Development of an On-Line O&M Manual

Albert L. Perez, Celia D.A. Earle, and Shane Ramcharansingh

Utilities have recognized that the true value in the management of information is in the ability to efficiently access data. Therefore, many water and wastewater utilities are re-engineering the management and flow of information throughout their organizations. Among recent re-engineering projects is the implementation of on-line information systems to manage the vast amounts of information within the utilities. Unlimited amounts of information, including O&M manuals, as-built drawings, manufacturer's catalogs, troubleshooting guides, equipment photographs, and process flow diagrams, can be stored on on-line systems.

Traditionally, operations staff are confronted with the task of having to search through three-ring binders on bookshelves for the retrieval of equipment operations or maintenance information. The task is greatly simplified through the use of an electronic O&M manual. By using an intuitive point-and-click interface, utilities staff can immediately access up-to-date information with no physical searching required.

Among the advantages of on-line documentation is reduced obsolescence. Materials can be easily updated since the entire O&M information is in electronic format within a central library and is much less likely to become obsolete.

Faster and more accurate access to specific information is another advantage. Information of interest can be quickly retrieved and presented, regardless of the actual number of pages of text, procedures, drawings, diagrams, photographs, tables, equipment data, and/or manufacturer's catalogs.

On-line information is highly portable. Most electronic O&M manuals use compact disc read-only memory (CD-ROM) or a network for distribution. On the average, 1,540 pounds of manuals, drawings, and other O&M information can be stored on a single,inexpensive CD-ROM, which is sufficiently rugged for field use in a notebook computer. When hard copy of selected information is needed, it can be printed on any number of types of printers.

Compared to paper-based information, users tend to be more enthused about the retrieval of information presented via an electronic O&M manual. Many operations and maintenance personnel admit that although they were hesitant to shuffle through volumes of paper manuals, racks of drawings, and file cabinets of manufacturers' catalogs, they actually enjoy surfing the system to look up information. Any increase in the use of, and subsequent familiarity with, accurate operations and/or maintenance information jointly benefits the utility and the individuals affected.

Studies indicate that employees learn roughly twice as fast with on-line information and remember it two to three times as long when they can interact with the information that they seek. Electronic O&M manuals encourage and rely upon interaction from the users as they select the information that they wish to review. The net result is a four- to six-fold increase in the overall effectiveness of the operations and maintenance training.

Computerized O&M manuals considerably reduce the use of paper and storage space, along with the associated costs. One CD-ROM equals about 150,000 sheets of paper, and storage space is about 0.1% of that required for equivalent paper materials.

One of the principal concerns expressed by utilities considering an electronic O&M manual involves the possibility (and cost) of using existing operations and maintenance information. Existing O&M manuals, drawings, diagrams, procedures, instructions, forms, manufacturer's catalogs, equipment data, etc., can all be transferred into the electronic information system. Often, the majority of the required operations and maintenance information exists. The cost-effective transfer and incorporation of the existing information not only protects the substantial investment previously made by the utility, but also reduces the cost of implementing an electronic O&M manual.

As part of the expansion efforts for its Springtree Water Treatment Plant, the city of Sunrise elected to develop an O&M manual that captured processes within the existing portion of the plant and expanded processes. At the time of the project, the city was engaged in the development of a citywide area network intended to facilitate communication among its departments and provide a means for on-line information transfer. This initiative provided the platform for the city's decision to implement an electronic O&M manual at the Springtree WTP.

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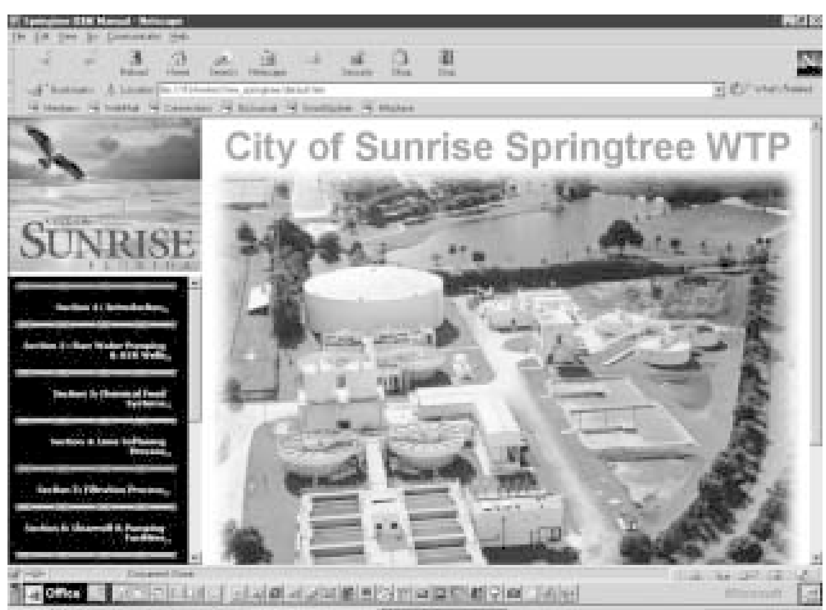
The treatment process consists of two separate lime softening and filtration plants. Plant A, constructed in 1974, has a flow of 8 MGD, and Plant B, constructed in 1990, has 12 MGD. As part of an expansions project, Plant B was expanded to 24 MGD. The electronic O&M manual developed for the project addressed specifically processes within Plant B and processes added as part of the expansion efforts.

An HMTL platform, the same as used for the World Wide Web on the Internet, was used for the Springtree plant. Web pages for the on-line document were developed using Microsoft Frontpage 98 and viewed using Microsoft Internet Explorer Version 4.0 as the browser software. Databases within the O&M manual were established and hyperlinked to allow manipulation and accessibility of information by pointing and clicking at the various text and reference indexes created.

Similar to an Internet Web site, the electronic O&M manual has a menu listing on the left side of the page that provides hyperlinks for direct access to sections of the O&M manual, record drawings, process flow diagrams, equipment summary sheets, and a directory for access to the respective equip-



Home Page for the Springtree WTP electronic O&M manual.

ment manufacturer's Internet Web sites.

Access to information from the home page may be accomplished by selecting the desired link on the scrolling menu. Additionally, links have been superimposed over unit processes on an aerial photograph to allow access to operation and maintenance information by simply pointing and clicking on the particular process unit.

The retrieval of vital operation and maintenance information is simplified through the use of an Internet-environment type database. The electronic O&M manual provides navigational features similar to those of a conventional Internet Web site, which is advantageous in that it inherently offers a greater degree of familiarity to the end user.

