



Filter Backwash Recycling Rule

Technical Guidance Manual



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ABBREVIATIONS

List of abbreviations and acronyms used in this document:

ASCE	American Society of Civil Engineers
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
CADD	Computer Aided Drafting and Design
CFR	Code of Federal Regulations
CT	The Residual Concentration of Disinfectant (mg/l) Multiplied by the Contact Time (minutes)
DAF	Dissolved-Air Flootation
DBP	Disinfection By-Products
DE	Diatomaceous Earth
DOC	Dissolved Organic Carbon
EPA	Environmental Protection Agency
FBRR	Filter Backwash Recycling Rule
FR	Federal Register
gal	gallons
gpd	gallons per day
gpm	gallons per minute
gpm/ft ²	gallons per minute per square foot
GWUDI	Groundwater Under Direct Influence of Surface Water
HAA5	Haloacetic Acids (monochloroacetic, dichloroacetic, trichloroacetic, monobromoacetic, and dibromoacetic acids)
hrs	Hours
IESWTR	Interim Enhanced Surface Water Treatment Rule
Kgal	Thousand Gallons
LT1ESWTR	Long-Term 1 Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
MF	Microfiltration
MG	Million Gallons

mg/L	milligrams per liter
MGD	Million Gallons per Day
m/h	meters per hour
M/R	Monitoring/Reporting
NOM	Natural Organic Matter
NTU	Nephelometric Turbidity Unit
O&M	Operation and Maintenance
PN	Public Notification
PWS	Public Water System
PWSID	Public Water System Identification
SOP	Standard Operating Procedure
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TT	Treatment Technique
TTHM	Total Trihalomethanes
TTHMFP	Total Trihalomethanes Formation Potential
UF	Ultrafiltration
UV ₂₅₄	Ultraviolet absorbance at 254 nanometers
WTP	Water Treatment Plant
X log removal	Reduction to 1/10 ^x of original concentration
μ or μm	Micron (10 ⁻⁶ meter)
μg/L	Micrograms per liter

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1. INTRODUCTION

1.1 OVERVIEW

The Filter Backwash Recycling Rule (FBRR) establishes regulatory provisions governing the way that certain recycle streams are handled within the treatment processes of conventional and direct filtration water treatment systems. The FBRR also establishes reporting and recordkeeping requirements for recycle practices that will allow States and EPA to better evaluate the impact of recycle practices on overall treatment plant performance. The FBRR published in the Federal Register (66 FR 31086, June 8, 2001) presents the specific regulatory requirements that must be met by affected systems. Figure 1-1 contains a flowchart that presents the FBRR requirements. Figure 1-2 contains a timeline with the key dates for both States and systems. This document has been developed to provide operators with the practical guidance and relevant information to assist them in complying with the FBRR provisions. It outlines detailed methods for complying with each portion of the FBRR, and provides other useful information regarding recycle practices and filter backwashing not specifically required by the FBRR.

1.2 FBRR COMPONENTS

The FBRR applies to public water systems (PWSs) that meet **all** of the following three criteria (40 CFR 141.76(a)):

- System is a Subpart H system (i.e., uses surface water or ground water under the direct influence of surface water);
- System treats water by conventional or direct filtration processes; and,
- System recycles one or more of the following: spent filter backwash water, thickener supernatant or liquids from dewatering processes. Chapter 2 provides more information on regulated recycle streams.

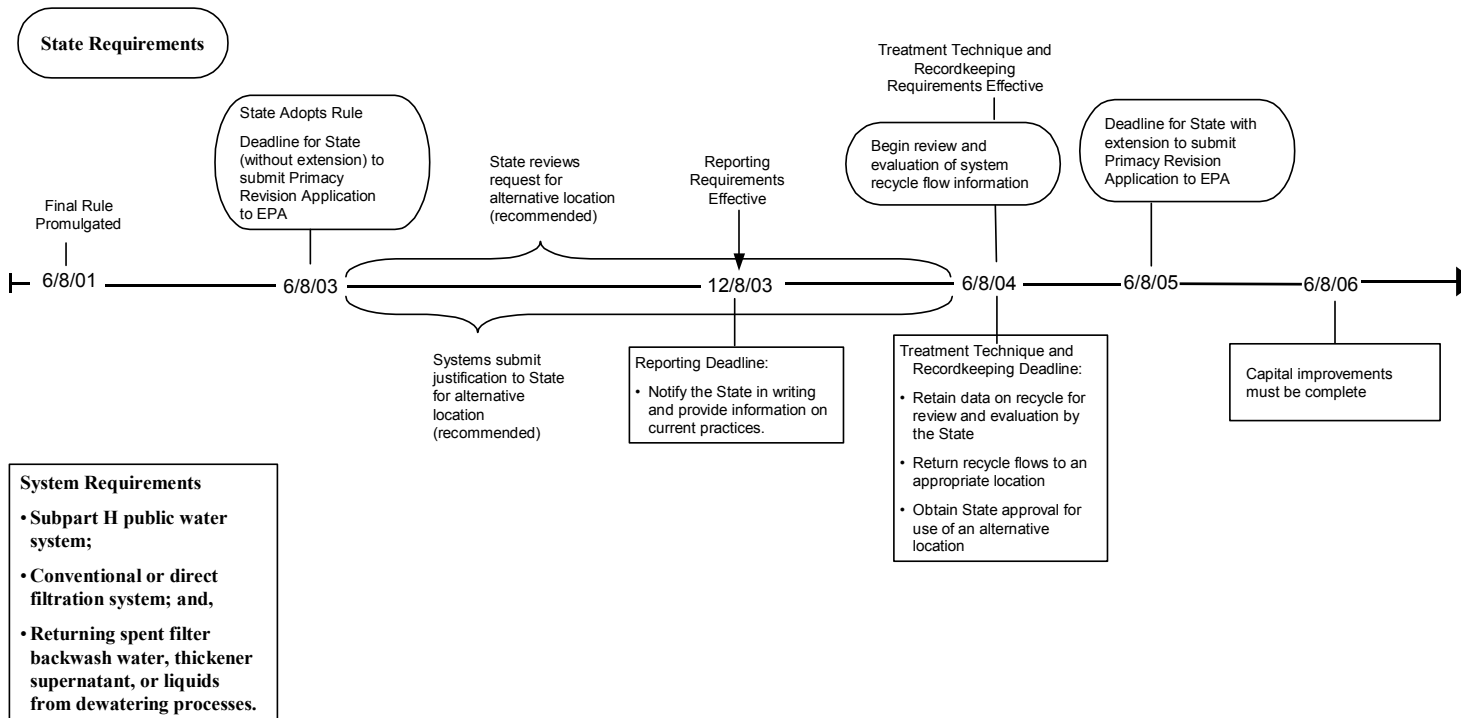
Conventional filtration, as defined in 40 CFR 141.2, is a series of processes including coagulation, flocculation, sedimentation, and filtration resulting in substantial particulate removal.

