Flow Equalization

EPA Technology Transfer Seminar Publication

FLOW EQUALIZATION

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NOTICE

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INTRODUCTION AND CONCEPT

GENERAL

The cyclic nature of wastewater flows in terms of volume and strength is well recognized. Nearly all municipal wastewater-treatment plants today are processing unsteady wastewater flows. However, improved efficiency, reliability, and control are possible when physical, biological, and chemical processes are operated at or near uniform conditions. For this reason, flow equalization is employed in the field of water supply and in the treatment of some industrial wastewater. At present, the advent of more demanding water-quality standards is stirring interest in the application of flow equalization to municipal wastewater treatment.

The primary objective of flow-equalization basins for municipal wastewater plants is simply to dampen the diurnal flow variation, and thus achieve a constant or nearly constant flow rate through the downstream treatment processes. A desirable secondary objective is to dampen the concentration and mass flow of wastewater constituents by blending the wastewater in the equalization basin. This results in a more uniform loading of organics, nutrients, and other suspended and dissolved constituents to subsequent processes.

Through achieving these objectives, flow equalization can significantly improve the performance of an existing treatment facility, and is a useful upgrading technique. In the case of new plant design, flow equalization can reduce the required size of downstream facilities.

VARIATIONS OF FLOW EQUALIZATION

Equalization of municipal wastewater flows may be divided into three broad categories.

- Equalization of dry weather flows
- Equalization of wet weather flows from separate sanitary sewers
- Equalization of combined storm and sanitary wastewater

This publication is primarily concerned with equalization of dry weather flows. This procedure provides a technique for achieving normal operation of a treatment plant under near ideal loading conditions. Its relatively low cost makes it attractive for upgrading an overloaded plant.

Increased wet weather flows in sanitary sewers is the sum of two components, infiltration and inflow. In some cases, it is feasible to equalize stormwater inflow, depending on its magnitude and duration. Infiltration from high ground water tables can seldom be equalized. Equalization of wet weather flows from combined storm and sanitary sewers usually requires very large storage basins. The design of equalization basins to deal with these types of flow requires a special knowledge of the collection system, precipitation patterns, topography, and other factors not directly related to wastewater treatment. Strictly speaking, wet weather and combined sewer flow equalization cannot be considered as a wastewater-treatment upgrading technique, and the design of such a facility is beyond the scope of this publication. However, the concepts presented for dry weather flow equalization are generally applicable to equalization of wet weather and combined wastewater flows.

In some instances, large interceptor sewers entering the treatment plant can be effectively used as storage basins to dampen peak diurnal dry weather flow variations. In such cases, velocity becomes of critical importance to avoid deposition and subsequent abnormally heavy "first flush" loads. Nightly or weekly drawdown of the interceptor system is necessary to flush out solids which may have been deposited during the previous storage period.

Although the use of influent sewers for equalization should not be ignored, the most positive and effective means to maximize the benefits possible with equalization is through the use of specially designed equalization basins. These basins should normally be located near the head end of the treatment works, preferably downstream of pretreatment facilities such as bar screens, comminutors, and grit chambers. Adequate aeration and mixing must be provided to keep the basins aerobic and prevent solids deposition.

It is sometimes desirable to locate the equalization basin at strategic locations within the collection system. This offers the added advantage of economically relieving trunk sewer overload during peak flow periods.[1] However, it does result in the need for a pumping facility and therefore is best located where a need for pumping already exists.

Equalization basins may be designed as either in-line or side-line units. In the in-line design shown on figure 1a, all the flow passes through the equalization basin. This results in significant concentration and mass flow damping. In the side-line design shown on figure 1b, only that amount of flow above the daily average is diverted through the equalization basin. This scheme minimizes pumping requirements at the expense of less effective concentration damping.

For new construction and for upgrading large plants, it is desirable to construct compartmentalized or multiple basins. This feature will allow the flexibility to dewater a portion of the facility for maintenance or equipment repair while still providing some flow equalization. Where a basin is designed for storage and equalization of wet weather flows, compartmentalized tanks will allow the utilization of a portion of the basin for dry weather flow equalization.

Single basin installations may be used for upgrading small plants, but must have the provision to be dewatered while maintaining complete treatment. This will require a bypass line around the basin to allow the downstream portion of the plant to operate unequalized when the flow equalization facility is out of service.

