Nova Scotia
Department of Environment and Labour

Treatment Standard 02/2003:

Treatment Standard
for
Municipal Groundwater Source Water Facilities

Preamble

Serious outbreaks of waterborne disease in Canada and elsewhere have heightened public awareness that threats to water quality can have a profound impact on our health, the environment, and the economy. In order to safeguard public health, and re-instill confidence in Nova Scotia's public drinking water systems, it is imperative that drinking water supplies be kept clean, safe and reliable. The goal of drinking water programs is to protect public health. In order to achieve this goal, it is important that drinking water programs meet industry accepted standards and guidelines.

This treatment standard sets the minimum level for treated water quality parameters for municipal public water supplies using groundwater sources that are not under the direct influence of surface water. Municipal water utilities should deliver to the consumer an adequate supply of drinking water that meets or surpasses drinking water standards. This objective is achieved most economically and effectively when the source water is taken from the highest-quality source available, the water is appropriately treated and water quality is maintained during transmission to the consumer. It would be considered unacceptable for systems capable of exceeding this standard to allow their water quality to degrade in quality to only meet the minimum requirements.

Nova Scotia has entrenched the health-related *Guidelines for Canadian Drinking Water Quality* (GCDWQ) within provincial legislation covering water treatment and distribution systems. For parameters not covered in this treatment standard, the GCDWQ will serve as the minimum requirements for facility operations. In addition to the GCDWQ, this treatment standard is not intended to replace, but to be used in conjunction with, the *Nova Scotia Guidelines for Monitoring Public Drinking Water Supplies.*

Background

One of the major objectives of a water supplier is to provide users with drinking water that is free of microbial pathogens to prevent waterborne disease. Water suppliers can achieve this level of public health protection by providing treatment to assure that pathogens found in water supplies are removed or inactivated.

The provision of safe drinking water is a major public health issue. Proper treatment and disinfection advancement during the 20th century and into the 21st century has shown how important a safe drinking water supply is to society. One hundred years ago, typhoid and cholera epidemics were common in North America.

Disinfection was a major factor in reducing these epidemics. However, disinfection is only one step in a multiple-barrier approach for the delivery of safe water.

In 1990, the US Environmental Protection Agency's Science Advisory Board concluded that minimizing the risk of exposure to microbial pathogens in water was likely the greatest remaining health challenge for water suppliers. Acute health effects from exposure to these pathogens are documented and associated illness can range from mild to moderate cases lasting only a few days to more severe infections that can last several weeks and may result in death for those with weakened immune systems. Other microbial pathogens, resistant to traditional disinfection, include *Giardia lamblia* and *Cryptosporidium*, and when discovered in a groundwater supply, their presence is most likely due to surface water infiltration into groundwater systems.

The Nova Scotia Department of Environment and Labour (DEL) has developed a *Protocol for Determining Groundwater Under the Direct Influence of Surface Water*. All groundwater treatment facilities that are determined to be under the influence of surface water are required to:

- remediate the conditions resulting in surface water influence; or
- meet the *Treatment Standard for Municipal Surface Source Water Treatment Facilities*.

The recognized water treatment philosophy is to incorporate the multiple-barrier strategy to best protect the public health from waterborne disease. Groundwater treatment for supplies not under the influence of surface water typically includes the reduction of microbial pathogens by disinfection processes. This treatment standard, which constitutes the second line of defence in the multiple-barrier drinking water management approach, does not relieve the water supplier from their duties to:

1. Ensure groundwater wells are properly constructed, are located in areas where there is minimal potential for contamination, and have appropriate wellhead protection measures in place. These source protection measures represent the first line of defence in the multiple-barrier concept and, as such, protect public health by reducing the risk of contaminating the drinking water source.
2. Ensure water quality is monitored and maintained in the distribution system. The distribution system represents the last physical barrier in the multiple-barrier concept and, as such, well designed and operated distribution systems are key to providing safe, clean drinking water to consumers.

Section 2 of the *Nova Scotia Environment Act* clearly states its purpose is to support and promote the protection, enhancement and prudent use of the environment while recognizing certain goals, such as maintaining environmental protection as essential to the integrity of ecosystems, human health and the socio-economic well-being of society. Section 2 (e) identifies government as having a catalyst role in many areas including the development of policies, standards, objectives and guidelines.

