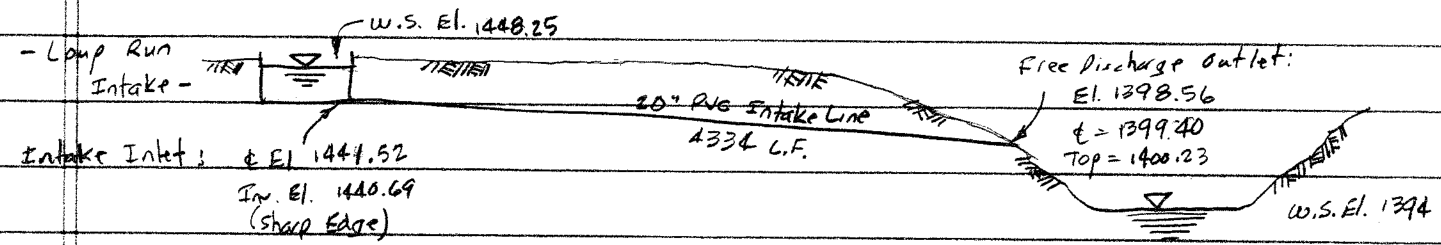
∴ Flow Capacity Could Range From 8.6 to 11.2 mgd, depending on condition of Pipe! Since Max. Permitted withdrawal from Mill Run is 5.0 mgd, 24" Main has adequate Capacity!

AWA ROP No. 10057

BY: NG
DATE: FEB. 1, 2010

"Loup Run Intake Hydraulic Analysis"

A. Capacity of Intake Line to Tipton Reservoir



- Hydraulic Sketch - Loup Run Intake -   - Tipton Reservoir -

1. Compute Capacity - Inlet control (Ref. "Handbook of Hydraulics," 6th Ed., Prater & King)

$$Q = C_d A (2gh)^{1/2}$$

h = W.S. El. - Intake ℄ El.

$h = 1448.25 - 1441.52 = 6.73$ ft.)

$$Q = 0.62\left[\left(\frac{20}{12}\right)^2 \pi/4\right]\left[(2(32.2)(6.73)\right]^{1/2}$$

$C_d = 0.62$ (Sharp-edged entrance

$A = \pi d^2/4 = \pi\,(20/12)^2/4 = 2.18\ ft^2$

$Q =$ **28.1 cfs (18.2 mgd or 12,6?? gpm)**

2. Compute capacity - outlet control (Ref "Water Resources Eng'r." 3rd Ed, Linsley, et al)
(Assume h_L is effective to top of outlet)

$$h_L = \left(K_e + 1 + \frac{29 n^2 (L)}{R^{4/3}}\right)\frac{V^2}{2g}$$

h_L = (1448.25 - 1400.23) = 48.02 ft.
(W.S. El.) (Top of outlet)

$$48 = \left(0.5 + 1.0 + \left[\frac{29(0.01)^2(4334)}{(0.417)^{1.333}}\right]\right)\frac{V^2}{2(32.2)};\ V = 8.6\ fps.$$

~~$K_e = 0.5$ (sharp-edge inlet)~~

$n = 0.01$ (PVC pipe) ≈ f

$L = 4{,}334$ ft.

$R = A/wp = 2.18/5.23 = 0.417$

$Q = VA = 2.18\,(8.6) =$ **18.73 cfs (12.1 mgd or 8407 gpm)**

3. Compute open channel flow (Mannings formula) - Assume Normal Flow
(For Information Purposes Only)

$$Q = 1.49/n\ S^{1/2}\ R^{2/3} A$$

$n = 0.010$ (PVC)

$wP = \pi d = 3.14\left(\frac{20}{12}\right) = 5.23$

$$Q = 1.49/0.010\,(48/4334)^{1/2}\left(\frac{2.18}{5.23}\right)^{2/3}(2.18) = \textbf{19.1 cfs (12.3 mgd)}$$

$A = \frac{\pi d^2}{4} = \frac{3.14(20/12)^2}{4} = 2.18$

(cont.)