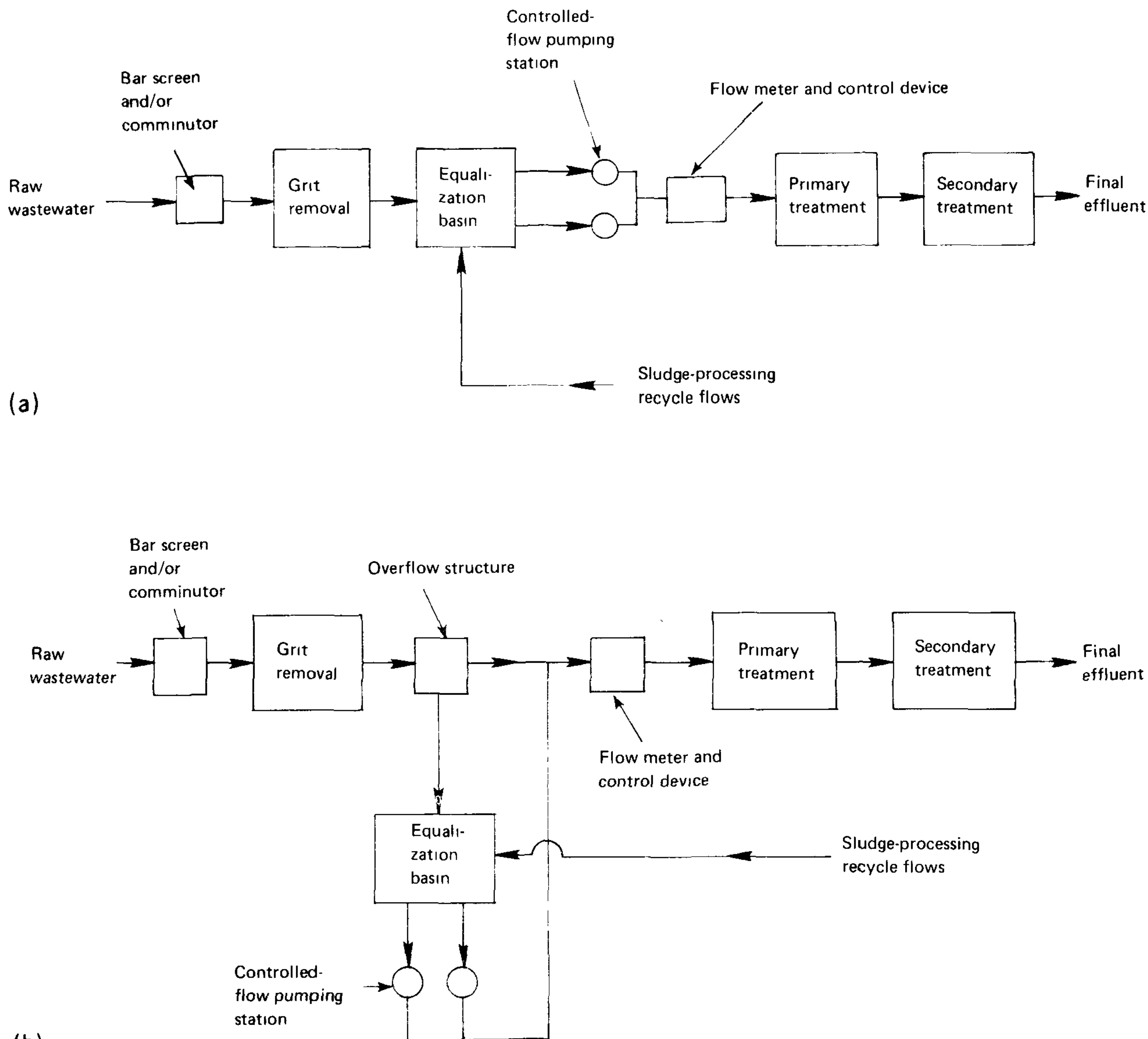


Figure 1. Schematic flow diagrams of equalization facilities: (a) in-line equalization; (b) side-line equalization.

BENEFITS OF DRY WEATHER FLOW EQUALIZATION

Flow equalization has a positive impact on all treatment processes from primary treatment to advanced waste treatment.

IMPACT ON PRIMARY SETTLING

The most beneficial impact on primary settling is the reduction of peak overflow rates resulting in improved performance and a more uniform primary effluent quality. Flow equalization permits the sizing of new clarifiers based on equalized flow rates rather than peak rates. In an existing primary clarifier that is hydraulically overloaded during periods of peak diurnal flow, equalization can reduce the maximum overflow rate to an acceptable level. A constant influent feed rate also avoids hydraulic disruptions in the clarifier created by sudden flow changes, especially those caused by additional wastewater lift pumps suddenly coming on line.

LaGrega and Keenan[2] investigated the effect of flow equalization at the 1.8-mgd Newark, N.Y., Wastewater Treatment Plant. An existing aeration tank was temporarily converted to an equalization basin. They compared the performance of primary settling under marginal operating conditions, with and without equalization. The results are shown in table 1.

It has been demonstrated[3,4] that preaeration can significantly improve primary settling. Roe[3] concluded that preaeration preflocculates suspended solids (SS), thereby improving their settling characteristics. Indications are that this benefit may be realized by aerated equalization basins. This benefit may be diminished when the equalized flow is centrifugally pumped to the primary clarifier, due to the shearing of the floc.

IMPACT ON BIOLOGICAL TREATMENT

As contrasted to primary treatment or other mainly physical processes where concentration damping is of minor benefit, biological treatment performance can benefit significantly from both concentration damping and flow smoothing. Concentration damping can protect biological

Table 1.—*Effect of flow equalization on primary settling, Newark, N.Y.*

Item	Normal flow	Equalized flow
Primary influent SS, mg/l	136.7	128
Primary effluent SS, mg/l	105.4	68
SS removal in primaries, percent	23	47

Note.—Average flow slightly higher in unequalized portion of study.

processes from upset or failure from shock loadings of toxic or treatment inhibiting substances. Therefore, in-line equalization basins are preferred to side-line basins for biological treatment applications.

Improvement in effluent quality due to stabilized mass loading of BOD on biological systems treating normal domestic wastes has not been adequately demonstrated to date. It is expected that the effect will be significant where diurnal fluctuations in organic mass loadings are extreme. This situation may arise at a wastewater-treatment plant receiving a high-strength industrial flow of short duration. Damping of flow and mass loading will also improve aeration tank performance where aeration equipment is marginal or inadequate in satisfying peak diurnal-loading oxygen demands.[5]

The optimum pH for bacterial growth lies between 6.5 and 7.5. In-line flow equalization can provide an effective means for maintaining a stabilized pH within this range.

Flow smoothing can be expected to improve final settling even more so than primary settling. In the activated-sludge process, flow equalization has the added benefit of stabilizing the solids loading on the final clarifier. This has two ramifications:

- The mixed-liquor suspended solids (MLSS) concentration can be increased thereby decreasing the food-to-mass ratio (F/M) and increasing the solids retention time (SRT). This may result in an increased level of nitrification, and a decrease in biological sludge production. It may also improve the performance of a system operating at an excessively high daily peak F/M.

- Diurnal fluctuations in the sludge blanket level will be reduced. This reduces the potential for solids being drawn over the weir by the higher velocities in the zone of the effluent weirs.

MISCELLANEOUS BENEFITS

In chemical coagulation and precipitation systems using iron or aluminum salts, the quantity of chemical coagulant required is proportional to the mass of material to be precipitated. Damping of mass loadings with in-line equalization will improve chemical feed control and process reliability, and may reduce instrumentation complexity and costs.

Flow smoothing will reduce the surface area required and enhance the performance of tertiary filters. A constant feed rate will lead to more uniform solids loadings and filtration cycles.

The equalization basin provides an excellent point of return for recycled concentrated waste streams such as digester supernatant, sludge-dewatering filtrate, and polishing-filter backwash.

Some biochemical oxygen demand (BOD) reduction is likely to occur in an aerated equalization basin. A 10- to 20-percent reduction has been suggested[a] for an in-line basin equalizing raw wastewater. However, the degree of reduction will depend upon the detention time in the basin, the aeration provided, wastewater temperature, and other factors. For an existing treatment plant, a simple series of oxygen uptake studies on a representative sample of wastewater can determine the BOD reduction that will occur.

Roe[3] observed that preaeration may improve the treatability of raw wastewater by creating a positive oxidation-reduction potential, thereby reducing the degree of oxidation required in subsequent stages of treatment.

[a]Dr. Robert E. Baumann, private communication, Iowa State University, Dec. 11, 1972.