Direct filtration, as defined in 40 CFR 141.2, is a series of processes including coagulation and filtration, but excluding sedimentation, and resulting in substantial particulate removal.

The FBRR consists of three distinct components:

- Reporting (40 CFR 141.76(b)): The FBRR requires a system to notify the State about its recycle practices if the system is a Subpart H system, a conventional or direct filtration plant, and recycles one or more of the regulated recycle streams.

Figure 1-2. Filter Backwash Recycling Rule
Rule Requirements and Implementation Timeline



Systems must notify the State by December 8, 2003. Reporting requirements are contained in Chapter 3.

- **Recycle Return Location (40 CFR 141.76(c)):** The FBRR requires spent filter backwash, thickener supernatant, or liquids from dewatering processes to be returned through all the processes of a system's existing conventional or direct filtration system (if the system practices recycle), as defined in 40 CFR 141.2. Systems can receive State approval to recycle at an alternate location. Details of the recycle return location requirements are discussed in Chapter 4.
- **Recordkeeping (40 CFR 141.76(d)):** The FBRR also includes recordkeeping requirements related to recycling procedures. Systems must collect and retain certain recycle information beginning June 8, 2004. Recordkeeping requirements are presented in Chapter 5.

If systems are unsure if the rule applies to them, they should contact their State office or Primacy Agency.

1.3 FBRR OBJECTIVE

What is *Cryptosporidium*?

Cryptosporidium is an intestinal parasite that can be passed through a water treatment plant and into the drinking water supply. Infection can cause gastrointestinal illness, lasting up to two weeks, and may even be life threatening for people with weakened immune systems. Several outbreaks of cryptosporidiosis have been traced to *Cryptosporidium* in drinking water. The worst outbreaks occurred in Milwaukee in 1993 when more than 400,000 people fell ill with flu-like symptoms.

Cryptosporidium is difficult to treat (inactivate) because it is resistant to most disinfectants used by water treatment systems. Consequently, other treatment processes, such as sedimentation and filtration, must be effective in removing *Cryptosporidium* oocysts from raw water and recycle streams.

The objective of the FBRR is to improve the control of microbial pathogens, particularly *Cryptosporidium*, in public drinking water systems by helping to ensure that recycle practices do not compromise the ability of treatment plants to produce safe drinking water. Recycle streams have the potential to contain higher concentrations of *Cryptosporidium* oocysts than source water streams and could therefore introduce additional *Cryptosporidium* oocysts into the treatment process. An increase in the concentration of *Cryptosporidium* oocysts in the treatment process may increase the risk of *Cryptosporidium* oocysts in finished water and threaten public health. *Cryptosporidium* oocysts are of concern because they are not easily inactivated by commonly used disinfectants, such as chlorine (sedimentation and filtration are the main barriers for removal of *Cryptosporidium*).

1.4 OUTLINE OF THE DOCUMENT

This guidance manual is divided into two parts. Part I addresses issues specifically related to the FBRR regulatory requirements. It is designed to guide systems through the requirements for regulatory compliance with the FBRR. To make this process as straightforward as possible, EPA has developed flowcharts and worksheets that can be used as a reference during assessment of relevant filter backwash issues.

Part II provides guidance on recycle management options and operational considerations that may assist systems in understanding recycle processes. It addresses issues that are important to the effective management of potential recycle streams, but **are not specifically required by the FBRR regulations**. While compliance with the regulatory requirements is important for all affected systems, there are additional non-regulatory issues comprising the full scope of management of potential recycle streams. By addressing this broader range of recycling issues, systems will be able to develop strategies to achieve and maintain optimal overall treatment plant performance. This guidance manual should be a useful tool for any public water supply operator interested in improving plant performance, and not just those affected by the FBRR provisions.

Part I of the guidance is organized into four chapters and presents rule requirements:

Chapter 2. Regulated Recycle Streams: This chapter identifies the three regulated recycle streams and discusses the sources of recycle streams with respect to conventional and direct filtration processes.

Chapter 3. Reporting Requirements: This chapter contains information on the reporting requirements for systems.

Chapter 4. Recycle Return Location: This chapter presents the requirements for recycle return location to ensure compliance with the FBRR. This chapter also presents issues associated with recycling to a location that does not take advantage of the entire treatment train.

Chapter 5. Recordkeeping Requirements: This chapter presents recordkeeping requirements for systems and provides a detailed description of the data collection components of the FBRR.

Part II of the document is organized as follows and is strictly guidance for systems:

Chapter 6. Part II Overview: This chapter discusses the purpose of Part II and how to evaluate collected data on recycle practices.

Chapter 7. Recycle Streams: This chapter describes different recycle streams (regulated and non-regulated) and characteristics of recycle streams.

Chapter 8. Operational Considerations and Modifications: This chapter presents information on how to modify the main treatment train process or better manage recycle streams to minimize the impacts of recycle streams on finished water.

Chapter 9. Equalization: This chapter describes equalization of recycle streams and discusses the advantages and disadvantages of equalization. Case studies are presented.

Chapter 10. Treatment of Recycle Streams: This chapter describes the concept of treatment and discusses the advantages and disadvantages of treating recycle streams. This chapter also describes specific treatment options and issues associated with each treatment option. Case studies are presented.