B. Summary of Computed Discharges – Loup Run Intake

1. Inlet Control Capacity = 28.1 cfs
2. Outlet Control Capacity = 18.7 cfs ← controls!
3. Normal Flow = 19.1 cfs (for info. purposes only)

☆ use 18.7 cfs as max. discharge capacity for Loup Run Intake (12.1 mgd or 8,400 gpm)

APPENDIX E

DRAFT DROUGHT CONTINGENCY PLAN

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATERSHED MANAGEMENT

DROUGHT CONTINGENCY PLAN CHECKLIST

Please include this checklist with your plan. Place a checkmark in the "Yes" box where the item is included in the plan.

Yes	
☒	Each plan shall include a completed Drought Contingency Plan Summary form.
The following are requirements of: 4 Pa. Code Chapter 118, Section 4 Contingency Plans--- Public Water Supply.	
☒	Each public water supply agency shall submit three copies of the drought contingency plan to the Commonwealth Drought Coordinator, for distribution to PEMA, the Department and other interested Commonwealth agencies, including the Pennsylvania Public Utility Commission if applicable. Each public water supply agency shall submit a copy of the drought contingency plan to the counties in which the public water supply agency serves water.
☒	The name, address and telephone number of the public water supply agency, and the names of officers or other persons responsible for directing operations during a drought emergency.
☒	A description of the ground and surface water sources utilized by the system, including all interconnections, and the locations and yields of the sources.
☒	Data indicating the total water obtained from each source in the same year as the preceding (above) inventory of water sources.
☒	Data indicating the average Annual and Maximum daily water use for the system for the most recent year of record.
☒	A description of criteria to be used by the agency in identifying the onset of water shortage problems in the system.
☒	A plan of actions which will be taken by the public water supply agency to respond to drought or water shortage conditions, including public notice such as newspaper, radio or television notice, a water conservation program, development of emergency supplies, and rationing. The plan shall provide for actions to be taken to achieve a phased reduction of total system withdrawal and use.
☒	A procedure for the granting of variances or exemptions to the provisions of a plan to address extraordinary hardships which may exist as a result of a plan, including a provision for appeal as specified in § 120.9(e) (relating to excess use charges). For purposes of this section, "extraordinary hardship" means a permanent damage to property, including perishable raw or processed products, or other personal or economic loss which is substantially more severe than the sacrifices borne by other water users subject to a public water supply agency's drought contingency plan. The procedure shall include, when appropriate, consideration of: (i) Impact of water use reductions upon: a. Public health and safety, including pharmaceutical processes. b. Food and raw fiber production, including protection of perishable raw or processed products. c. Delivery of electric generation services. d. The maintenance of employment. (ii) The measures and efforts previously undertaken to conserve water or to provide for water storage and releases, and the ability of users to implement additional conservation measures.

If any of the required items are not included please explain on the next page.

Public Water Supply Agency

Drought Contingency Plan

ALTOONA WATER AUTHORITY
(Name of Public Water Supply Agency)

JULY 28, 2011
(Date Submitted)

1) Name, address, and telephone number of the public water supply agency.

Name of Agency: ALTOONA WATER AUTHORITY

Address: 900 CHESTNUT AVENUE, ALTOONA, PA 16601-4617

Telephone No: (814) 949-2222 Fax: (814) 949-2254

2) Name, address and telephone number of officers or other persons responsible for directing operations during a drought emergency.

Name of Agency: MARK A. PERRY, GENERAL MANAGER

Address: 900 CHESTNUT AVENUE, ALTOONA, PA 16601-4617

Telephone No: (814) 949-2222 Fax: (814) 949-2254

E-mail Address: mperry@altoonawater.com

Name of Agency: MICHAEL V. SINISI, P.E., AUTHORITY ENGINEER

Address: 900 CHESTNUT AVENUE, ALTOONA, PA 16601-4617

Telephone No: (814) 944-2597 Fax: (814) 949-8921

E-mail Address: msinisi@altoonawater.com

3) **A description, including locations and yields, of the water sources used by the facility as well as water available through interconnections with other public water supply agencies.**

Surface Water: (Stream, spring, reservoir, pond, quarry, etc.)