From the screen giving the description of the chemical feed system, the user is able to access process flow diagrams by clicking on the hyperlinks within the text and may also retrieve information on the process description, operations, controls, maintenance, and safety from the menu.

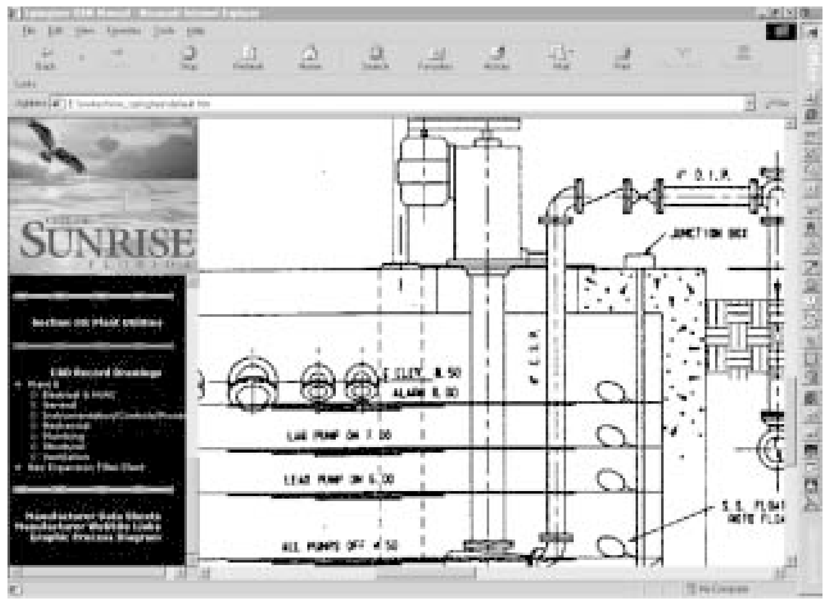
Plant operations staff often face the cumbersome task of having to find record drawings for facilities built long ago, requiring many hours of search and retrieval of archives, and at times the information cannot be found at all because of misplacement. The Springtree O&M Manual is equipped with a record drawing database. Within this database, all the record drawings for the facility have been electronically archived by discipline. Using the viewing software, the user is able to zoom, pan, and print the drawing at the click of a button.

The ability to obtain specific equipment design criteria information and nameplate data is particularly important for both maintenance and equipment replacement. Typically, operations staff have had to resort to searching through manufacturers' O&M manuals to find specific equipment information. For the Springtree WTP O&M manual, a database containing equipment data sheets for major unit process equipment was developed. Each equipment data sheet provides general design criteria information and equipment nameplate data.

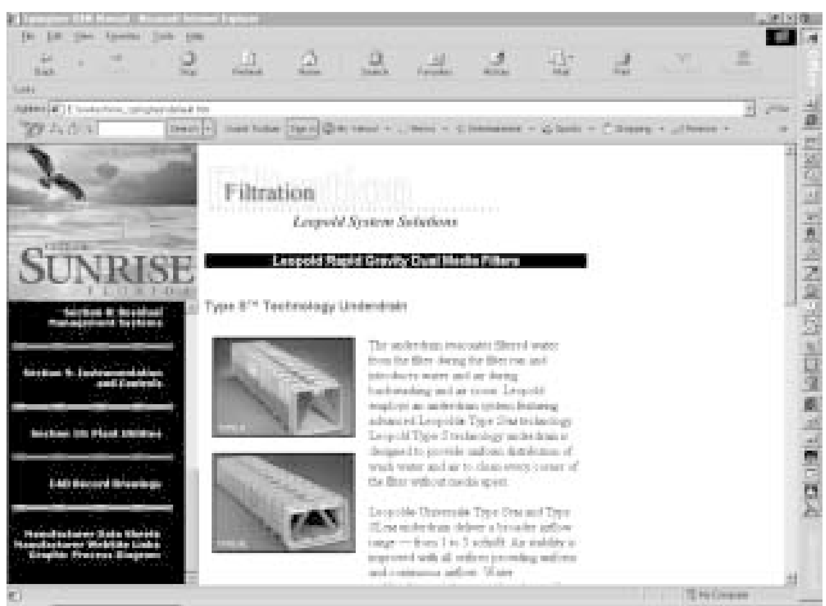
Additionally, a directory of equipment manufacturers' Internet Web sites was developed. By simply pointing and clicking at a manufacturer's link for the desired equipment, the user may gain immediate access to the manufacturers' Internet Web site. Typically, these sites provide information on the manufacturers' local representatives, technical guidelines, procurement of spare parts, and product selection.

Collectively, the benefits of an on-line system can reduce a utility's annual operations and maintenance expenses. Significant savings can be achieved by increasing information accuracy, currency, availability, and portability, as well as decreasing training, maintenance overtime, and risk factors. ■

Description of the chemical feed system in Section 3 of the manual.



Record drawing retrieved.



Internet Web site of the underdrain supplier for the filters at the Springtree WTP.

Effects of Sand And Silt on Membrane Treatment Processes

Frederick Bloetscher and Gerhardt M. Witt

Traditional treatment processes, such as lime softening and filtration, don't have the same requirements as membrane processes. Membranes require raw water with low suspended solids and turbidity and minimal microbiological constituents. Detrimental influences may be natural or they may result from man-made activities, such as construction and testing of wells.

Most drilled wells historically have had steel casings. While steel provides structural strength and durability, it also provides a growth medium for iron bacteria and other organisms. Wells producing water that will be treated by membrane plants should have casings other than steel, such as fiberglass, styrene rubber, acrylonitrile butadiene styrene, or polyvinyl chloride (PVC). The selection of the casing is dependent on a number of factors, including downstream treatment, collapse strength, tensile strength, burst strength, and compressive strength. These concerns with well design, expressed in AWWA Standards A100-98, should be evaluated in conjunction with the existing system.

In addition to well casing type, there are a series of biofouling potentials that should be evaluated, including sand, silt, and colloidal materials, and a review of is needed of the well's uphole velocity, which affects the amount of material that can be drawn into the well. While there are standards for each of these measures, our experience indicates the standards may be insufficient to protect membrane systems.