Appendix A – Glossary

Appendix B – Worksheets

Appendix C – Reporting Example for 3.0 MGD Plant

Appendix D – Reporting Example for 20 MGD Plant

Appendix E – Reporting Example for 48 MGD Plant

Appendix F – Characteristics of Spent Filter Backwash

Appendix G – Characteristics of Thickener Supernatant

Appendix H – Characteristics of Liquids from Dewatering Processes

1.5 ADDITIONAL INFORMATION

A rule summary (eight pages long) and quick-reference guide (two pages) are available on the FBRR and provide a brief summary of the rule requirements. The implementation guide developed for States is also available. These documents can be obtained from your State office or on EPA's website (www.epa.gov/safewater/filterbackwash.html). You can also contact the Safe Drinking Water Hotline at 1-800-426-4791 for general information or visit the EPA Office of Ground Water and Drinking Water website (www.epa.gov/safewater).

PART I

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2. REGULATED RECYCLE STREAMS

2.1 INTRODUCTION

The prime objective of the FBRR is to ensure an adequate level of public health protection by minimizing the risk associated with *Cryptosporidium* in recycle flows. Under the Interim Enhanced Surface Water Treatment Rule (IESWTR) and Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) provisions, all surface water and ground water under the direct influence of surface water systems are required to achieve at least 2-log removal of *Cryptosporidium*. The recycling of spent filter backwash water and other recycle streams could impact treatment processes and finished water quality. Recycle streams may affect treatment processes due to hydraulic surges or high concentrations of contaminants in the recycle stream. The FBRR regulates three recycle streams: spent filter backwash water, thickener supernatant, and liquids from dewatering processes. These three recycle streams have the potential to adversely impact finished water quality because they may occur in sufficient volumes to create unmanageable hydraulic surges and may contain elevated concentrations of *Cryptosporidium* oocysts and other microbial and chemical contaminants.

Rule Reference:

40 CFR 141.76 (a)

(a) *Applicability.* All subpart H systems that employ conventional filtration or direct filtration treatment and that recycle spent filter backwash water, thickener supernatant, or liquids from dewatering processes must meet the requirements in paragraphs (b) through (d) of this section.

2.2 TREATMENT PROCESSES AND ORIGINS OF RECYCLE STREAMS

The FBRR applies to conventional and direct filtration systems that recycle spent filter backwash water, thickener supernatant, or liquids from dewatering processes. While conventional and direct filtration systems have the potential to create other unregulated recycle streams, such as filter-to-waste flows, only the three aforementioned recycle streams are regulated by the FBRR. The following sections provide a general background on conventional and direct filtration treatment processes and the origin of recycle streams. Although there are several variations of conventional and direct filtration processes, only the basic configurations will be presented here. More detailed information on recycle stream origins is contained in Chapter 7.

Regulated Recycle Streams

Spent filter backwash water
Thickener supernatant
Liquids from dewatering processes

Unregulated Residual Streams (not all-inclusive)

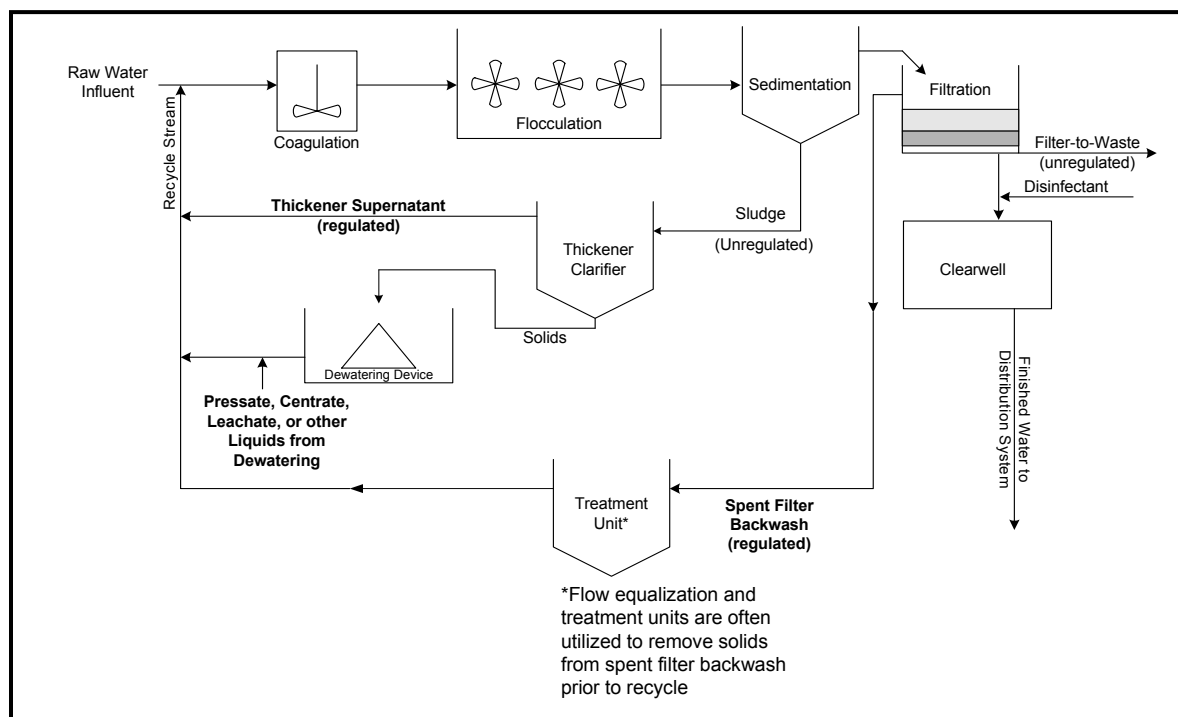
Filter-to-waste
Membrane concentrate
Ion exchange regenerate
Sludge
Diatomaceous earth slurry

2.2.1 Conventional Treatment Plants

Conventional treatment plants, by definition (40 CFR 141.2), employ the following four unit processes: coagulation, flocculation, sedimentation, and filtration. The coagulation and rapid mix process usually has a short reaction time and is followed by the flocculation process. The flocculation process forms floc, which then settle in the sedimentation basin. Periodically, accumulated solids from sedimentation basins are removed. Solids can either be disposed to the sanitary sewer, discharged to a sewer or surface water (this option requires a discharge permit), or thickened and possibly dewatered, with ultimate disposal to a landfill or land-application. Particles not removed by coagulation, flocculation, and sedimentation are typically removed by the filters. Figure 2-1 shows a typical conventional treatment system.