Name	Location	Safe Yield (gpd)

Refer to Plan of Reservoir System and June 2011 Reservoir Operation and Management Plan

Ground Water: (wells) (Disonnected from System; Potential Emergency Water Source)

Name	Location	Safe Yield(gpd)
31st Street Well Field	31st Street & Industrial Railroad	Well No. 1 - 280,000
	City of Altoona, PA	Well No. 2 - 720,000
		Well No. 3 - 1,000,000
		Total - 2,000,000

Interconnections (names of water suppliers; also list locations and maximum amounts available)

Name of Supplier	Location	Maximum Amount Available
Borough of Hollidaysburg	Plane 9 WTP	1.45 MGD
Borough of Bellwood	Bellwood WTP	0.85 MGD
Borough of Duncansville	Plane 9 Transmission Main	0.50 MGD
Freedom Twp. Water & Sewer Auth.	Plane 9 Transmission Main	0.1095 MGD
Blair Twp. Water & Sewer Auth.	Plane 9 Transmission Main	0.45 MGD
Mill Road Water Assn.	Plane 9 Transmission Main	0.003 MGD
Grandview Trailer Park	Plane 9 Transmission Main	0.006 MGD
Willowbrook Mobile Home Park.	Plane 9 Transmission Main	0.035 MGD

Description of the operation and how the above sources are used.

Normal operation of the regional, multi-reservoir water supply is governed principally by reservoir management and economic concerns. The system consists of 12 reservoirs with a total capacity of 2.85 billion gallons and maximum permitted withdrawal rate of 14.5 mgd. Current consumption is 9.0 mgd. Historically, the system has not been affected by drought conditions over the last 30 years, especially since recent lost-water efforts have been successful (15 - 18%). The reservoirs have maintained sufficient storage for even the most severe depletion condition. Therefore, the factors that govern system management include location of individual gravity storage, reservoir water quality, intermunicipal supply requirements, cost of treatment and transmission, reservoir capacity. Typically, the Authority operates the Horseshoe Curve, Tipton, Plane Nine, Bellwood and Mill Run Reservoir systems on a continuous basis. The Kettle and Homer Gap systems are operated on a stand-by/contingency status based on water quality, operating cost and water supply considerations. Depending on the level of storage and depletion conditions, the entire reservoir storage system is available to meet system demand. The system is entirely interconnected with the ability to transfer water throughout the service area and by a complex system of gravity and pumped transmission lines. Refer to the June 2011 Reservoir Operation and Management Plan.

4) **Data indicating the average Annual and Maximum daily water use for the system for the most recent year of record.**

Year of Record	**2010**	
Average (annual) Daily Water Use	**9,277,409**	**gpd**
Maximum Daily Water Use	**12,084,004**	**gpd**
Average Daily Water Use	**9,000,000**	**gpd**

5) **Data indicating the total water obtained from each source in the same year used in Question 3.**

No.	Source: Include all interconnections; if there are more than 12 sources, group the smallest ones into No. 12.	Total water used During Year, MG
1	Mill Run Reservoir	941.5
2	Allegheny Reservoir (Mill Run System)	Included with Mill Run
3	Homer Gap Resevroir	0.0
4	Kittanning Point Reservoir (Horseshoe Curve System)	Included with Impounding Reservoir
5	Wm L. Cochran Impounding Reservoir (Horseshoe Curve System)	547.50
6	Lake Altoona (Horseshoe Curve System)	Included with Impounding Reservoir
7	Plane Nine Reservoir (Plane Nine System)	593.0
8	Blair Gap Reservoir (Plane Nine System)	Included with Plane Nine
9	Muleshoe Reservoir (Borough of Hollidaysburg - Operated as Part of Plane Nine System)	Included with Plane Nine
10	Tipton Reservoir (Includes Loup Run Intake)	453.0
11	Bellwood Reservoir	750.0
12	Kettle Reservoir	0.0
13	31st Street Well Field	0.0

6) **A description of criteria *(Trigger Points)* to be used by the Supplier in identifying the various onset of drought response levels in the system.**

Write a brief description of the triggers used and the reason for their selection
(see guidelines" in Pa. DEP drought information center).