Sand Production

The concentration of sand produced by a water supply well should normally be less than the AWWA Standard for Water Wells A100-97 of 5.0 mg/L during a two-hour pumping cycle when pumping at the design rate. While any recommendations for limiting sediment concentration must take into account water use, method of treatment, type of sediment, and sediment source, the authors believe this criterion is insufficient to mitigate problems with treatment at the membrane plant. The standard should be 1 mg/L or less, which can be met by a properly designed well system. EPA and the National Water Well Association (1975) have recommended the following limits, which support our recommendation:

A. 1 mg/L — water to be used directly in contact with, or in the processing of, food and beverages.
B. 5 mg/L — water for homes, institutions, municipalities, and industries.
C. 10 mg/L — water for sprinkler irrigation systems, industrial evaporative cooling systems, and other uses where a moderate amount of sand is not especially harmful.
D. 15 mg/L — water for flood-type irrigation and where the nature of the water-bearing formations and the overlying strata are such that pumping this amount of sand will not seriously shorten the useful life of the well.

The limits suggest reasonable goals that can be achieved if good well design, construction, and development practices are followed. In older wells or wells in problem aquifers, a well may pump unacceptable amounts of sediment. If the well cannot be redeveloped by conventional techniques, a special sand separator can be installed as a permanent part of the well system. A sand separator may not remove all sediment, however, and should not be used as a substitute for good well design and construction practices. In addition, the removal of too much sand can cause catastrophic collapse of the formation.

Sand testing should be performed on each production well on a yearly basis in conjunction with step-drawdown testing. Two types of sand testing equipment are the Rossum Sand Tester and the Lakos Laval Sand Separator.

The purpose of sand testing is to determine the amount of sand being pumped from a well. This is important because sand abrasion, especially that of quartz sand, can adversely affect the longevity of pumps, motors, column pipes, and pipelines. The abrasion then creates points of potential corrosion by both electrolysis and bacteria. Sand production is also an indicator that there may be structural concerns with the well and/or well screen. Continued sand production can cause catastrophic collapse of the formation around a well and is a serious concern.

While the Rossum Sand Tester is the method accepted by the AWWA, the authors' experience has indicated that a Lakos Laval Sand Separator provides a better method of quantifying sand produced from a well, mainly because it tests larger volumes of water over a greater period of time.

The amount of sand produced in milligrams per liter for each individual pumping rate is determined by the following equation (Witt, 1983):

$$S = S_{wt}(1000)/(3.785Qt)$$

where:

S	=	sand content, mg/L
S_{wt}	=	weight of sand, grams
1000	=	equation constant, mg/gm
3.785	=	equation constant, liters per gallon
Q	=	flow rate through the sand separator, gallons per minute
t	=	time, minutes

The well should be pumped at its design rate for two hours, and sand samples should be collected at 5, 30, 60, and 120 minutes without stopping the pumping. Sand samples are removed from the sand separator and analyzed. The amount of sand pumped during normal operation is realistically reflected in the 120-minute sand sample.

Large discrepancies in the amount of sand collected at the 5-minute sample as compared to the amount of the 120-minute sample is of concern as it may be an indication of water hammer to the formation and thus operational failure of the valves in a well and/or at the plant.

It should be noted that the Lakos Laval Sand Separator only removes sand particles in the range of 74 microns with 98% efficiency. This means that particles less than 74 microns will pass through the sand separator.

Colloidal Testing

The authors have determined a mechanism for colloidal testing of individual wells (Witt, 1994): CUNO model No. 1M2 filter media containers (housing) that allow a filter cartridge (Betapure Filter Catalog No. AU19B11NG) to be placed inside. Colloidal testing should be performed both prior to and after well disinfection to allow evaluation of the effectiveness of the disinfection procedure. The filter pore spaces are 5.0 microns, which allows for the capture of most clay- and silt-sized particles. Clay- and silt-sized particles can clog the gravel pack and well screens, causing increased drawdown, loss of production, and increased operating

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cost. Continued withdrawal of silts and clays can, like sand, cause sinkhole formation. The production of clays and silts may also be an indication of structural concerns with well casings and screens. A pressure gauge on each side (in-flow and out-flow) of the filter apparatus allows the measurement of the change in pressure across the filter cartridge. In addition to measuring pressure, the system is designed to allow measurement of the silt density index (SDI).

The following is an outline of the procedure to set up the cartridge filter:

A. Disinfect the filter holder with bleach and attach the colloidal test apparatus to the side of the discharge line.
B. Flush the bleach out of the cartridge filter holder by opening the valve to the discharge line.
C. Insert the cartridge filters into the holder without touching the filter (open an end of the plastic bag and insert the filter, then remove the plastic bag).
D. Turn on water to run through the filter.
E. Check and note the discharge rate after 5.0 minutes; check and note the pressure in (P_{in}) and pressure out (P_{out}).
F. Check and note P_{in} and P_{out} at least once a day. Note any color changes in the filter and/or any growths on the filter. Once the pressure differential between P_{in} and P_{out} increases to more than 28 psi, remove the filter using plastic gloves. The filter should be visually inspected and stored in a PVC container. Note any odor. Culture swabs may be obtained and sent for microbiological analysis. The filters should be placed in PVC containers and sent for x-ray diffraction and microscopic analysis.

Silt Density Index Testing

ASTM Standard D-4189-94 is an empirical measurement of the potential of silt, colloidals, bacteria, colloidal silica, organic molecules, and/or corrosion products to foul a membrane. In addition, entrained air and filtration aids, such as cationic polymers and alum, may also foul membranes. SDI testing is used to predict the tendency of a water supply to foul membranes, and it can also be used as an indicator of materials that can cause fouling of well screens and gravel packs. Therefore, to obtain a comprehensive size range of particles, we suggest that SDI testing be performed.

The SDI test simply measures the decay in flow rate through a 47- mm diameter, 0.45- µm pore size membrane. The 0.45-µm membrane is used because it is more susceptible to clogging by colloidal matter than by hard particles such as sand and scale. Furthermore, the 0.45-µm size is smaller than the 5.0-µm size of the pre-filter and therefore measures particles that would pass through the pre-filter and clog the membrane, which is approximately 0.5 µm in size. The measured decay in flow rate is converted to a number between 1 and 100.

The SDI number is a function of the rate at which the membrane clogs with colloidal material. The larger the SDI number, the greater the fouling tendency of the water.

To perform the SDI test, a Millipore SDI or Fouling Index Test Kit or an equivalent is required. The SDI equipment includes a 47-mm filter holder, a pressure regulator, a pressure gauge, valves, fittings, tweezers, 0.45-µm membrane filter discs, a stop watch, and a 500- ml graduated cylinder.