Based on the Department's responsibilities, minimum water treatment requirements have been identified to verify that systems in Nova Scotia meet current environmental standards. The Department of Environment and Labour believes that through the implementation of the minimum treatment standards in Nova Scotia, the health of all Nova Scotians and visitors will be better protected by reducing the likelihood of an adverse water quality event by implementing industry accepted standards for safety and protection from exposure to pathogens.

The goals of this treatment standard include:

- setting treatment efficiency levels to remove/inactivate microbiological pathogens;
- identifying the industry standard for CT log reduction;
- detailing minimum disinfection benchmarks.

This treatment standard only applies to true groundwater systems that are not under the influence of surface water. This treatment standard recognizes that true groundwater has effective natural particle removal as the water has passed through natural media such as sand, clay, gravel, etc. The disinfection benchmark values have accordingly been set at *4-Log Reduction* (99.99%) of viruses to ensure that the disinfectant applied, chemical or physical, is in contact with the water for a sufficient amount of time to adequately inactivate microbial pathogens found in groundwater. Contact Time (CT) is used for chemical disinfectants such as chlorine. Ultra violet (UV) disinfection is a physical form of disinfection and performance measurement will depend on system design to meet virus reduction requirements. This treatment standards allows for the use of UV as a primary disinfectant only.

Groundwater Treatment Standard

Effective Date
May 01, 2003

Affected Systems
This standard applies to all municipal Public Water Supplies (PWS) using groundwater sources that are not under the direct influence of surface water (GUDI). For the purposes of this treatment standard, groundwater source facilities falling under GUDI are considered to be a surface water source facility and must meet the requirements of the *Treatment Standard for Municipal Surface Water Treatment Facilities*.

GUDI is defined as: "any water beneath the surface of the ground with:

(i) significant occurrence of insects or other macro-organisms, algae, organic debris, or large-diameter pathogens such as *Giardia lamblia* or *Cryptosporidium*; or

(ii) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions."

Groundwater under the direct influence of surface water may be determined for individual sources in accordance with criteria established and/or accepted by the DEL. The DEL determination of direct influence may be based on site-specific measurements of water quality and/or documentation of well construction characteristics and geology with field evaluation.

This standard applies only to municipal groundwater facilities which have been determined to not be under the direct influence of surface water. This is determined using the most current version of the *Protocol for Determining Groundwater Under the Direct Influence of Surface Water* issued by the Department of Environment and Labour.

Basic Provisions
All water systems are to provide a *System Assessment Report* to the Department of Environment and Labour. The findings of this report will determine the system requirements to meet the standards.

This standard establishes the disinfection treatment criteria required for groundwater source drinking water supplies. Based on the *System Assessment Report*, all systems that do not meet the minimum treatment requirements will be required to work towards full compliance within the identified timelines. Given that some systems will require time to upgrade treatment processes, interim requirements are also detailed.

- On or before April 1, 2004:
  - A municipality, using groundwater sources that have passed Step 1 of the *Protocol for Determining Groundwater Under the Direct Influence of Surface Water* (i.e. GUDI Screen), must provide to the Department a detailed plan regarding how their system will attain full compliance with this treatment standard;
  - Full health-related parameter testing and analysis is required for raw and treated water as per the chemical, physical and microbiological parameters stated in the

Guidelines for Canadian Drinking Water Quality;

- On or before April 1, 2005, facilities using groundwater sources that have failed Step 1 of the *Protocol for Determining Groundwater Under the Direct Influence of Surface Water*, must determine whether any well within the water supply is influenced by surface water and provide to the Department individual well assessment documents (See Steps 2 & 3 of the *Protocol for Determining Groundwater Under the Direct Influence of Surface Water*);
  - For facilities that have been determined to be under the direct influence of surface water, the responsible municipality must provide to the Department a detailed plan regarding how their system will attain full compliance with the *Treatment Standard for Municipal Surface Water Treatment Facilities*;
  - For groundwater systems that are determined to be non-GUDI, the responsible municipality must provide to the Department a detailed plan regarding how the system will attain full compliance with the requirements of this treatment standard;
  - Full health-related parameter testing and analysis is required for raw and treated water as per the chemical, physical and microbiological parameters stated in the *Guidelines for Canadian Drinking Water Quality*;

- On or before April 01, 2008, all construction and operational systems must be in place to meet the requirements of this treatment standard.