Operation of the regional, multi-reservoir water supply system depends on a number of factors not entirely related to storage. These include cost of treatment and transmission, intermunicipal supply requirements, capacity of individual reservoirs, reservoir water quality and location of individual gravity storage. The June 2011 Reservoir Operation and Management Plan utilized simulation modeling to determine dependable or safe yields from the reservoir sources. Res-Sim (Version 3.0) developed by the US Army Corps of Engineers, modeled each reservoir according to various demand conditions. The analysis included a reliability and deficiency assessment, depletion and drought duration determination and shortage index calculations for individual reservoir sources. Fundamental to the analysis is the fully integrated nature of the distribution system. This allows individual reservoir systems in deficit to be supplemented with those reservoirs systems in surplus. Distribution system transfers (pump stations and storage tanks) accomplish these functions. It was determined that a dependable flow of 12.82 mgd approximates the 50-year drought condition. Therefore, a baseline of 12.0 mgd was established which can safely be delivered during drought periods within the parameters of state drought declarations and without mandatory restrictions. For demands above 12 mgd and when storage levels dictate, a combination of voluntary and mandatory restrictions were simulated for various demands and staged storage levels established. Please refer to the Reservoir Operation and Management Plan for the justification of staged drought triggers.

7) **A plan of actions (Supply Extension Measures and Demand Reduction Measures) which will be taken by the public water supply agency to respond to drought or water shortage conditions. (See next Page)**

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATERSHED MANAGEMENT

ALTOONA WATER AUTHORITY
(BLAIR COUNTY)
DROUGHT CONTINGENCY PLAN SUMMARY

Date Adopted by PWS July 28, 2011 Date Approved by DEP ____________

Trigger Point	Demand Measures	Supply Measures
DROUGHT WATCH (STAGE I) - For Total System Demand Below 12.0 MGD - Trigger: State Declares Drought Watch for the Area. Monitor Storage Levels and Days Remaining until Feb. 28 For Total System Demand Above 12.0 MGD - Trigger: See Attached Table	**STAGE I** Voluntary Restrictions on Nonessential Water Use Conduct Public Notices	System-wide Leakage and Loss Reduction Survey
DROUGHT WARNING (STAGE II) - For Total System Demand Below 12.0 MGD - Trigger: State Declares a Drought Warning for the Area. Monitor Storage Levels and Days Remaining Until Feb. 28 For Total System Demand Above 12.0 MGD - Trigger: See Attached Table	**STAGE II** Identify Customers That Could Be Shed From System: INDUSTRIAL CUSTOMERS NON-ESSENTIAL PUBLIC USE (HIGH) COMMERCIAL CUSTOMERS USE Notify the Division of Water Use Planning at 717-772-4048 if State has not issued drought warning.	Identify Reserve Sources of Interconnections: Borough of Hollidaysburg Borough of Bellwood Borough of Duncansville Blair Twp. Water & Sewer Auth. Freedom Twp. Water & Sewer Authority (3 private water systems per Water Allocation Permit) Request Instream Flow Requirement Reduction, If Applicable (Contact the Commonwealth Drought Coordinator for approval. Use Form 3900-FM-WM0026.)
DROUGHT EMERGENCY (STAGE III) - For Total System Demand Below 12.0 MGD - Trigger: Governor Declares a Drought Emergency for the Area. For Total System Demand Above 12.0 MGD - Trigger: See Attached Table	**STAGE III** Implement Water Rationing Plan After Approval by the Commonwealth Drought Coordinator (if authorized). Shed Customers Identified in Stage II Work closely with Local Officials and have Intensive Public Relations to keep all Customers Informed of Daily Status.	List Emergency Sources and Equipment Necessary to Utilize Each Source. 31st Street Wellfield (pumping/chlorination system operational with proper testing/monitoring) Request Instream Flow Requirement Reduction, If Applicable (Contact the Commonwealth Drought Coordinator for approval. Use Form 3900-FM-WM0026.)