In a conventional plant, flows that may be recycled include: spent filter backwash (regulated), gravity thickener supernatant from sedimentation solids (regulated), dewatering liquids (regulated), and filter-to-waste (not regulated). The potential recycle stream origin locations are shown in Figure 2-1.

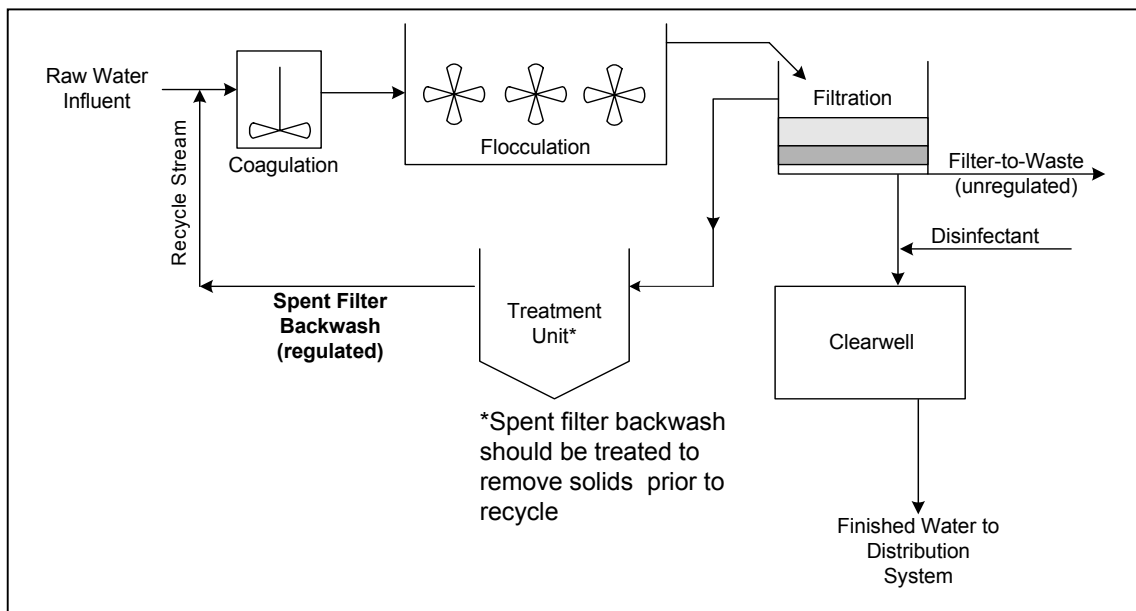
Figure 2-1. Example Conventional Filtration System with Recycle



2.2.2 Direct Filtration Plants

Direct filtration treatment omits the sedimentation process but is otherwise similar to conventional filtration treatment. Water in the treatment train goes directly from coagulation/flocculation to filtration, where solids are removed (see Figure 2-2). Hence, direct filtration systems do not produce sedimentation solids or clarification residuals during primary processes. Although the raw water turbidity of direct filtration plants is usually lower than most conventional plants, the solids loading to the filters may be higher because of the absence of the sedimentation process prior to filtration. If spent filter backwash is not treated prior to recycle, solids loading onto the filters will increase over time because there is no other way for solids to be removed from the treatment train. Therefore, solids are typically removed from recycle streams prior to being returned to the primary treatment train/plant headworks.

Figure 2-2. Example Direct Filtration System with Recycle



2.3 RECYCLE FLOWS REGULATED BY THE FBRR

Many different types of residual streams may be recycled at drinking water treatment plants. EPA originally identified twelve recycle streams for study in the proposed rule. Based on *Cryptosporidium* occurrence data and possible effects on finished water, three recycle streams were selected for regulation by the FBRR. These recycle streams are:

- Spent filter backwash water;
- Thickener supernatant (sometimes referred to as sludge thickener supernatant); and,
- Liquids from dewatering processes.

These three recycle streams are described in more detail in the following sections. Process solids recycled from clarification units are not regulated by the FBRR. However, if softening systems or contact clarification systems recycle any of the regulated flows (spent filter backwash, thickener supernatant, or liquids from dewatering processes), then these systems must comply with the requirements of the FBRR.

2.3.1 Spent Filter Backwash

Spent filter backwash is generated when water is forced through the filter, counter to the flow direction used during treatment operations. This action cleans the media by dislodging accumulated particles, including microorganisms, captured by the filter media. Consequently, the resulting spent filter backwash contains particles trapped in the filter during treatment operations, including particles produced from coagulation and pathogens such as *Cryptosporidium*. The practice of recycling may reintroduce these particles into the treatment process. Spent filter backwash water typically averages 3% to 6% of total plant production (McGuire, 1997). However, on an instantaneous basis, the spent filter backwash flows could be as high as 60% (or higher in some instances) of the plant flow. More information on spent filter backwash water characteristics is available in Chapter 7.



Spent filter backwash can be recycled with or without treatment or flow equalization.

2.3.2 Thickener Supernatant

Thickener supernatant is the decanted clear water that exits a sludge thickening basin after gravity settling. Some plants recycle the supernatant from the thickener. Depending on whether the thickener is operated in a batch mode or a continuous mode, the supernatant can be recycled to the plant intermittently or continuously.

Some plants combine the flows from several plant processes prior to thickening. The flow entering gravity thickeners primarily consist of sedimentation basin sludge but can also include spent filter backwash and flows from dewatering devices. Factors affecting the quantity of thickener supernatant produced include:

- The raw water quality;
- The quantity of residuals produced (dependant upon the raw water quality, coagulation scheme, and the sludge collection/removal efficiency);
- The level of treatment provided to thickener influent flows; and,
- The volume of the spent filter backwash (if spent filter backwash is discharged to the thickener).

More information on thickener supernatant is contained in Chapter 7.