DETERMINATION OF EQUALIZATION REQUIREMENTS

The design of an equalization basin requires the evaluation and selection of a number of features as follows:

- In-line versus side-line basins
- Basin volume
- Degree of compartmentalization
- Type of construction—earthen, concrete, or steel
- Aeration and mixing equipment
- Pumping and control concept
- Location in treatment system

The design decisions must be based on the nature and extent of the treatment processes used, the benefits desired, and local site conditions and constraints.

It may not be necessary to equalize the entire influent flow where high flow or concentration variations can be attributed to one source, such as an industry. In these cases the desired benefits can be achieved by simply equalizing the industrial flow. This can be accomplished through construction of an equalization basin at the industrial site or through in-house industrial process modifications to effect an equalized wastewater discharge.

DETERMINATION OF REQUIRED VOLUME

Two methods are available for computing equalization volume requirements. One procedure is based on the characteristic diurnal flow pattern. In this case, the function of the basin is to store flows in excess of the average daily flow and to discharge them at times when the flow is less than the average. The required volume can be determined graphically through the construction of a hydrograph. The second procedure is based upon the mass loading pattern of a particular constituent. This method computes the volume required to dampen mass loading variations to within a preset acceptable range.[6,7]

Since the prime objective of flow equalization in wastewater treatment is to equalize flow, the determination of equalization volume should be based on the hydrograph. Once the volume has been determined for flow smoothing, the effect on concentration and mass load damping can be estimated. The required volumes for side-line and in-line basins will be identical. The hydrograph procedure is discussed below.

The first step in design involves the establishment of a diurnal flow pattern. Whenever possible, this should be based upon actual plant data. It is important to note that the diurnal pattern will

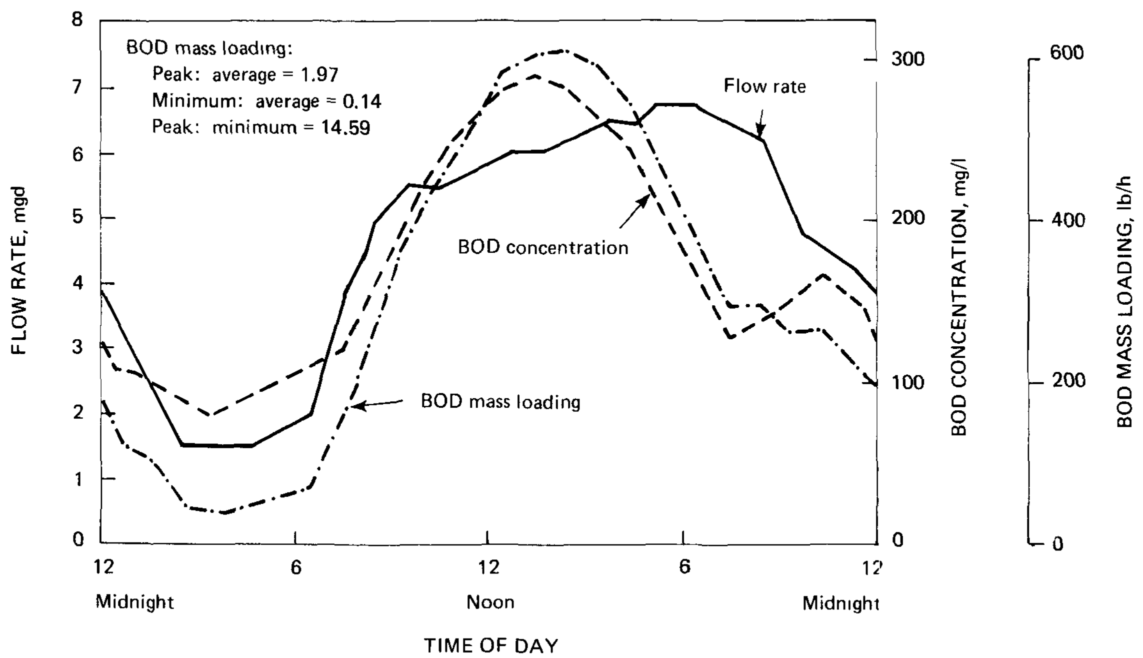


Figure 2. Raw wastewater flow and BOD variation before equalization.

vary from day to day, especially from weekday to weekend, and also from month to month. The pattern selected must yield a large enough basin design to effectively equalize any reasonable dry weather diurnal flow. Figure 2 depicts a typical diurnal flow pattern. The average flow rate is 4.3 mgd. For purposes of this example, the average flow is used as the desired flow rate out of the equalization basin. The diurnal peak and minimum flow rate for this example are 1.7 and 0.45 times the average, respectively.

The next step involves the actual construction of the hydrograph. The hydrograph for this example is shown on figure 3. The inflow mass diagram is plotted first. To do this, the hourly diurnal flows are converted to equivalent hourly volumes, and accumulated over the 24-hour day. A line is then drawn from the origin to the end point on the inflow-mass diagram. The slope of this line actually represents the average flow for the day.

Enough tank volume must be provided to accumulate flows above the equalized flow rate. This normally requires a volume equivalent to 10 to 20 percent of the average daily dry weather flow. To determine this volume, the inflow mass diagram must be enveloped with two lines parallel to the average flow line and tangent to the extremities of the inflow mass diagram. These are shown as lines A and B on figure 3. The required volume is represented by the vertical distance between these two lines. In this illustration, the required volume for equalization is 740,000 gallons, which represents approximately 17 percent of the average daily flow.

The physical interpretation of the hydrograph is simple. At 8 a.m. the equalization basin is empty, as signified by the tangency of the inflow mass diagram with the bottom diagonal. At this point, plant flow begins to exceed the average flow rate and the tank begins to fill. This is represented by the divergence of the inflow mass diagram and the bottom diagonal. At 5 p.m. the basin is full, as shown by the tangency of the inflow mass diagram with the top diagonal. Finally, the tank is drawn down from 5 p.m. to 8 a.m. on the following day, when the flow is below average.