Treatment Standards

The purpose of having a treatment standard is to set the minimum parameters that are recognized for water treatment and distribution facility operations in which to maintain public health protection. This treatment standard considers utilizing disinfection treatment processes required to achieve the level of health protection. The safe, clean water supply is addressed by the implementation of the multiple-barrier approach. This includes:

- source water and/or wellhead protection;
- effective treatment/disinfection process operations;
- effective distribution system operation and water quality maintenance;
- quality control - sampling, testing and monitoring.

Research and field work results support optimizing particle removal for surface supplies from water treatment facilities to maximize public health protection from microbial pathogens. True groundwater is recognized to have effective natural filtration. This standard recognizes that a groundwater supply, when compared to a treated surface water supply, may contain higher levels of non health-related turbidity. This treatment standard identifies specific parameter values, record keeping and reporting requirements. As deemed necessary by DEL, where there is concern regarding the quality of the water being provided to consumers, groundwater facilities may need to meet the enhanced monitoring requirements identified in this standard.

The system owner must ensure they comply with all other health-related parameters of the *Guidelines for Canadian Drinking Water Quality* and the *Guidelines for Monitoring Public Drinking Water Supplies*.

Groundwater Treatment Standard

Introduction

True groundwater is recognized to have effective natural particle removal as the water has passed through natural media such as sand, clay, gravel, etc. This provides for a certain level of assurance that many of the known biological contaminants found in surface water supplies have been adequately removed naturally. This treatment standard recognizes natural filtration of true groundwater. It is also recognized that some systems may require the use of GUDI wells to ensure an adequate supply of water for the system. GUDI wells must meet the *Treatment Standard for Municipal Surface Water Treatment Facilities*.

General Requirements

- Each well, or treatment facility, is required to have a minimum of two disinfection units configured to apply disinfection treatment to the potable water at all times and to ensure that inadequately disinfected water does not enter the water distribution system;
    - Overall system redundancy may be considered for multi-well systems that have sufficient capacity to meet maximum day system demands with the largest well out of service provided all wells have a minimum of one operational disinfection unit and the owner has standard operational procedures and contingency plans to ensure public safety is not compromised;
    - Operational management plans may be considered for regional water system operations provided the owner(s) has standard operational procedures and contingency plans to ensure public safety is not compromised;
    - These alternatives will be evaluated on a case-by-case basis.
- Each disinfection unit must be designed to meet the well/facility rated design flow capacity;
- Inadequately disinfected water must not enter the distribution system unless in emergency to meet system needs and/or maintain positive pressures. If inadequately disinfected water enters a distribution system, DEL must be notified and a boil water advisory issued as required by the *Guidelines for Monitoring Public Drinking Water Supplies*;
- Treatment must be sufficient to ensure *4-Log Reduction* (99.99%) inactivation and/or reduction of viruses by the disinfection processes;
- A free chlorine residual must be maintained in the distribution system;
- Turbidity monitoring must be conducted on a regular basis at the groundwater source facility and in the distribution system.
- Sampling locations in the distribution system must be adequate to appropriately characterize the distribution system.
- Any changes to the sampling locations are to be approved by DEL.

Disinfection Requirements

This treatment standard allows for the use of ultra violet (UV) light as a primary disinfectant for the reduction of pathogens that are typically associated with groundwater supplies. UV is effective for the reduction of viruses but does not provide for continued disinfection capabilities following exposure to the light. Facilities using UV, or other acceptable primary disinfection methods, are required to apply chlorine, or other acceptable alternative disinfectant such as monochloramine or chlorine dioxide, as a secondary disinfectant to maintain an effective disinfectant residual in the distribution system.

Note: *Alternate Disinfection Processes* - The application of alternative disinfectants is acceptable provided that the formation of disinfection by-products is minimized and the alternate disinfectant has been shown to achieve the level of disinfection that is required with chlorination. Notwithstanding the use of alternative disinfectants, it will be necessary to maintain a disinfectant residual throughout the distribution system as indicated in the standard. Alternative disinfectant application will be evaluated on a case-by-case basis.