To calculate the SDI of given water, the following formula is used:

$$SDI = [1 - (T_1/T_F)]100/T_T$$

where:

SDI = Silt Density Index (an empirical number between 1 and 100)

T_1 = The initial time to fill 500 milliliters, seconds

T_F = The final time to fill 500 milliliters, seconds

T_T = The total time test is performed, minutes

It is important to note the color of the filter, because coloration is an indication of the clogging medium. If microorganisms are suspected, then it is important to preserve the filter in a sterile container, such as a petri dish. This filter can then be sent for microbiological analysis.

Uphole Velocity

The AWWA standard states that well casing velocity should be 5 fps. Use of these standards has not been contrary to traditional treatment plant performance requirements or operations. The fact that sand and silt, in quantities as specified in the AWWA standards, may exist may in fact enhance traditional lime softening or coagulation processes. However, the need for better quality water, especially where organics are an issue, necessitates the conversion to higher quality treatment mechanisms that are less tolerant of sand, silt, and biological agents. Our experience in open hole and screened wells indicates that the velocity needs to be lower than 3 fps and preferably below 2.5 fps for membrane processes.

One method of controlling the SDI is through the regulation of the uphole velocity of water in the well. Decreasing the velocity will decrease the SDI of the water. For water supply wells, an uphole velocity of less than 5.0 fps is recommended. The following formula is used to calculate the uphole velocity (Heald, 1994):

$$V = 0.4085Q/d^2$$

where:

V = uphole velocity, feet/second
Q = pumpage rate, gal./ minute
d = inner well diameter, inches

For example, using the design pumping rate of 500 gpm and a pipe minimum inner diameter of 8.0 inches (the inside diameter of the well screen), the calculation yields an uphole velocity of 3.19 fps, well below the requirement of 5 fps for the wells.

Conclusions

- Existing industry standards for well design, construction, and testing may be insufficient for membrane treatment plants.
- Regardless of standards (or lack thereof), design professionals must recognize the need for other outside disciplines, such as chemistry and microbiology, to be involved in raw water supply designs.
- Individuals doing system design must understand the feed water requirements for membrane process;
- Tests on each production well must be performed in the presence of a licensed professional geologist and engineer.
- Bacteriological tests should be collected by and performed under the supervision of a licensed professional geologist and competent biologist on each well on a monthly basis.
- The composite raw water from the wells should be continually monitored for undissolved organic and inorganic solids (sand, silt, clay, and microorganisms) using methods appropriate for the level of treatment, in conjunction with a hydrogeologist and biologist.
- Sand separators such as the Lakos Laval should be installed at membrane water treatment plants to address sand concerns and avoid long-term operating and maintenance cost increases.
- Pigging of all new raw water supply lines should be mandatory, and the ability to periodically pig the lines in the future should be provided.
- A velocity of at least 12 fps must be achieved and sustained for flushing the largest pipe going a water treatment plant.
- Wells should be designed with nonferric well casing for the inner-most casing.
- Uphole velocity should be less than 2.5 fps.
- Water hammer must be addressed in the aquifer as well as the well casing and pipeline. ■

A Practical Guide to Sampling and Testing Filter Media

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The water filtration industry has generally accepted AWWA B100 *Standard for Filtering Material* as the law for describing filtration materials used in municipal water filters. The standard states that it is not a specification, that it only describes minimal requirements, and that the user of the standards must evaluate the options contained in the standards. Some parameters and operations are not fully described in the standard. One such operation is the sampling of semi-bulk containers on the job site. The B100 Standard Committee is drafting methods for the next revision. Until then, this paper provides several methods for obtaining representative samples and details the practices used to protect and identify them.

Section 5.3 of the standard states: "If filter materials testing is not witnessed at the shipping point by the purchaser, the material should be tested at the job site." We recommend that filtering materials be tested at the point of manufacture, as most manufacturers are equipped to do the sampling and testing as a function of their quality control programs. Also, most manufacturers are thoroughly familiar with the B100 requirements.

Representatives of some larger utilities make periodic inspections of filter material manufacturers to qualify the manufacturer as an acceptable supplier. When filtering material is produced, the utility representatives witness the sampling and identify the sampled material, using tags or their distinctive mark. After testing acceptance, the material is shipped directly to the job site with no further testing required. This procedure decreases turn-around time for the project and eliminates all of the challenges associated with job site sampling and testing.

Section 5 of the B100 standard, "Verification," recommends sampling of semi-bulk containers across the cross section of the material being loaded at the production site. If the purchaser hasn't witnessed filter materials testing at the shipping point, the standard recommends that the material be tested at the job site in accordance with ASTM D 75, *Standard Practice for Sampling Aggregates*. However, ASTM D 75 does not provide a procedure for sampling semi-bulk containers on the job site. None of the four methods it provides — Sampling from a Flowing Aggregate Stream (Bins or Belt Discharge), Sampling from the Conveyor Belt, Sampling from Stockpiles or Transportation Units, and Sampling from Roadway (Bases and Subbases)— is suitable for sampling semi-bulk containers. In fact, ASTM D 75 states that sampling coarse aggregate or mixed coarse and fine aggregate from stockpiles or transportation units should be avoided whenever possible and particularly when the sampling is done for determining aggregate properties that may be dependent upon the grading of the sample.

Sampling

Sampling is as important as testing. Poor sampling practices yield unrepresentative test reports that can consume an enormous amount of time from project personnel. Valuable resources are often spent analyzing results that became invalid the moment the sampling plan failed to meet the sampling requirements of the B100 Standard.

The key to developing a sound sampling program for filtration media is strict adherence to AWWA B100 and the referenced ASTM procedures. Whether testing is required as part of an on-site quality assurance program or as the result of project specifications, the sampling program must satisfy several procedural requirements.

The accompanying worksheet FBL-B100-96 was developed to ensure that a sampling and testing plan addresses basic AWWA requirements. The bottom section of the worksheet can be used as a guide for determining the sampling and testing procedures referenced in the B100 standard (the worksheet and reference guide are only applicable to AWWA B100-96 edition). Sometimes it takes several attempts to get sampling and testing procedures right, with each attempt becoming a costly learning experience. The worksheet should help reduce resampling, retesting, and reanalyzing.

The first task in developing any on-site sampling program is a complete and accurate inventory of all the media that requires testing. It is best to include as many types and sizes as possible during each round of sampling to reduce the amount of nonproductive time spent by project and laboratory personnel in additional sampling at a later time. In addition, some test procedures may take several days from preparation to completion, making sample turnover time an important factor. This is especially true for short installation schedules.