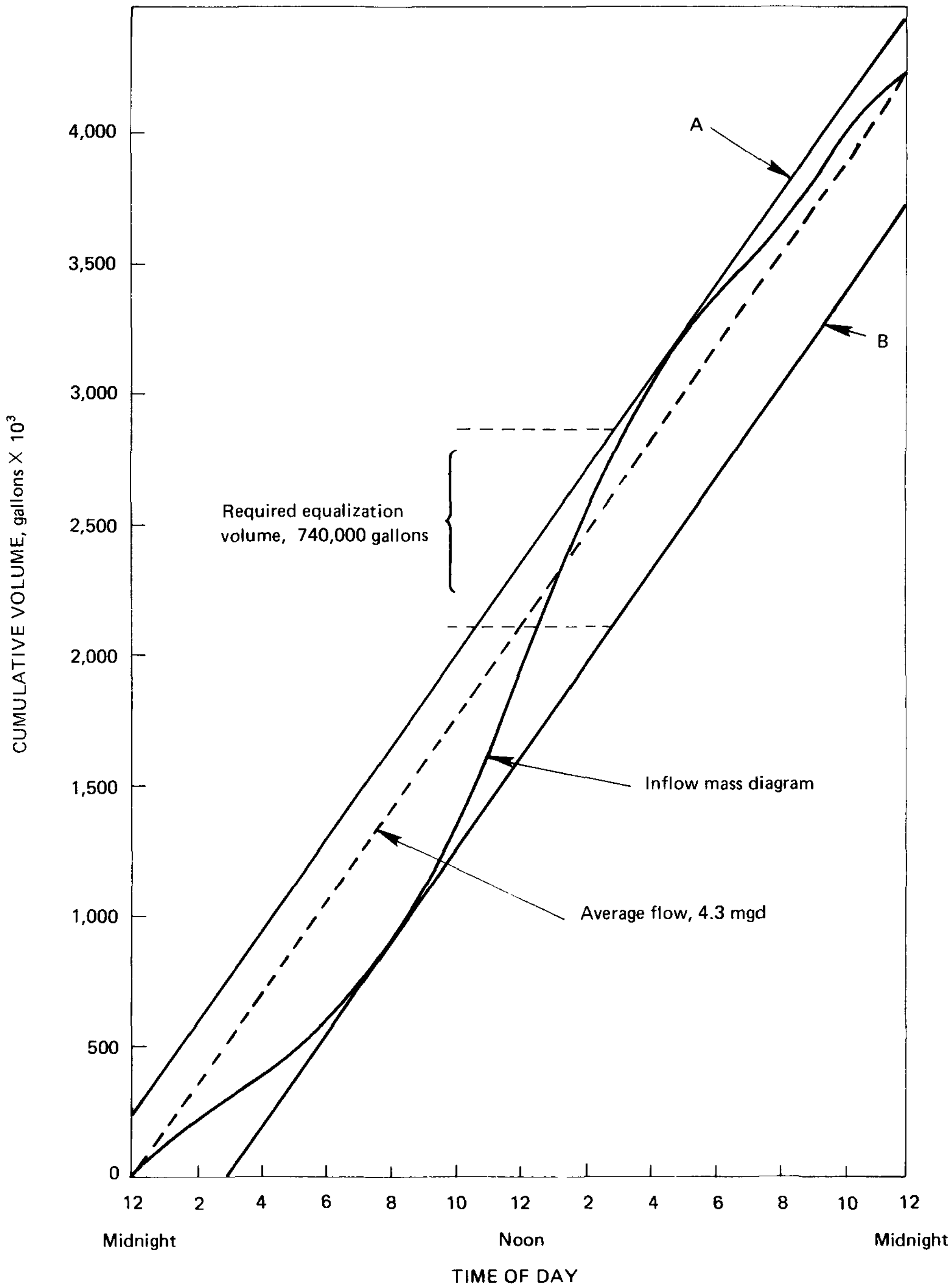


Figure 3. Hydrograph for typical diurnal flow.

The actual equalization-basin volume must be greater than that obtained with the hydrograph for several reasons, including

- Continuous operation of aeration and mixing equipment will not allow complete drawdown.
- Volume must be provided to accommodate anticipated concentrated plant recycle streams.
- Some contingency should be provided for unforeseen changes in diurnal flow.

The final volume selected should include adequate consideration of the conditions listed above and will also depend on the basin geometry. For the example presented herein, a basin volume of approximately 1 million gallons is adequate.

IMPACT OF EQUALIZATION ON DIURNAL CONCENTRATION VARIATION

At this point, it is appropriate to examine the impact of flow equalization on mass loading and concentrations. As previously mentioned, side-line equalization has a minimal effect on diurnal concentration variations. The following discussion is therefore limited to in-line basins.

An hourly concentration plot for raw wastewater BOD is plotted with the diurnal flow pattern on figure 2. Note that low BOD concentrations occur at night with low flows, and high BOD concentrations occur during the daytime with high flows. This is a typical pattern for dry weather flows and BOD's. Because of this characteristic, the mass loading rate of raw wastewater BOD, shown on figure 2, exhibits even greater fluctuations. If this wastewater is equalized in a 1 million gallon in-line basin, the equalized flow will exhibit the characteristics shown on figure 4, provided

- The basin is designed to provide complete mixing.
- There is no BOD reduction in the basin.

This damping effect would be similarly beneficial for all concentration variables including SS, nitrogen, phosphorus, and toxic constituents.

On figure 4, the changes in BOD concentration are most pronounced during periods of minimum wastewater volume in the equalization tank. If desired, increased damping can be achieved by increasing the active volume of the tank, i.e., the volume in excess of that obtained from the hydrograph.

BASIN CONSTRUCTION

Equalization basins can be provided through the construction of new facilities or through the modification of existing facilities of sufficient volume. Equalization may be implemented with relative ease in an upgrading plan that calls for the abandonment of existing tankage. Facilities which may be suitable for conversion to equalization basins include aeration tanks, clarifiers, digesters, and sludge lagoons.

New basins may be constructed of earth, concrete, or steel. Earthen basins are generally the least expensive. They can normally be constructed with side slope varying between 3:1 and 2:1 horizontal to vertical, depending on the type of lining used. To prevent embankment failure in areas of high ground water, drainage facilities should be provided for ground water control. In large basins where a combination of aerator action and wind forces may cause the formation of large waves, precaution should be taken in design to prevent erosion. It is also customary to provide a concrete pad directly under the equalization basin aerator or mixer. The top of the dikes should be wide enough to insure a stable embankment. For economy of construction, the top width of the dike should be sufficient to accommodate mechanical compaction equipment.