- *Disinfection Requirements:*
  - Chemical disinfection through the use of chlorine, or alternate disinfection method, shall contribute a minimum of *4-Log Reduction* of viruses;
    - see *Table 1 - CT Log Reduction*;
    - Note: Requirement of *4-Log Reduction* or 15 minutes actual contact time, whichever is greater, for chlorine disinfection systems.
  - Physical disinfection through the use of ultra violet (UV) light, or alternate disinfection method, shall contribute a minimum of *4-Log Reduction*;
    - Suppliers of UV disinfection equipment must supply written verification that the system will continually achieve this requirement when operated as designed;
  - Disinfection equipment must be operated in such a manner as to prevent inadequately disinfected water from entering a distribution or storage facility;
  - Water systems must be equipped with alarm capabilities to notify operations staff if the disinfection process fails to operate properly;
  - Standard operational procedures must be developed, implemented and communicated to all operations staff.

- *Chlorine Residual Monitoring Requirement:*
  - Continuous monitoring is required for finished water leaving the treatment facility or well, with measurements taken at no more than five-minute intervals;
  - Continuous monitoring is required, with measurements taken at no more than five-minute intervals, of the water leaving a water storage structure within a water distribution system;

- *Ultra Violet (UV) Light Monitoring Requirement:*
  - UV systems must be designed to provide a minimum dosage of 40 mJ-sec/cm^2 at all points within the reactor at all times when water is passing through the treatment process provided that the water quality characteristics indicate that this is a sufficient dosage;
    - Water flow must either be stopped or directed to waste or another disinfection method must be used to achieve *4-Log Reduction* during the minimum designed warm-up period for the specific unit or any other UV reactor downtime;
  - UV disinfection systems must be equipped with UV sensors reading calibrated UV intensity;
  - The control system must be configured in a manner to shut down UV lamp operation and water flows and the system must be configured with alarm notification in the event of:
    - High temperature in the reactor, lamp, ballast or transformer;

        - Low UV dosage;
        - High flow rate that causes dose to fall below design specifications; or
        - Low UV intensity.
    - UV lamp operation must be monitored in a manner that ensures bulb replacement can be accomplished prior to the maximum lamp life expectancy.

Distribution System Disinfection Requirements

- *Free Chlorine Residual Values and Sampling Requirements:*
    - The disinfection process must be operated in such a manner as to ensure that a 0.2 mg/L minimum free chlorine residual is achieved throughout the water distribution system at all times;
    - The maximum free chlorine residual of water delivered to consumers is 4.0 mg/L;
    - Grab sample monitoring of the distribution system is required.
    - Sampling and testing frequency for chlorine residual monitoring of the distribution system is the same as for bacteriological sampling requirements as stated in the *Guidelines for Monitoring Public Drinking Water Supplies*.

Turbidity Requirements

- *Turbidity Monitoring Requirement*:
    - For water entering a distribution system or pipeline from a groundwater facility turbidity levels must not exceed 1.0 NTU:
        - In at least 95% of the measurements taken by grab sampling for each calendar month (minimum frequency of once/day or more frequently if stated in the facility *Approval to Operate*); or
        - In at least 95% of the time each calendar month if continuous monitoring is the method of turbidity measurement.
            - For systems experiencing elevated turbidity measurement related to well pump start-up, such as with air bubble formation, the continuous monitoring recording may be delayed for up to 4 minutes, 59 seconds. However, it is recommended that all turbidity data be captured for trending purposes.
    - For groundwater supplies that exceed 1.0 NTU for water entering a distribution system or pipeline, a maximum of 5.0 NTU may be permitted if the owner demonstrates that the turbidity is non-health related and that the disinfection process is not compromised by the use of this less stringent value.
- *Distribution Turbidity Values:*
    - An aesthetic objective turbidity value of 5.0 NTU or less must be achieved on distribution system sampling based on each calendar month;
    - Sampling and testing frequency is the same as for bacteriological sampling requirements as stated in the *Guidelines for Monitoring Public Drinking Water Supplies* or as stated in the *Approval to Operate* for the facility.

Record Keeping Requirements

The following information must be recorded and retained by the facility and made available to DEL upon request, or as indicated:

- Record of all GUDI assessments completed on each well in the groundwater system and sent to DEL;
- System assessment reports are to be sent to DEL;
- All turbidity measurements;
- All source water and/or wellhead protection information;
- Disinfection application data (dosage, CT determinations, UV dosage calculations), chlorine residual or UV intensity data for primary and/or secondary disinfectant application;
- Chlorine residual values in the distribution system;
- All incidents of free chlorine residual measurements below 0.2 mg/L in the distribution system must be detailed with a description of any actions taken;
- All incidents of turbidity measurements that exceed the values stated in this standard must be detailed with a description of any actions taken;
- All incidents of suspected and/or confirmed disease outbreaks, as deemed by the Medical Officer of Health, which have been attributed to the water system.