2.3.3 Liquids from Dewatering Processes

The liquids removed from sludge, by mechanical or other means, are referred to as liquids from dewatering processes. In mechanical dewatering processes, drinking water plants often use belt presses, centrifuges, filter presses, vacuum presses, and other similar sludge-concentrating equipment. Sludge can also be dewatered in a sludge drying bed, lagoon, or monofill (sludge-only landfill). Sludges are dewatered in order to reduce their volume, which facilitates handling and disposal. The volume of the dewatering liquid depends on the volume and solids content of the thickened sludge fed to the dewatering devices. Recycle flows from dewatering devices are produced at low rates and unlikely to cause a plant to exceed operating capacity. However, the dewatering liquid may contain *Cryptosporidium* oocysts because it is derived from solids that may hold high concentrations of oocysts. More information on liquids from dewatering processes is contained in Chapter 7.

2.4 REFERENCE

McGuire, M. J. 1997. (Draft) Issue Paper on Waste Stream Recycle and Filter-to-Waste in Water Treatment Plants. Prepared for an American Water Works Association (AWWA) Technical Work Group.

3. REPORTING REQUIREMENTS

3.1 INTRODUCTION

The FBRR has specific reporting requirements. Systems must submit the required information to the State by December 8, 2003 (see Figure 3-1). This information is known as the Recycle Notification and can provide useful data for evaluating system recycle practices. A worksheet has been developed to assist systems with reporting the required information (Recycle Notification form in Appendix B). A completed example of this worksheet is included at the end of this chapter. Systems will want to check with their State to make sure the reporting format is acceptable. Examples that may be useful when completing the forms are presented in Appendices C, D, and E.

3.2 RECYCLE NOTIFICATION

Each system that uses conventional or direct filtration and recycles spent filter backwash water, thickener supernatant, or liquids from dewatering processes must provide the State with the following written information by December 8, 2003:

- A plant schematic showing the origin of all recycle streams, the hydraulic conveyance used to transport the recycle streams, and the location where the recycled streams enter the treatment process.
- Typical recycle flow, highest observed plant flow experienced in the previous year, and design flow for the treatment plant. All flows must be reported in gallons per minute (gpm).
- The State-approved operating capacity for the plant, if the State has made such a determination.

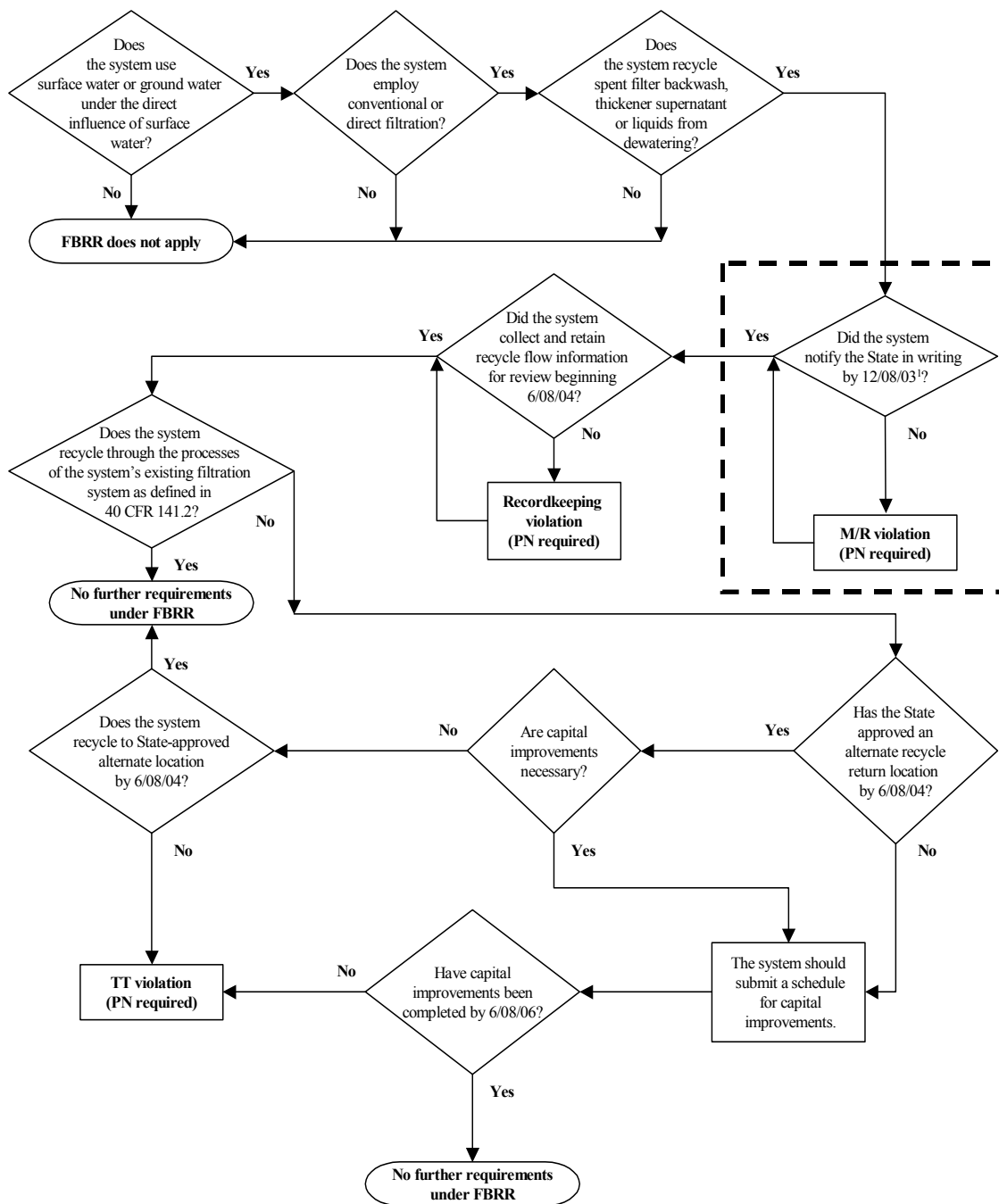
Rule Reference:
40 CFR 141.76 (b)

(b) Reporting. A system must notify the State in writing by December 8, 2003, if the system recycles spent filter backwash water, thickener supernatant, or liquids from dewatering processes. This notification must include, at a minimum, the information specified in paragraphs (b)(1) and (2) of this section.

The submitted data will be evaluated by the State to determine whether the system's current recycle return location is acceptable or if the system must make modifications. A system that fails to submit this information to the State commits a monitoring/reporting violation, which requires Tier 3 public notification. Failure to notify the public within one year of the violation is a violation of the Public Notification Rule.