Altoona Water Authority
Drought Contingency Plan
Trigger Points

Stage I - Drought Watch

a. For total system demand below 12.0 mgd,
Trigger: State Declares Drought Watch for the Area

b. For total system demand above 12.0 mgd, Trigger:

Demand	System Storage (mg)	% Total	System Storage Days
12.0	1,080	41	90
12.5	1,200	45	96
12.8	1,269	48	99
13.0	1,319	50	101
13.5	1,446	55	107
13.75	1,510	57	110
14.0	1,697	64	121
14.5	2,084	79	144
14.64	2,196	83	150

Note: All reservoir systems brought on-line in the intervening period between Stage I and Stage II.

Monitor Storage Levels and Days Remaining Until February 28.

Stage II - Drought Warning

a. For total system demand below 12.0 mgd,
Trigger: State Declares Drought Warning for the Area

b. For total system demand above 12.0 mgd, Trigger:

Demand	System Storage (mg)	% Total	System Storage Days
12.0	720	27	60
12.5	821	31	66
12.8	885	33	69
13.0	928	35	71
13.5	1,042	39	77
13.75	1,098	41	80
14.0	1,199	45	86
14.5	1,404	53	97
14.64	1,464	55	100

Note: Monitor Storage Levels and Days Remaining Until February 28.

Stage III - Drought Emergency

a. For total system demand below 12.0 mgd,
Trigger: Governor Declares a Drought Emergency for the Area

b. For total system demand above 12.0 mgd, Trigger:

Demand	System Storage (mg)	% Total	System Storage Days
12.0	480	18	40
12.5	571	22	46
12.8	629	24	49
13.0	669	25	51
13.5	771	29	57
13.75	824	31	60
14.0	919	35	66
14.5	1,114	42	77
14.64	1,171	44	80

Petition PADEP for Emergency Utilization of 31st Street Well Field
(1.0 - 2.0 mgd capacity)

8) Procedure for Granting Variances.

This procedure will be implemented if mandatory water use restrictions are imposed and the Governor has not declared a drought emergency in our area.

(1) If compliance with the prohibition of non-essential use of water would result in extraordinary hardship upon a water user, the water user may apply for an exemption or variance, which would expire with the termination of the mandatory water use restrictions, unless otherwise specified in the exemption or variance. For purposes of this section, extraordinary hardship means a permanent damage to property or other personal or economic loss which substantially more severe than the sacrifices borne by other water users subject to the prohibition of non-essential use of water.

(2) A water user believing he suffers an extraordinary hardship and desiring to be wholly or partially exempt from the restrictions on the non-essential use of water shall submit a written request with full documentation supporting the need for the requested relief to the public water supplier responsible for adopting and implementing this plan. The application shall contain information specifying:

(i) The nature of the hardship claimed and reason for the requested exemption or variance.

(ii) The efforts taken by the applicant to conserve water and extent to which water use may be reduced by the applicant without extraordinary hardship.

(3) The public water supplier or a designee will review the application and may request the applicant to provide within a reasonable time additional information as necessary to review the application. A written decision will be provided within seven working days when possible, or if perishable products are involved, within one working day of submission of an application; or a request will be made for additional information as necessary to review an application. The evaluation will consider impacts on public health and safety, food and fiber production and preservation, pharmaceutical processes, electric generation, maintenance of employment, measures already taken by the user to conserve and store water, and the ability to further implement conservation measures. An exemption or variance will be granted only to the extent necessary to relieve extraordinary hardship.

(4) Any person aggrieved by a decision relating to such an exemption or variance rendered by a public water supplier or designee may file, within 30 days of the decision, an action with the Court of Common Pleas in the County where the water service is provided, in accordance with 2 Pa. C.S. §§551 - 555 and 751 – 754 (relating to the Local Agency Law).

(5) An appeal from an initial decision of the public water supplier or designee will not act as a supersedeas, stay or injunction of that decision.

(6) An exemption or variance may be modified or rescinded by the public water supplier if public health, safety and welfare require further reduction in water use.

(7) An exemption or variance granted to a water user for a specific property, purpose or person is not transferable to another property, purpose or water user without approval from the public water supplier.