Inventory data must include the exact number of bags of each media type and size along with bag weights. When project specifications require anthracite, sand, and gravel to be tested on-site, it will be necessary to number each bag of anthracite of a specific size. Likewise, each bag of sand and gravel of similar size will be numbered. This not only makes it easier to confirm inventory numbers, but it will also aid in determining which bags will be randomly sampled. After inventory is complete, the sampling program can begin to be developed.

Worksheet Section 1: Type of Media

Determine the types of filter media or filter gravel that require testing. AWWA B100-96 covers five different types of materials: anthracite, silica sand, high-density sand (classified as filter media), silica gravel, and high-density gravel (classified as filter gravel). The worksheet is limited to those five types.

Worksheet Section 2: Media Size

From the inventory list indicate the size of media and/or gravel to be tested. For filter media the size is usually the effective size range and uniformity coefficient, e.g., ES 0.95 mm x 1.05 mm and UC $\leq$ 1.30, while gravel is sized using upper and lower size limits, e.g., 3/4 x 1/2 inches.

Worksheet Section 3: No. of Bags in Lot

From the inventory list indicate the total number of bags of each specific type and size of media requiring testing. This information is critically important in developing the sampling program because it determines the minimal number of bags of a specific type and size media that must be sampled. These individual samples will ultimately be combined to produce a single composite sample.

Worksheet Section 4: Number of Bags to Sample

Sampling programs often fail the requirements of AWWA by not sampling the proper number of bags per lot size. The composite sample must be representative of the lot, which can only be accomplished by being comprised of a minimal number of sub-samples taken from the lot. Valid sampling programs comply with AWWA B100-96, Section 5.2, Table 4, "Sampling of Bagged Media," which determines the minimal number of bags required to be sampled per the lot of

F.B. Leopold Co., Inc. Engineered Filter Media Division
Media Site Sampling Worksheet Form:FBL-B100-96

Job Name: Location: Contract # Date: ______________________
Engineer: Contact: Phone: ______________________
Contractor: Contact: Phone: ______________________
City: Contact: Phone: ______________________

FILTERING MATERIALS SAMPLING AND TESTING FIELD SUMMARY

Sampling						Testing						
Section 1 Type of Media	Section 2 Media Size	Section 3 # of Bags in Lot	Section 4 # of Bags to Sample	Section 5 Individual Bag #s to Sample	Section 6 Sample ID #	Section 7 Sizing ES/UC % over % under	Section 8 Specific Gravity	Section 9 Acid Sol.	Section 10 Moh Hardness	Section 11 Flat & Elongated	Section 12 Fractured Faces	Section 13 Other

Anthracite (A), Sand (S), Support Gravel (SG), High Density Sand (HD-S), High Density Gravel (HD-G)
AWWA B-100-96, TABLE C, pg. 24 2 ASTM D 3665 Random Sampling

TESTING PROCEDURES REFERENCE TABLE

	Anthracite		Silica Sand		HD – Sand		Silica Gravel		HD Gravel	
	AWWA	ASTM	AWWA	ASTM	AWWA	ASTM	AWWA	ASTM	AWWA	ASTM
Practice for Sampling		D 75		D 75		D 75		D 75		D 75
Reducing Field Samples		C 702		C 702		C 702		C 702		C 702
Random Sampling		D 3665		D 3665		D 3665		D 3665		D 3665
Sieve Analysis (Sizing) Effective Size / UC	Sec. 5.3.4 Sec. 5.3.4.3	C 136 E 11	Sec. 5.3.4 Sec. 5.3.4.3	C 136 E11	Sec. 5.3.4 Sec. 5.3.4.3	C 136 E 11	Sec. 5.3.4	C 136 E 11	Sec. 5.3.4	C 136 E 11
Specific Gravity	Sec. 5.3.3	C 128	Sec. 5.3.3	C 128	Sec. 5.3.3	C 128	Sec. 5.3.3 Sec. 5.3.3.1	C 127	Sec. 5.3.3	C128
Acid Solubility	Sec. 5.3.1		Sec. 5.3.1		Sec. 5.3.1		Sec. 5.3.1		Sec. 5.3.1	
Moh Hardness	Sec. 5.3.4.6		N/A		Sec. 5.3.4.6		Sec. 5.3.4.6		N/A	
Shape / Flat & Elongated	N/A		N/A		N/A		Sec 5.3.2.2		Sec 5.3.2.2	
Fractured faces	N/A		N/A		N/A		Sec. 5.3.2.1		Sec. 5.3.2.1	
Clay, Dust, Micaceous and Organic Matter		C 117 C 40		C 117 C 40		C 177 C 40				

media specific to type and size. Occasionally additional bags will have to be included in the sampling scheme to achieve the minimal weight limit for composite samples. In using the table, if a truckload of anthracite, e.g., E.S. 0.95 mm x 1.05 mm UC $\leq$ 1.30, is comprised of 18 superbags weighing 2500 pounds each, a minimum of five superbags would need to be randomly sampled and combined to produce one composite sample representing the entire truckload of material. If the same truck were delivering a load of anthracite in cubic foot bags weighing 50 pounds each, the number of bags to be sampled increases to 80 (since the total number of bags on the truck is 900). A word of advice about sampling and testing cubic foot bags: perform the sampling and testing at the media manufacturers' facility during production where it is much less messy and the integrity of the bags is not compromised.

Worksheet Section 5: Individual Bag Numbers to Sample

Identify the actual bag numbers to sample using the numbers placed on the bag. Picking five bag numbers arbitrarily doesn't make them random; some bias exists. A method of determining random bag numbers for sampling can be found in ASTM D 3665, *Practice for Random Sampling of Construction Materials*, referenced in ASTM D 75 *Standard Practice for Sampling Aggregates*. Both of these ASTM procedures, along with ASTM C 702 *Standard Practice for Reducing Samples of Aggregate to Testing Size,* are required reading for any personnel involved with sampling, testing, or review.

To determine which bags to sample, refer to ASTM D 3665 and find Table 1, "Table of Random Numbers." Earlier it was determined that a minimum of five superbags required sampling from the example truckload of anthracite superbags. Laying both pages of Table 1 on a flat surface, randomly with a pointer place a mark in the body of the table. The number directly under the mark is read. For example, a number of 0.280 would indicate that the first bag number would be determined by a number in row 28. The same procedure is repeated, randomly placing another mark on the table and recording that number. For example, a number of 0.799 would indicate that the bag number we are looking for is in column 7. The number in column 7, row 28 of Table 1 of ASTM D 3665 is 0.660. The process is repeated, row and column, until at least five numbers have been determined. Sometimes it is better to pick a few additional numbers just in case problems of duplicate bag numbers arise later.