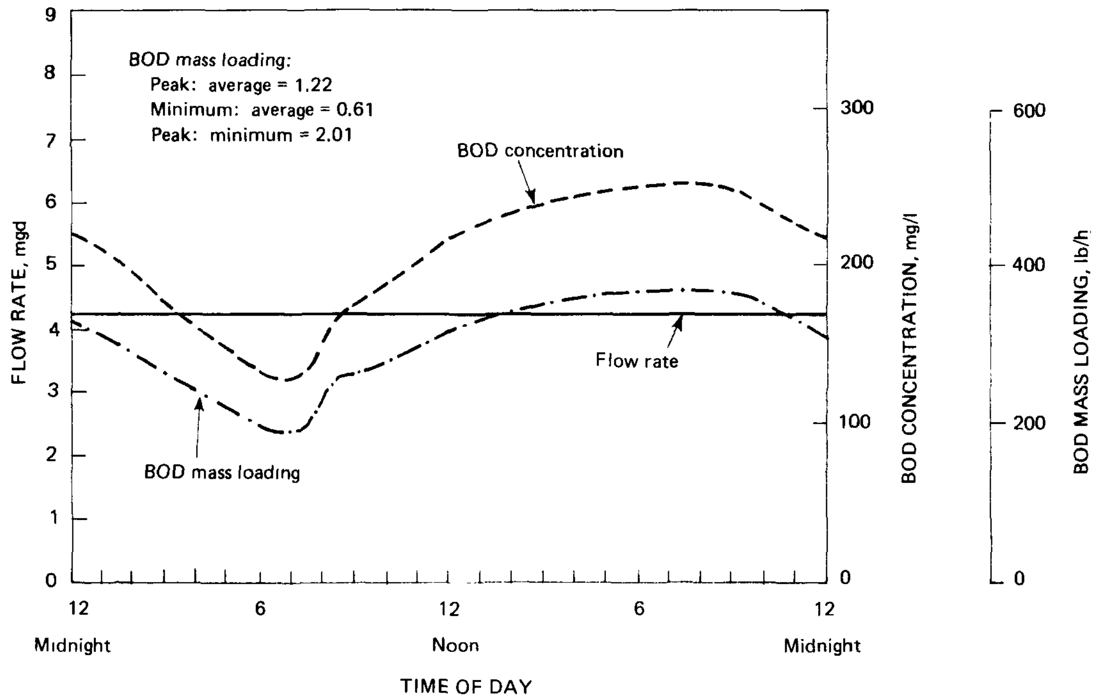


Figure 4. Raw wastewater flow and BOD variation after equalization.

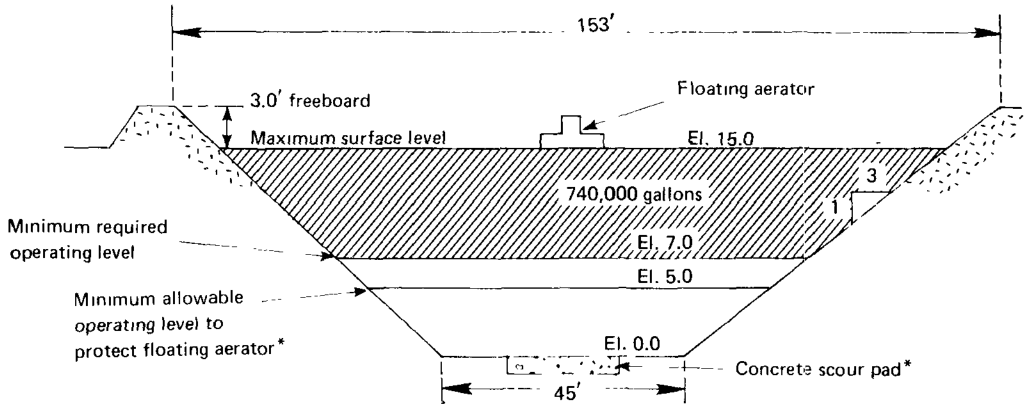
In-line basins should be designed to achieve complete mixing in order to optimize concentration damping. Elongated tank design enhances plug flow and should be avoided. Inlet and outlet configurations should be designed to prevent short circuiting. Designs which discharge influent flow as close as possible to the basin mixers are preferred.

To continue the previous illustration, an earthen basin has been selected for the equalization facility. A square plan has been chosen to effect optimum mixing. A section view of the basin with appropriate dimensions is shown on figure 5. The volume requirement computed from the hydrograph is provided in the upper 8 feet. Note that the minimum required operating depth lies above the minimum allowable aerator operating level.

AIR AND MIXING REQUIREMENTS

The successful operation of both in-line and side-line basins requires proper mixing and aeration. Mixing equipment should be designed to blend the contents of the tank, and to prevent deposition of solids in the basin. To minimize mixing requirements, grit removal facilities should precede equalization basins wherever possible. Aeration is required to prevent the wastewater from becoming septic. Mixing requirements for blending a municipal wastewater having an SS concentration of approximately 200 mg/l range from 0.02 to 0.04 hp per 1,000 gallons of storage. To maintain aerobic conditions, air should be supplied at a rate of 1.25 to 2 ft^3/min per 1,000 gallons of storage.[8]

Mechanical aerators are one method of providing both mixing and aeration. The oxygen transfer capabilities of mechanical aerators operating in tap water under standard conditions vary from 3 to 4 pounds O_2 per horsepower-hour. Baffling may be necessary to insure proper mixing, particularly with a circular tank configuration. Minimum operating levels for floating aerators



Volumes.
El. 0.0 to El. 7.0 approximately 260,000 gallons
El. 7.0 to El. 15.0 approximately 740,000 gallons
Total volume = 1,000,000 gallons

*These dimensions will vary with aerator design and horsepower

Figure 5. Earthen equalization basin.

generally exceed 5 feet, and vary with the horsepower and design of the unit. Low-level shutoff controls should be provided to protect the unit. The horsepower requirements to prevent deposition of solids in the basin may greatly exceed the horsepower needed for blending and oxygen transfer. In such cases, it may be more economical to install mixing equipment to keep the solids in suspension and furnish the air requirements through a diffused air system, or by mounting a surface aerator blade on the mixer.

It should be cautioned that other factors, including maximum operating depth and basin configuration, affect the size, type, quantity, and placement of the aeration equipment. In all cases, the manufacturer should be consulted.

PUMP AND PUMP CONTROL SYSTEMS

Flow equalization imposes an additional head requirement within the treatment plant. As a minimum, this head is equal to the sum of the dynamic losses and the normal surface level variation. Additional head may be required if the basin is to be dewatered to a downstream location. It may be possible to dewater the basin upstream (e.g., ahead of raw wastewater pumps) by gravity.

Normally, the head requirement cannot be fulfilled by gravity, thereby requiring pumping facilities. The pumping may precede or follow equalization. In some cases pumping of both raw and equalized flows will be required. Influent pumping will require larger capacity pumps to satisfy diurnal peaks.

Gravity discharge from equalization will require an automatically controlled flow-regulating device.