The Recycle Notification form (provided in Appendix B and included as an example at the end of this chapter) can be used for the Recycle Notification, if the form is accepted by the State. Systems are required to keep a copy of the Recycle Notification and all other information submitted to the State. Systems that use, or plan to use, an alternate recycle return location may want to request approval for the alternate recycle location when submitting the Recycle Notification to the State. All alternate recycle return locations must be approved by the State by June 8, 2004. Chapter 4 provides more information on the required recycle return location.

Figure 3-1. Filter Backwash Recycling Rule Provisions- Reporting Requirements



1. Notification includes information specified in 40 CFR 141.76 (b) (1) and (2). 40 CFR 141.76 (b)(1) requires a plant schematic showing the origin of all recycle flows, the hydraulic conveyance used to transport them, and the recycle return location. 40 CFR 141.76 (b)(2) requires typical recycle flow (in gpm), highest observed plant flow for previous year (in gpm), treatment plant design flow (in gpm), and State-approved operating capacity (if a State determination has been made).

3.2.1 Plant Schematic

The plant schematic may take a variety of formats, such as Computer Aided Drafting and Design (CADD), Power Point, neatly hand-drawn figures, copy of an existing plant schematic, or other formats acceptable to the State. The contents of the schematic are more important than its format. The schematic must clearly show the following:

- Origin of all recycle streams;
- Method of transporting recycle streams, including conduits, pipes, pumps, valves, and flow controllers; and,
- Location of re-entry for recycled stream to the treatment process.

If the recycle streams undergo equalization or treatment prior to re-entering the main treatment train, this information should also be displayed in the schematic. Figures 3-2 and 3-3 are examples of acceptable schematics.

Figure 3-2. Example Plant Schematic for Recycle Notification

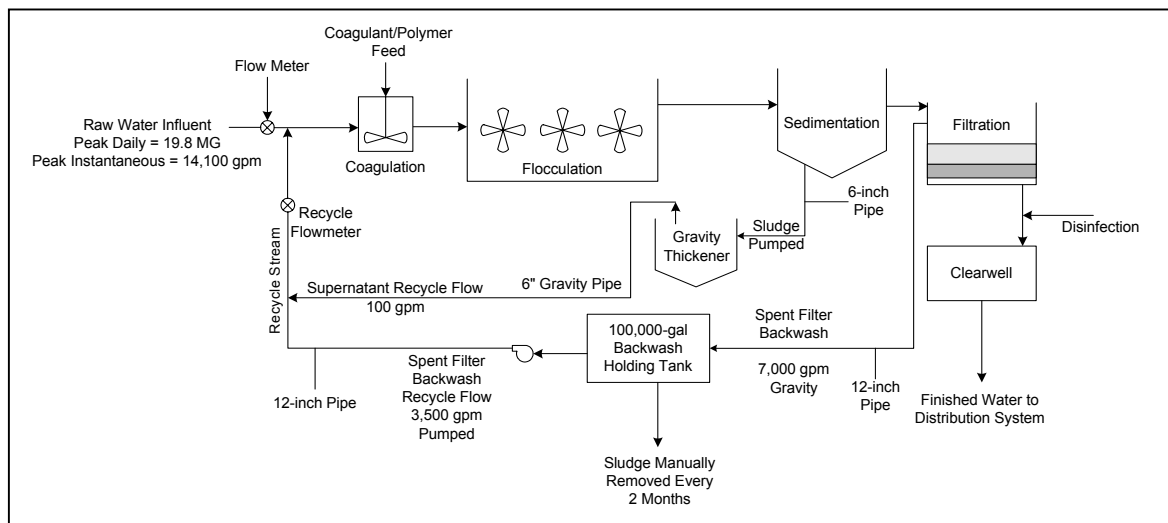
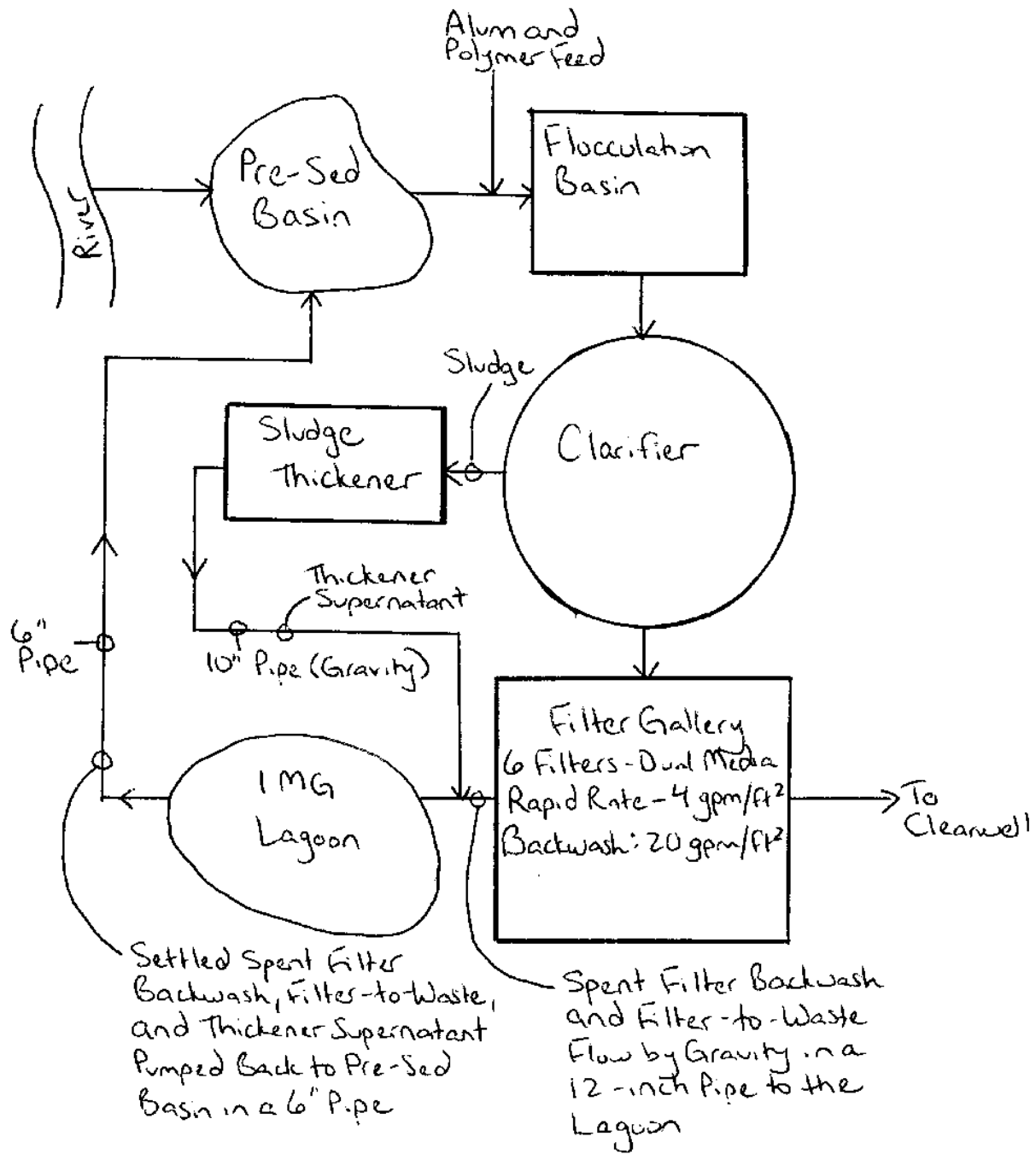