Each of the five random numbers is then multiplied by the total number of bags. If the number of bags is 18, we multiply 18 by 0.660, and the bag number we are after is 11.88, which rounds to bag number 12. Completing the process our bag numbers are 12, 15, 8, 10, and 4. If the same bag numbers are repeated, and if you haven't determined extras, disregard the number and use Table 1 to determine additional numbers. Although the process may seem complicated, it is easier after reading the whole of ASTM D 3665. The process of establishing bag numbers takes less than five minutes from start to finish.

The act of sampling begins after the bags have been identified and located. There are a variety of sampling methods used in recovering samples from bagged filter media, and these will be described later. Regardless of the method used, each bag must be sampled using the same method and procedures; all samples will be weighted equally. When sampling tubes are used, it is important to recover the sample from a cross section of each bag when a sample is recovered. Individual samples should be tagged and bagged until it is determined that the combined weight of the individual samples can produce a composite sample of sufficient size to fulfill the requirements of AWWA.

Worksheet Section 6: Sample ID Number

The composite sample must meet the minimal weight limits defined in AWWA B100-96 Section 5.2, Table 3, "Minimum Size of Composite Sample." Sometimes the weight of the samples removed from the superbags, when combined into the composite sample, will fail to meet the limit. If each sample removed from the anthracite superbags in the above example weighed one pound, the composite sample would weigh five pounds. Although it may be of adequate size for testing purposes, it fails to meet a requirement of B100. In the example, Table 3 indicates that the minimal size of the composite sample is ten pounds since the maximum size of particles in the sample are smaller than 3/8 inch. The weight of the composite sample must be increased by an additional five pounds, either by randomly determining additional bags to sample or by doubling the size of the samples recovered from each of the original five bags. Again, care must be taken to ensure that individual sample size is roughly the same; big differences can skew test results.

Once the individual samples have been combined to form the composite sample, and the composite meets the weight requirements of AWWA B100-96 Table 3, the sample can be reduced. Although sampling of anthracite and sand generally produces composite samples of manageable size, quite often — and especially with gravels — the composite sample will need to be reduced for handling purposes. Reduction is accomplished by one of the methods recognized in ASTM C 702, *Standard Practice for Reducing Samples of Aggregate to Testing Size*. The characteristic determining how the composite sample will be reduced is the moisture condition of the sample. If the sample has visible moisture on the surface, it is reduced using the cone and quartering method of reduction. If the composite is dry, it is reduced using a mechanical splitter or riffle to avoid crushing individual grains.

When reducing samples by the cone and quartering method, make sure the sample is handled in a manner that will not cause it to crush during the repeated quartering process. A good practice when reducing composite samples to testing size is to create splits of the sample that can be archived for later use if problems occur during testing.

When the composite sample has been reduced to a manageable size, it should be placed in a clean, airtight container, which is then sealed to prevent contamination. The container must be affixed with a sample ID number, initial weight, and the signature of the person responsible for verifying the sampling program. Include as much information in the sample ID number as possible, and make sure that the sampling information is forwarded to the testing laboratory along with the sample.

Sampling Methods

Some materials and transportation containers are not easily sampled. One sampling method is to insert a small grain thief into the bag and reseal the bag using tape. However, that compromises the integrity of the bag, and subsequent handling may affect the sealing method. Also, the grain thief is not suitable for gravel material in cubic-foot sacks. The samples may be reduced using a mechanical splitter, also known as a riffler, or the cone and quarter method — both referenced in ASTM C 702. The cone and quarter method involves placing the material on a hard and clean surface, mixing the material by forming cones at least three times, flattening the material, dividing the material into quarters, bagging two opposite quarters, and repeating until the appropriate sample size has been obtained. All of these methods are logistically difficult at the job site because of the number of bags involved.

Dry anthracite and granular activated carbon have been successfully sampled from semi-bulk containers using a brass seed sampler, which consists of two nested tubes containing slotted openings. One end of each tube is pointed, and the other end is open. The inside tube is rotated so that the slots are not aligned, and the sampler is inserted into the semi-bulk container to refusal, but not through the bottom or sides of the container. The inside tube is rotated so that the slots align and both tube openings align to allow the sample to flow into the sampler. The inside tube is again rotated so that the slots are not aligned and the sampler is removed from the container. The sample is poured from the open end of the sampler into the sample storage container. Care must be exercised to not force the sampler into the container being sampled, especially with a hammer, and to not force the tubes to rotate as that could cause attrition of the material being sampled.

The brass sampler has not been found to be suitable for sampling silica gravel, silica sand, high-density gravel, and high-density sand in semi-bulk containers. Generally, it is not possible to insert the brass sampler into those materials without applying substantial force, which tends to bind the tubes both on opening and closing. Also, some of the larger gravels will not flow through the slotted openings. Alternative methods for sampling such materials in semi-bulk containers must be devised since the B100 and the ASTM standards do not describe any sampling techniques. Four methods have been used and have met with varying success. They are, in decreasing order of accuracy:

1. Crosscut sampling from a flowing stream out of a hopper.
2. Emptying the bags and cone and quartering per ASTM C 702 as described above.
3. Removing a portion of the material and obtaining a sample of the center of the bag.
4. Surface sampling off the top of the bag. This will not yield a representative sample and is not recommended.

Various apparatus and equipment are necessary to obtain a flowing stream from a semi-bulk container of material in the field. Equipment may consist of a support structure, a hopper large enough to contain one semi-bulk container, a flow control valve such as a slide gate, a method to support the semi-bulk container to be filled (such as a fork lift), and sampling devices (such as pans or buckets). The container to be sampled is deposited into the structure-supported hopper and the same container is positioned below the slide gate. On cue the slide gate is opened and samples are taken through the flowing stream. The samples are deposited into another container for compositing and reduction per ASTM C 702. This method of sampling is recommended only for those projects that have a large number of containers to sample and production sampling was not performed. The time required to perform this procedure and its expense tend to be prohibitive. It is recommended that the third method described above be employed where a portion of the material is removed from the container and a sample is obtained. The least desirable method is to sample the top of the container, as this usually does not provide a representative sample.