A flow-measuring device is required downstream of the basin to monitor the equalized flow. Instrumentation should be provided to control the preselected equalization rate by automatic adjustment of the basin effluent pumps or flow-regulating device.

MISCELLANEOUS CONSIDERATIONS

The following features are considered to be desirable for the design of the equalization facility:

- Equalization should be preceded if possible with screening and grit removal to prevent grit deposition and rag fouling of equipment in the basin.
- Surface aerators should be fitted with legs to support and protect the units when the tank is dewatered.
- Facilities should be provided to flush solids and grease accumulations from the basin walls.
- A high-water-level takeoff should be provided for withdrawing floating material and foam.
- An emergency overflow should be provided.

COSTS

The development of alternatives for any plant upgrading program should include at least one which incorporates flow equalization. In all cases, the added cost of flow equalization must be measured against the savings in cost of modifying downstream processes to accept diurnal variations and the improved performance that can be achieved by operating downstream processes under relatively constant loading conditions.

The cost of flow equalization will vary considerably from one application to another, depending on the basin size, construction selected, mixing and aeration requirements, availability of land, location of facility, and pumping requirements. Some judgment must be made on the distribution of pumping costs. Pumping costs for an equalization basin used to upgrade existing facilities should be charged to the basin.

Capital costs for equalization facilities have been estimated by Smith et al.[9] and are listed in table 2. The costs for earthen basins include plastic liner and floating mechanical aerators. The costs for the concrete basins include diffused aeration facilities. Pumping costs are based on the construction of a separate equalization basin effluent pumping station. The costs were developed in conjunction with activated-sludge treatment-system designs, and therefore include a proportional amount of the engineering fees and interest during construction.

The construction cost for the earthen equalization basin on figure 5 is estimated at $80,000. The cost includes excavation, plastic liner, sand subbase, concrete scour pad, dike fill, underdrain, and a 40-hp floating aerator. The costs do not provide for pumping costs, land costs, engineering and legal fees, nor interest during construction.

Table 2.—*Cost of equalization facilities (EPA Index 175)*

Plant size, mgd	Basin size, millions of gallons	Earthen basin		Concrete basin	
		With pumping	Without pumping	With pumping	Without pumping
1	0.32	$124,000	$ 72,300	$175,000	$124,000
3	.88	170,000	84,000	333,000	247,000
10	2.40	318,000	134,000	779,000	595,000

PERFORMANCE AND CASE HISTORIES

Little full-scale operating data are currently available to compare the performance of wastewater-treatment plants with and without flow equalization. However, an increasing number of plant designs are incorporating the use of equalization facilities for upgrading existing plants and construction of new plants. The following case histories are presented as examples of equalization basin design.

YPSILANTI TOWNSHIP, MICH.

A flow-equalization project at the Ypsilanti Township Sewage Treatment Plant is currently under way. The treatment facility consists of two adjacent activated-sludge plants recently upgraded from 7.0 mgd to treat a total flow of 9.0 mgd. Two 350,000-gallon digesters have been converted to equalization tanks. Data will be collected over a 2-year study period for each plant. The flow will be equalized to one plant the first year while background data are collected for the remaining plant. The situation will be reversed the second year, with the flow being equalized to the second plant while unequalized flow performance data are collected on the first plant. Comparison of these data will be made to determine the beneficial effects of flow equalization on each plant.

FOND DU LAC, WIS.

This case illustrates a situation in which only a portion of the flow is equalized. The city of Fond du Lac, Wis., presently employs a single-stage trickling-filter plant to treat combined municipal-industrial wastes. Placed in operation in 1950, the plant was designed to treat an ultimate dry weather flow of 8.0 mgd and a BOD loading of 12,500 lb/d. The facility is presently treating an average of 7.1 mgd with a BOD loading of 24,000 lb/d, and hence is organically overloaded. This condition is aggravated by the fact that the waste discharges from a major industrial contributor (a tannery) are presently concentrated during daylight hours. The tannery discharges wastes to the the treatment plant via a separate force main. It accounts for about 35 percent of the BOD and 50 percent of the SS into the plant, and about 15 percent of the influent flow, resulting in a widely fluctuating BOD and SS diurnal load profile.

The wide fluctuations in organic loading are resulting in reduced performance of the trickling filters. This, in conjunction with the advent of more stringent treatment standards, has rendered this facility inadequate. Plans are presently under way to upgrade the treatment plant.

This case represents an ideal situation for employing partial equalization in the upgrading scheme. The volume of the wastes from the tannery is relatively small compared to the total volume of flow received at the plant, whereas the organic contribution is significant. Therefore, a relatively small volume equalization tank is all that is required to attain effective organic load equalization. In addition, because the tannery discharges to the treatment plant via a separate force main, equalization may be accomplished at the treatment-plant site. The effect of equalizing the tannery flow over 24 hours is illustrated on figure 6.

Located at the plant site are six abandoned square anaerobic digesters, each measuring 50 feet by 50 feet by 17.5 feet deep. Four of the units have fixed covers and two have floating covers. The utilization of these tanks for equalizing the tannery flow was investigated. The investigations indicate