Figure 3-3 Example Hand-drawn Plant Schematic for Recycle Notification



3.2.2 Flow Information

Under the FBRR, four types of flow information are required to be reported to the State:

- Typical recycle flow (in gpm);
- Highest observed plant flow experienced in the previous year (in gpm);
- Design flow for the treatment plant (in gpm); and,
- State-approved operating capacity (if available).

The State can evaluate this information to determine if recycle practices create design flow exceedances or exceedances of the State-approved operating capacity.

Typical Recycle Flow

The typical recycle flow must be reported to the State. This value must include all recycle flows covered by this rule (spent filter backwash, thickener supernatant and liquids from dewatering processes) that are returned to the treatment train. Some States may regulate additional recycle streams and may require these to be reported as well. Methods for determining recycle flows include:

- Metering at one location or individually;
- Estimating based on backwash rates or basin overflow rates;
- Estimating from pump records, if pumps are used;
- Estimating from hydraulic conveyance capacity of the conduit; or,
- Estimating by drop in water surface elevation in a tank.

Appendices C, D, and E provide examples of how to determine the typical recycle flow. The recycle flow must be reported to the State in gpm.

Highest Observed Plant Flow in the Previous Year

To determine the highest observed plant flow experienced in the previous year, a review of plant monitoring records should be conducted. The flow should be measured at a point that accurately captures the total amount of water passing through the treatment system at a given time, including raw water and recycle flows. Locations for measuring this flow may include:

- Flowmeters at the plant inlet that record both raw water and recycle flow. In some plants, these flows may be measured separately or the flowmeter may be located such that both flows are recorded simultaneously.
- Flow into the clearwell (if representative of plant influent flow, such as in a small system). This flow may be obtained from pumping records, metered, or estimated. Measuring the flow exiting the clearwell may not provide an accurate

plant flow if clearwell water is used for backwashing filters or other plant processes or if the distribution pump rate varies from the raw water rate.

- Raw water and recycle pump records (if pumps are used).

The important point to remember is that both raw water and recycle flows should be included in determining the highest observed plant flow for the previous year. The Recycle Notification form (in Appendix B) can be used to report flow information to the State. A completed example of this form is included at the end of this chapter. Systems will want to check with their State first to make sure this reporting form is acceptable.

Examples in Appendices C, D, and E provide guidelines for identifying the highest observed plant flow. Some plants may operate in a manner such that the highest observed raw water flow will not coincide with the highest observed recycle flow. Also, the highest observed raw water flow may not represent the highest observed plant flow if recycle flows are significant (see example in Appendix C for an illustration of a situation where the highest observed plant flow occurred when recycle flows were being returned at a significant rate). The highest observed plant flow must be reported in gpm.

Design Flow

The design flow for the treatment plant does not require measurement and should be available from design documents, facility plans, or operation and maintenance manuals. The design flow must be reported to the State in gpm.

State-Approved Operating Capacity

If the State has determined and approved an operating capacity for a system, the system must provide this information as part of the Recycle Notification. Systems may want to contact the State to verify if they have a State-approved operating capacity.

3.2.3 Recycle Notification Form

The Recycle Notification form in Appendix B can be used for the Recycle Notification to the State, if the form is acceptable to the State. A completed example of this form is shown on the next page (also found in Appendix C). Other examples illustrating how to complete this form can be found in Appendices C, D, and E.

**FILTER BACKWASH RECYCLING RULE
RECYCLE NOTIFICATION FORM**

SYSTEM NAME Example 3.0 MGD Plant

PWSID _____ DATE Dec 1, 2003

Check with your State or Primacy Agency to make sure this form is acceptable.

Does your system use conventional or direct filtration? Yes (conventional)

Does your system recycle spent filter backwash water, thickener supernatant, or liquids from dewatering processes? Yes (spent filter backwash)

If you answered yes to both questions, please report the following:

1. What is the typical recycle flow (in gpm)? 1,500 gpm
2. What was the highest observed plant flow for the system in the previous year (in gpm)?
2,500 gpm
3. What is the design flow for the treatment plant (in gpm)? 2,080 gpm
4. Has the State determined a maximum operating capacity for the plant? If so, what is it? 2,080 gpm
5. Please include a plant schematic that shows:
 - the origin of **all** recycle flows (spent filter backwash, thickener supernatant, liquids from dewatering processes, and any other);
 - the location where **all** recycle flows re-enter the treatment plant process; and
 - the hydraulic conveyance used to transport **all** recycle flows.

Comments: The highest observed plant flow of 2,500 gpm exceeds State-approved operating capacity.

6. Are you requesting an alternate recycle location? _____ Yes No
- An alternate recycle location is one that does not incorporate all treatment processes of a conventional filtration plant (coagulation, flocculation, sedimentation, and filtration) or direct filtration plant (coagulation, flocculation, and filtration). The State or Primacy Agency must approve the recycle location by June 8, 2004. Please contact your State or Primacy Agency on what additional information may be needed.