Reporting Requirements

- An annual report of the system, including flow records for compliance with the *Water Withdrawal Approval* are to be submitted to DEL;
- Water quality and analysis reports are to be provided to the Department upon request and/or as identified in the facility *Approval to Operate*;
- The facility must meet all emergency reporting requirements as established by the Department or any other regulatory body;
- The Boil Water Advisory Protocol and Communication Plan as stated in the *Guidelines for Monitoring Public Drinking Water Supplies* must be adhered to;
- Immediate notification, to the Department of Environment and Labour, of a health-related adverse water quality situation is required.

Enhanced Monitoring Requirements

For a groundwater system which supplies water that cannot meet the requirements of this standard, to a distribution system or pipeline, either belonging to the system or a respective third party, DEL may require the following:

- Sampling of the distribution system for bacteriological monitoring must be increased in frequency by double those stated in the facility *Approval to Operate*;
    - For facilities without an identified frequency requirement for bacteriological monitoring, the requirement will be double the frequency at the current accepted sampling locations and shall be no less than double those stated in the *Guidelines for Monitoring Public Drinking Water Supplies*;
- The minimum free chlorine residual in the distribution system is 0.4 mg/L;
- Sampling in the distribution system must be adequate to appropriately characterize the distribution system;
- Distribution system sampling must be reported on a monthly basis;
- Distribution sampling locations must be indicated on a map that illustrates the current distribution system and a copy of the sampling location map is to be provided to DEL;
- Any changes to the sampling locations are to be approved by DEL;
- Standard operational procedures and emergency contingency plans must be developed, implemented and communicated to all staff for the interim period. These procedures and

plans must be made available to DEL staff upon request;

- The Boil Water Advisory Protocol and Communication Plan as stated in the appropriate section of the *Guidelines for Monitoring Public Drinking Water Supplies* must be adhered to;
- If at any time the bacteriological parameters are not met, the owner will be required to issue a boil water advisory in accordance with the *Guidelines for Monitoring Public Drinking Water Supplies*. The boil water advisory will be removed by DEL in consultation with the Medical Officer of Health and the owner when all concerns regarding adverse water quality have been addressed as identified in the *Guidelines for Monitoring Public Drinking Water Supplies*.

Backup Water Systems

The purpose of a 'Backup Water System' is to serve as a resource in the event of a disruption of the normal water system supply, treatment and or distribution. If an owner has, or intends to have, a backup water supply to serve the community, the following parameters for a backup water system must be met:

- A backup water system is only to be used in emergency on a temporary basis;
- When a backup water system is used for supplying water for human consumption, the owner of the system must notify DEL and identify the anticipated period of time the system will be in service;
- For backup systems that meet the requirements of this treatment standard, the water system may continue to operate as under normal circumstances until the main water system is ready to be put back into service;
- For backup systems that do not meet the requirements of this treatment standard, the municipality must immediately initiate a 'Boil Water Advisory' as stated in the *Guidelines for Monitoring Public Drinking Water Supplies*;
- Based on the *Guidelines for Monitoring Public Drinking Water Supplies*, the boil water advisory will be removed by DEL in consultation with the Medical Officer of Health and the owner when all concerns regarding adverse water quality have been addressed as identified in the Guidelines.

Additional Information

Natural Filtration

True groundwater may be of better quality than surface water because of the natural filtration it receives prior to entering the water well. This natural filtration may provide for the physical removal of larger microbial pathogens. Filtration is a physical process whereby the particles are trapped by the natural media to prevent them from passing through and into the water well. Because turbidity monitoring is the most common method of assessing particle removal in drinking water systems, turbidity is the parameter required by this standard from which to monitor and safeguard the water entering the distribution system.

Disinfection

Disinfection is responsible for inactivating any microbial pathogens that pass through previous unit processes. Disinfection is the most important step in any water treatment process. New microbial challenges and increased knowledge of disinfection by-products makes it essential that the design of new and/or upgraded waterworks and the maintenance of these facilities reflect current knowledge, technologies and practices.