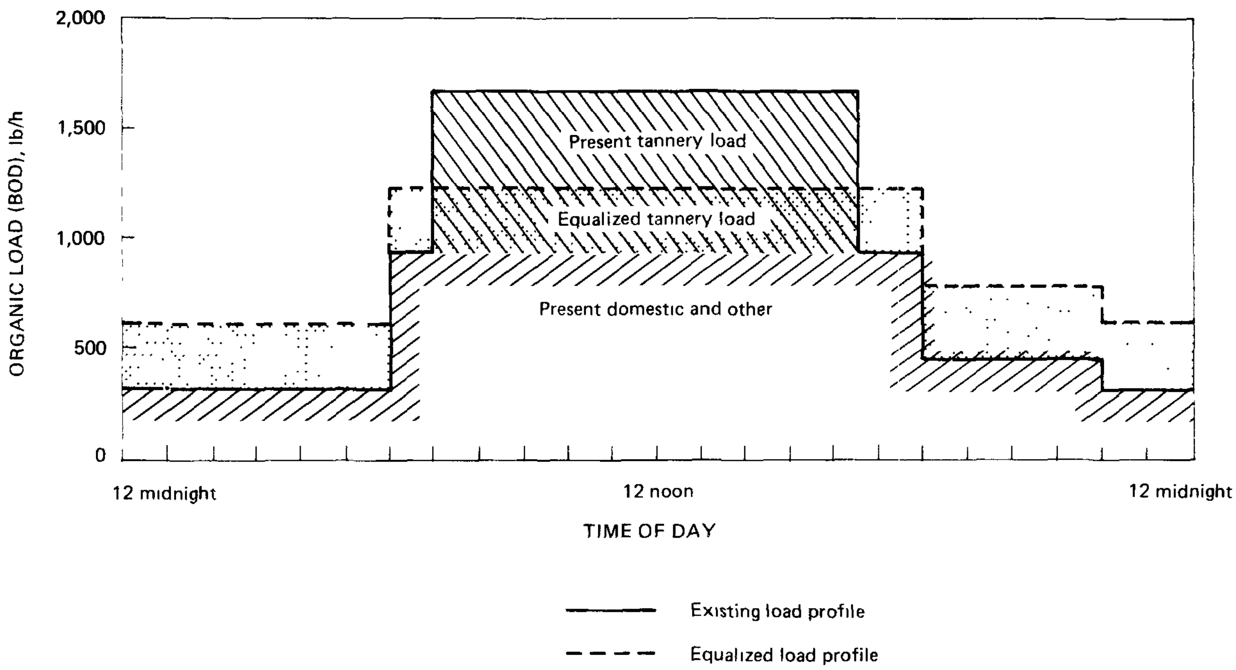


Figure 6. Effect of tannery flow equalization.

that the four fixed-cover tanks would be adequate for equalization for all but a few days each year when the use of the two additional tanks would be necessary because of high flows or maintenance.

The conversion of the abandoned digesters to equalization tanks entails complete modification of the four fixed-covered tanks and only minimal modification of the two tanks which have floating covers. The four fixed-covered tanks would each require the installation of a mechanical mixer to maintain solids in suspension, including structural modifications in order to support the mixers. A ventilation system would be required for the covered tanks to insure the safety of plant personnel who may enter the tanks for purposes of inspection or maintenance. Minor structural repairs and waterproofing of all six tanks would be necessary to insure their structural integrity and watertightness. The two floating covers would be removed and the pipe gallery would be converted to a pump station.

The cost for converting these units to equalization tanks is estimated at approximately $440,000. This cost includes process pumping equipment and piping, four mechanical mixers, tank ventilation system, instrumentation, electrical work, structural renovations and alterations, and engineering fees.

At present, additional studies are under way to evaluate the feasibility of equalization of tannery wastes at the tannery in lieu of equalizing these wastes at the plant site.

WALLED LAKE-NOVI, MICH.

The Walled Lake-Novi Wastewater Treatment Plant is a new 2.1-mgd facility employing side-line flow equalization. The treatment plant was placed into operation in 1971. It was designed to meet stringent effluent quality standards, including a summertime monthly average BOD_{20} of 8 mg/l, a wintertime monthly average BOD_{20} of 15 mg/l, and 10 mg/l of SS. The facility utilizes the activated-sludge process followed by multimedia tertiary filters. Ferrous chloride and lime are added ahead of aeration for phosphorus removal. Sludge is processed by aerobic digestion, and dewatered on sludge-drying beds. A schematic diagram of this facility is shown on figure 7.

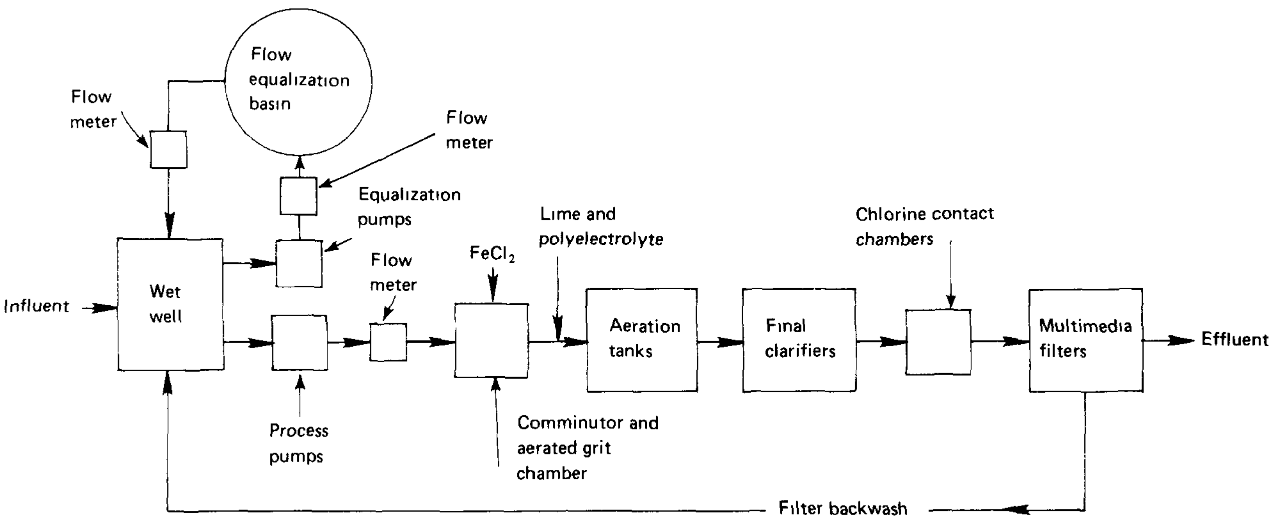


Figure 7. Walled Lake-Novi Wastewater Treatment Plant.

A major factor in the decision to employ flow equalization was the desire to load the tertiary filters at a constant rate. The equalization facility consists of a 315,000-gallon concrete tank which is equivalent in volume to 15 percent of the design flow. The tank is 15 feet deep and 60 feet in diameter. Aeration and mixing are provided by a diffused air system with a capacity of 2 ft^3/min per 1,000 gallons of storage. Chlorination is provided for odor control. A sludge scraper is installed to prevent consolidation of the sludge.

The equalization facility is operated as follows:[10] The process pumping rate is preset on the pump controller to deliver the estimated average flow to the treatment processes. The flow delivered by these pumps is monitored by a flowmeter which automatically adjusts the speed of the pumps to maintain the average flow rate. When the raw wastewater flow to the wet well exceeds the preset average, the wet well level rises, thereby actuating variable speed equalization pumps which deliver the excess flow to the equalization basin. When the inflow to the wet well is less than the average, the wet well level falls and an automatic equalization basin effluent control valve opens. The valve releases enough wastewater to the wet well to reestablish the average flow rate through the plant. Since this is a new plant as opposed to an upgraded plant, no comparative data exist. However, the treatment facility is typically producing a highly treated effluent with BOD and SS concentrations less than 4 mg/l and 5 mg/l, respectively.[8]

NOVI INTERCEPTOR RETENTION BASIN, OAKLAND COUNTY, MICH.