Sample Testing

The B100 standard bases most of the filtering material tests on existing ASTM standard tests. However, in some cases the B100 standard makes significant modifications that can affect the results, if the technician performing the testing is unaware. Prior to procuring the services of a testing laboratory, testing technicians should be asked whether they are experienced in AWWA B100 filtering material testing. If not, they should be cautioned that not all of the tests follow the ASTM standards exactly. If the testing facility does not have a copy of the B100 standard, the testing technicians should be instructed to obtain a copy and review it before the samples arrive. In some cases, additional testing equipment may need to be procured. Usually sieves will have to be obtained to complete a proper B100 sieve stack. The following is a discussion of each of the major test Procedures described in Section 5.3 of the B100 standard:

B100 Section 5.3.1: Acid Solubility

The acid solubility test is unique to the B100 standard, which describes the test in its entirety. Prior editions of the B100 standard required the hydrochloric acid concentration to be 20% and the sample had to stand for 24 hours, but the most recent edition uses a 1:1 ratio and a time limit of 30 minutes after effervescence ceases. This has decreased the time necessary to perform the test.

B100 Section 5.3.2: Gravel Shape

The gravel shape test is also unique to the B100 standard and is also described in its entirety. Of all the B100 tests, this is one of the most subjective. It requires the observer to estimate and identify various characteristics. The first is fractured faces, which are defined as a "surface surrounded by sharp edges, such as those produced by crushing, that occupy more than approximately 10% of the total surface area of the particle. This is intended to exclude a surface with small nicks and chips from classification as a fractured face." Section 4.1.2.1.3 allows no more than 25% by dry weight to have more than one fractured face. This definition not only requires the observer to estimate what constitutes 10% of the total area, but also whether the face is surrounded by sharp edges. Some flat surfaces that do not have sharp edges have been erroneously identified as fractured faces.

The other gravel shape test is shape determination. The shape is defined as "the ratio of the longest axis to the shortest axis of the circumscribing rectangular prism for a piece of gravel… determined using a caliper or a proportional divider." This procedure is less subjective in that the observer has the use of a mechanical device and only has to determine the circumscribing prism.

B100 Section 5.3.3: Specific Gravity

The B100 standard utilizes both the ASTM C 127 *Standard Test Method for Specific Gravity and Adsorption of Coarse Aggregate* and the ASTM C 128 *Standard Test Method for Specific Gravity and Adsorption of Fine Aggregate*. It also allows the use of the Noble Large Aggregate Test for silica gravel, but the test is unique to the standard and requires special equipment that most laboratories may not have. However, it is less complicated and faster to perform than ASTM C 127. Currently, the B100 Committee is considering a similar alternative test to be performed on anthracite if it can be shown to be as accurate and repeatable as the Noble Large Aggregate Test was shown for gravel.

The ASTM C 127 specific gravity test for silica gravel is reported as a saturated surface dry specific gravity. Inherent with this test and the ASTM C 128 is the determination as to when the material has been dried to a saturated surface dry condition, usually using towels to remove the excess moisture. Most technicians, with experience, are able to provide repeatable results. Another aspect of the ASTM C 127 test is that it is intended for material retained on a No. 4 (4.75 mm) sieve. Since many gravel gradations include a barrier layer that is 3.175 x 1.70 mm and a support layer of 6.35 x 3.175 mm, these tests need to be handled differently. The former should be tested in accordance with ASTM C 128 and the latter should be split between ASTM C 127 for the larger fraction and ASTM C 128 for the smaller fraction.

All other materials, including silica sand, are tested using the ASTM C 128 test and reported as apparent specific gravity. The procedure empirically determines the specific gravity of an aggregate or media on a bulk saturated surface dry basis and the absorption value in the bulk saturated surface dry state. These two values are then used to mathematically determine the specific gravity of the media in both an apparent and bulk basis. ASTM C 128 states that apparent specific gravity "pertains to the relative density of the solid materials making up the constituent particles *not including the pore space within the particle that is accessible to water*." It represents the specific gravity of the solid dense anthracite less the pore space. The pore space within anthracite, determined by absorption, is as much as eight times higher than that of silica or garnet materials. These higher absorption values widen the difference in specific gravity between the apparent and bulk saturated surface dry basis. In the case of anthracite, a more accurate or true value of specific gravity may be bulk (saturated surface dry), since it represents the specific gravity of the media particles when the pore spaces are saturated with water, as they are when in a filter.

B100 Section 5.3.4: Sieve Analysis

The most specified and possibly the most controversial test is the sieve analysis, which is also known as gradation analysis. It is performed in accordance with ASTM C 136 *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates* with significant modifications stipulated by B100. The most significant modifications are the sample size, machine-shaking times, sieve calibration, and sieve stack. The purpose of the sieve analysis for fine filtering material, such as silica sand, garnet sand, and anthracite, is to produce a plot of the results on semi-log paper to obtain the effective size and uniformity coefficient of the tested material. For a further explanation of these criteria, refer to the B100 standard. The purpose of the sieve analysis for gravel is to obtain the percent over and under size of the tested material.

The minimum sample size is listed in Table 6, "Minimum Sample Size for Sieve Analysis," of the B100 standard. However, for anthracite sieve analysis we find that using much more than the minimal sample size causes too much anthracite to accumulate on individual sieves, which can cause blinding of the sieve. If the sieve blinds, it may not allow all of the smaller particles to pass, which can lead to erroneous results. The reason is the difference in bulk density. The bulk density is 50 pounds per cubic foot for anthracite, 100 pounds per cubic foot for silica materials, and up to 300 pounds per cubic foot for high-density material. That means that the same weight sample of anthracite has twice the volume of the same weight of a silica material. We recommend that the anthracite sample size for sieving be no more than 150 grams. That size limit is also being considered in the next update of the B100 standard.

A significant modification of ASTM C 136 is the required machine shaking times. The B100 standard states that sieves generally require shaking times of 10 ± 0.5 minutes for sand and gravel and 5 ± 0.5 minutes for anthracite. This is in contrast to ASTM C 136, which directs the tester to "continue sieving for a sufficient period and in such manner that, after completion 1 mass % of the residue on any individual sieve will pass that sieve during 1 minute of continuous hand sieving." Most testing laboratories are unaware of the B100 requirement and that excessive sieving can reduce the particle sizes. The B100 standard cautions care when sieving to avoid breaking anthracite particles.

Calibration of sieves can be critical in obtaining accurate results. B100 requires that sieves conform to the tolerances required in ASTM E 11 *Standard Specification for Wire Cloth and Sieves for Testing Purposes* and "if compliance to specifications arise when nominal sieve openings are used, standard reference materials (glass spheres) certified by the National Bureau of Standards shall be used in accordance with their calibration procedure to accurately determine the effective opening size of each sieve."