In cases where chlorine is used as the primary disinfectant, the CT value needs to be calculated by taking into consideration pH and temperature of the water and the free chlorine residual.

All water treatment facilities must include disinfection to guard against microbial pathogens in the water. Disinfection processes must be approved and meet industry standards.

Regardless of the primary disinfection process utilized, the water distribution system must maintain a minimum free chlorine residual level (or other acceptable disinfectant residual) in order to provide an appropriate level of safety to the consumer.

Log Reduction – Free Chlorine

In order to ensure that required levels of disinfection for *4-Log Reduction* of viruses are achieved, this standard uses the concept of the disinfection concentration (C) multiplied by the actual time (T) that the finished water is in contact with the disinfectant. The calculated CT value ratio (CT_{Actual}) for virus reduction takes into account the pH and temperature of the water, lowest expected free chlorine residual and the effectiveness of the mixing of chemical in the water (baffling factor). Information used in determining the CT_{Actual} value for virus reduction is provided in the Tables 1 and 2.

To ensure that the different parameters and their effect on the disinfection process are best addressed, it is recommended that the calculation be based on:

1. the lowest temperature expected of the water when contacted by the disinfectant;
2. the highest pH value;
3. lowest expected residual at the first user location from the point of chemical application;
4. the least effective baffling condition of the chemical in the water - Baffling Factor (see Table 2); and
5. the highest flow rate.

Note: For systems that include the volume in a storage tank or standpipe for CT determination, the

calculation must be made based on the minimum operating level in the tank.

CT_{Actual} Calculation

To determine if a system meets the log reduction requirements the calculated concentration time ratio ($CT_{Actual}/CT_{Required}$) must be equal to or greater than 1.0 (the value identified).

Example:

The following example calculations are based on:

1. water temperature of **10°C**;
2. pH of water is **7.8**;
3. free chlorine residual of **1.0** mg/L;
4. complete mixing (see Table 2) - baffling factor of **1.0**; and
5. actual contact time between the point of chemical application and the first user is **20** minutes.

Based on the information above and by referencing Table 1, the $CT_{Required}$ value of '6' is used in the following calculation formula for determining if disinfection will provide for *4-Log Reduction* of viruses.

Step 1: Determining CT_{Actual}

CT_{Actual}	=	Concentration (mg/L) x Time (minutes) x Baffling Factor
CT_{Actual}	=	1.0 x 20 x 1.0
CT_{Actual}	=	20

Step 2: Determining $CT_{Required}$

Based on the log requirements, to achieve *4-Log Reduction* of viruses, the value must be taken from the table. Based on the free residual concentration, the water temperature of 10°C and the water pH of 7.8, the virus value used for determining CT_{Actual} is **6** as outlined under the 'example' heading.

Therefore, the $CT_{Actual}/CT_{Required}$ for this system is:

$CT_{Actual}/CT_{Required}$	=	20 / 6
$CT_{Actual}/CT_{Required}$	=	**3.3 Ratio** (must equal 1.0 or greater)

This indicates the system meets the CT *4-Log Reduction* for viruses requirement.

Log Reduction – Ultra Violet (UV)

Currently there is not a definitive industry standard calculation that can be fully depended upon. Until such time as one has been determined, all groundwater systems incorporating UV as a primary disinfectant must provide DEL with written verification from the manufacturer that the system will continually meet the requirement for *4-Log Reduction* of Viruses.

Table 1 - CT Log Reduction		
Temperature (º Celsius)	**pH**	
	6.0 to 9.0	**> 9.0**
0.5	12	90
5	8	60
10	6	45
15	4	30
20	3	22
25	2	15

Table 2 – Baffling Factor Determination		
Plug Flow (indicates complete mixing)	**1**	• very high length to width ratio – typical in pipelines
Superior	**0.7**	• perforated inlet baffle • serpentine or perforated intra-basin baffles • outlet weir or perforated launders
Average	**0.5**	• baffled inlet or outlet with some intra-basin baffles
Poor	**0.3**	• single/multiple unbaffled inlets and outlets • no intra-basin baffles
Unbaffled	**0.1**	• no baffles, separate inlet/outlet • mixed flow • high inlet/outlet flow velocities • low length to width ratio