This case[11] illustrates the utilization of an equalization basin within the wastewater collection system.

A portion of the wastewater collection system for the city of Novi, Mich., discharges to the existing Wayne County Rouge Valley Interceptor System. Due to the existing connected load on the Wayne County system, Novi's wastewater discharge to the interceptor system is limited to a maximum flow rate of 4 ft^3/s. This rate was matched by the existing maximum diurnal flows from the city. In order that additional population could be served, it was decided to equalize wastewater flows to the interceptor system. By discharging to the interceptor continuously at an average rate of flow, the total wastewater flows from the city of Novi to the Wayne County Rouge Valley Interceptor System could be increased by a factor of 2.6.

An 87,000-ft^3 concrete basin was constructed for equalizing flows. The tank has a diameter of 92 feet and a depth of 10.5 feet. Aeration and mixing are provided by a diffused air system with a capacity to deliver 2 ft^3/min per 1,000 gallons of storage.

An 87,000-ft^3 concrete basin was constructed for equalizing flows. The tank has a diameter of 92 feet and a depth of 10.5 feet. Aeration and mixing are provided by a diffused air system with a capacity to deliver 2 ft^3/min per 1,000 gallons of storage.

A manhole located upstream of the equalization basin intercepts the flow in the existing Novi trunk sewer. The intercepted wastewater flows into a weir structure which allows a maximum of 4 ft^3/s to discharge into the Wayne County system. The wastewater in excess of the preset average overflows into a wet well where it is pumped to the equalization basin. When flows in the interceptor fall below the preset average, a flow-control meter generates a signal opening an automatic valve on the effluent line of the basin, allowing stored wastewater to augment the flow.

REFERENCES

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METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Length	metre	m	*Basic SI unit*	39.37 in.=3.28 ft= 1.09 yd
	kilometre	km		0.62 mi
	millimetre	mm		0.03937 in.
	micrometre	μm.		3 937 X 10^{-3}=10^{3}A
Area	square metre	m^2		10.764 sq ft = 1.196 sq yd
	square kilometre	km^2		6 384 sq mi = 247 acres
	square millimetre	mm^2		0.00155 sq in.
	hectare	ha	The hectare (10 000 m^2) is a recognized multiple unit and will remain in international use.	2 471 acres
Volume	cubic metre	m^3		35.314 cu ft = 1.3079 cu yd
	litre	l	The litre is now recognized as the special name for the cubic decimetre.	1.057 qt = 0.264 gal = 0.81 X 10^{-4} acre-ft
Mass	kilogram	kg	*Basic SI unit*	2.205 lb
	gram	g		0.035 oz = 15.43 gr
	milligram	mg		0.01543 gr
	tonne or	t	1 tonne = 1 000 kg	0 984 ton (long) =
	megagram	Mg	1 Mg = 1 000 kg	1.1023 ton (short)
Time	second	s	*Basic SI unit*	
	day	d	Neither the day nor the year is an SI unit but both are important.	
	year	year		
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg	0.22481 lb (weight) = 7.233 poundals
Moment or torque	newton metre	N-m	The metre is measured perpendicular to the line of action of the force N. Not a joule.	0.7375 ft-lbf
Stress	pascal	Pa		0.02089 lbf/sq ft
	kilopascal	kPa		0.14465 lbf/sq in

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Velocity linear	metre per second	m/s		3.28 fps
	millimetre per second	mm/s		0.00328 fps
	kilometres per second	km/s		2.230 mph
angular	radians per second	rad/s		
Flow (volumetric)	cubic metre per second	m^3/s	Commonly called the cumec	15,850 gpm = 2.120 cfm
	litre per second	l/s		15.85 gpm
Viscosity	pascal second	Pa·s		0.00672 poundals/sq ft
Pressure	newton per square metre or pascal	N/m^2 Pa		0.000145 lb/sq in
	kilometre per square metre or kilopascal	kN/m^2 kPa		0.145 lb/sq in.
	bar	bar		14.5 b/sq in.
Temperature	Kelvin	K	*Basic SI unit*	$\frac{5F}{9} - 17.77$
	deqree Celsius	C	The Kelvin and Celsius degrees are identical. The use of the Celsius scale is recommended as it is the former centigrade scale.	
Work, energy, quantity of heat	joule	J	1 joule = 1 N-m where metres are measured along the line of action of force N.	2.778 X 10^{-7} kw hr = 3.725 X 10^{-7} hp-hr = 0.73756 ft-lb = 9.48 X 10^{-4} Btu
	kilojoule	kJ		2.778 kw-hr
Power	watt	W	1 watt = 1 J/s	
	kilowatt	kW		
	joule per second	J/s		

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Precipitation, run-off, evaporation	millimetre	mm	For meteorological purposes it may be convenient to measure precipitation in terms of mass/unit area (kg/m^3). 1 mm of rain = 1 kg/m^2	
River flow	cubic metre per second	m^3/s	Commonly called the cumec	35.314 cfs
Flow in pipes, conduits, channels, over weirs, pumping	cubic metre per second	m^3/s		
	litre per second	l/s		15.85 gpm
Discharges or abstractions, yields	cubic metre per day	m^3/d	1 l/s = 86.4 m^3/d	1.83 X 10^{-3} gpm
	cubic metre per year	m^3/year		
Usage of water	litre per person per day	l/person day		0.264 gcpd
Density	kilogram per cubic metre	kg/m^3	The density of water under standard conditions is 1 000 kg/m^3 or 1 000 g/l or 1 g/ml.	0.0624 lb/cu ft

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Concentration	milligram per litre	mg/l		1 ppm
BOD loading	kilogram per cubic metre per day	kg/m^3d		0.0624 lb/cu-ft day
Hydraulic load per unit area; e.g. filtration rates	cubic metre per square metre per day	m^3/m^2d	If this is converted to a velocity, it should be expressed in mm/s (1 mm/s = 86.4 m^3/m^2 day).	3.28 cu ft/sq ft
Hydraulic load per unit volume; e.g., biological filters, lagoons	cubic metre per cubic metre per day	m^3/m^3d		
Air supply	cubic metre or litre of free air per second	m^3/s l/s		
Pipes diameter	millimetre	mm		0.03937 in.
length	metre	m		39.37 in. = 3.28 ft
Optical units	lumen per square metre	lumen/m^2		0.092 ft candle/sq ft