In fact when sieving anthracite, silica sand, and high density sand, most laboratories use glass sphere calibrated sieves because the effective size tolerances of these filter materials are 0.001 mm. That is the difference between a filtering material being accepted or rejected. If glass sphere calibration is not available, the B100 allows replotting the data "using both the maximum and minimum permissible variation of average opening from the standard sieve designation as shown in Table 1, column 4 of ASTM E 11," also reproduced in Appendix B of the B100 Standard.

Most testing laboratories will list the effective sieve size as derived from the nominal sieve size opening. The effective sieve size is the average sieve opening determined by glass sphere calibration. The nominal size opening is the nominal dimension listed in ASTM E 11, Table 1. If the reported sieve opening varies from the nominal sieve opening, the sieves usually have been glass sphere calibrated. If the nominal sieve size is listed, it is usually assumed that the sieves are not glass sphere calibrated but still comply with the ASTM E 11 tolerances. Sieves that do not meet those tolerances must not be used. Laboratories and manufacturers experienced in B100 filtering material testing will usually maintain a separate set of glass sphere calibrated sieves for exclusive testing of filtering materials. If in doubt, ask the testing laboratory personnel if their sieves are glass sphere calibrated. If they are not, questions of calibration are relegated to replotting the results using the maximal and minimal permissible variation of average opening from the ASTM E 11, Table 1, standard sieve designation.

To avoid excessive interpolation when determining the effective size, the B100 standard requires that "the sieves used on a particular sieve analysis shall have openings such that the ratio between adjacent sizes is the fourth root of 2, or 1.1892." In other words, the sieves should be in consecutive order as listed in the B100 appendix, i.e., No. 10, No. 8, No. 6, No. 5, etc. Skipping one sieve size can drastically affect the effective size and uniformity coefficient and provide erroneous results, especially with the tolerances described above. The other stipulation by the B100 in choosing sieves is that "the nominal opening of only one sieve is smaller than the smallest effective size so that the greatest range of particle size distribution can be measured in one standard nest of six sieves." This is to ensure that the sieve stack is limited to the opening sizes of most importance to the gradation plot.

B100 Section 5.3.4.6: Mohs' Scale of Hardness

While B100 states that no standard test method has been found for hardness, all commercial laboratories should follow the same procedure. That is very ambiguous and makes for a very subjective test. The B100 Committee will be reviewing a test method to make it more objective. Meanwhile, most testers use various standards of known hardness to determine the hardness of filtering materials. Usually samples of the filtering material are mounted on sticks and used to scratch the standard rock samples of increasing hardness, using a firm, consistent pressure, until the filtering material can no longer produce scratches. The last scratched rock is used as the final Moh number. For instance, if a majority of the filtering material last scratches a 3.0 Moh hardness calcite, the material is said to have a Moh hardness greater than 3.0. The experience of the tester is important in selecting the samples, determining the edge of the sample to be used, maintaining a consistent pressure, and knowing when the sample is scratching the rock or when the sample is crushing under pressure. Moh's hardness is truly a subjective test with no present standard for guidance.

Recommendations

It is recommended that when modifying the B100 requirements, one should be intimately familiar with the basis of the standard as well as the effect the modification will have on the filtering material and the ability of a manufacturer to supply that material.

We recommend that, if at all possible, sampling and testing of filtering material be witnessed at the point of manufacture. Most manufacturers have the facilities to sample and test the materials on site and are experienced in the AWWA B100 requirements. If it is not possible to witness the sampling and testing at the point of manufacture, the manufacturer's sampling and testing is not adequate, or the filtering materials must be sampled and tested on site, a detailed sampling and testing program must be organized. The program must adhere to the B100 requirements as outlined before.

If an investigation of the methods used confirms that all procedures were in compliance with all standards, including the AWWA B100 and the appropriate ASTM standards, only then can the material be considered either compliant or not compliant with the AWWA B100 Standard for Filtering Material.

References

ASTM C 127 *Standard Test Method for Specific Gravity and Adsorption of Coarse Aggregate*, American Society for Testing and Materials.

ASTM C 128 *Standard Test Method for Specific Gravity and Adsorption of Fine Aggregate*, American Society for Testing and Materials.

ASTM C 136 *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate*, American Society for Testing and Materials.

ASTM C 702 *Standard Practice for Reducing Samples of Aggregate to Testing Size,* American Society for Testing and Materials.

ASTM D 75 *Standard Practice for Sampling Aggregate*, American Society for Testing and Materials.

ASTM D 3665 *Practice for Random Sampling of Construction Materials,* American Society for Testing and Materials.

ASTM E 11 *Standard Specification for Wire Cloth and Sieves for Testing Purposes,* American Society for Testing and Materials.

Standard for Filtering Material, B100-96, American Water Works Association.

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Glossary of Common Terms Used in This Publication

ASR	aquifer storage and recovery
AWT	advanced water treatment
AWWT	advanced wastewater treatment
AWWA	American Water Works Association
BOD	5-day biochemical oxygen demand
BOD_x	BOD test based on other than 5 days
CBOD	5-day carbonaceous BOD
COD	chemical oxygen demand
cfm	cubic feet per minute
cfs	cubic feet per second
CWA	Clean Water Act
DEP	Florida Dept. of Environmental Protection
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FAC	Florida Administrative Code
fps	feet per second
FSAWWA	Florida Section of AWWA
FWEA	Florida Water Environment Association
FWPCOA	Fla. Water & Pollution Control Operators Assoc.
GIS	Geographic Information System
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
hp	horsepower
I/I	Infiltration/Inflow
MGD	million gallons per day
mg/L	milligrams per liter
MLSS	mixed liquor suspended solids
MLTSS	mixed liquor total suspended solids
NPDES	Nat. Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
ORP	oxidation reduction potential
POTW	public-owned treatment works
ppm	parts per million
ppb	parts per billion
PSC	Public Service Commission
psi	pounds per square inch
PVC	polyvinyl chloride
RO	reverse osmosis
SCADA	supervisory control and data acquisition
SJRWMD	St. Johns River Water Mangement District
SFWMD	South Florida Water Management District
SRWMD	Suwannee River Water Management District
SSO	sanitary sewer overflow
SWFWMD	Southwest Florida Water Management District
TDS	total dissolved solids
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
USGS	United States Geological Survey
WEF	Water Environment Federation
WRF	water reclamation facility
WTP	water treatment plant
WWTP	wastewater treatment plant