Comments: _____

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4. RECYCLE RETURN LOCATION

4.1 INTRODUCTION

To ensure at least 2-log removal of *Cryptosporidium*, regulated recycle streams must be introduced at a location where the flow passes through the treatment processes of the system's existing conventional or direct filtration system or at an alternate location approved by the State (see Figure 4-1). The preamble of the FBRR cites eight studies on conventional and direct filtration systems that demonstrate 2-log *Cryptosporidium* removal. The 2-log *Cryptosporidium* removal was achieved in those studies when:

- Coagulation, flocculation, sedimentation (in conventional filtration only), and filtration were employed; and,
- The turbidity limits in the finished water as specified in the IESWTR and LT1ESWTR were met.

Rule Reference:

40 CFR 141.76 (c)

(c) Treatment technique requirement.

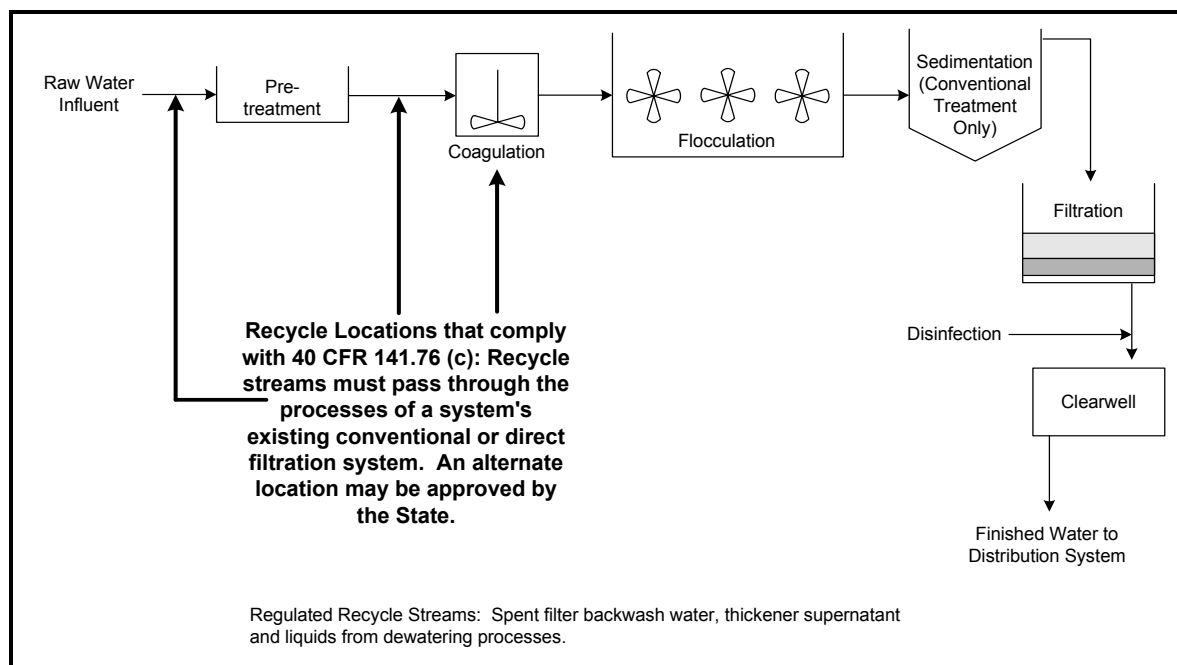
Any system that recycles spent filter backwash water, thickener supernatant, or liquids from dewatering processes must return these flows through the processes of a system's existing conventional or direct filtration system as defined in 40 CFR 141.2 or at an alternate location approved by the State by June 8, 2004. If capital improvements are required to modify the recycle location to meet this requirement, all capital improvements must be completed no later than June 8, 2006.

To obtain the 2-log *Cryptosporidium* removal, the FBRR requires recycle streams to pass through all conventional (coagulation, flocculation, sedimentation, and filtration) or direct (coagulation, flocculation, and filtration) filtration processes to receive optimum treatment.

An existing system may have a recycle location that does not incorporate all conventional or direct filtration treatment processes. The concerns associated with these recycle locations are:

- The return of the recycle stream after the point of primary coagulant addition may disrupt the chemistry of the treatment process and may impair treatment performance.
- If the recycle stream is not treated through coagulation and flocculation, oocysts and other contaminants could pass through the filters. Sedimentation and filtration are the main barriers to *Cryptosporidium* since it is resistant to certain disinfectants (primarily chlorine and chloramines) and proper coagulation and flocculation are necessary for optimum filter performance.
- The 2-log *Cryptosporidium* removal may not be achieved if the recycle stream does not pass through all treatment processes in a conventional or direct filtration system.

Figure 4-1. Examples of Recycle Return Locations



Treatment plants that return recycle streams to an alternate location (i.e., a location other than shown in Figure 4-1) in order to maintain optimal treatment performance may apply to the State to recycle at an alternate location. If the system has questions regarding the required recycle return location, they should contact the State or Primacy Agency.

4.2 TIMELINE FOR COMPLIANCE

A timeline for recycle location compliance is presented in Table 4-1. It presents several compliance scenarios and deadlines for submitting information or completing activities. Figure 4-2 contains a flowchart for recycle return location compliance. For a timeline of all rule requirements and deadlines, see Figure 1-2 in Chapter 1.

If a system currently recycles to a location that allows the recycle stream to be processed through the treatment processes of the existing conventional or direct filtration system, the system is not required to make any changes to the recycle return location. However, the system must comply with all reporting and recordkeeping requirements of the FBRR, as presented in Chapters 3 and 5.

If a system currently recycles to a location in the treatment process that does not allow the recycle stream to pass through the treatment processes of the system's existing conventional or direct filtration processes, the system may submit a request to the State for approval of this alternate recycle location. The checklist on page 27 may be useful when evaluating an alternate recycle return location. The State must approve or deny such a request by June 8,

2004. Systems may want to consider submitting an alternate return location request with the Recycle Notification information due on December 8, 2003 (see Chapter 3 for details).

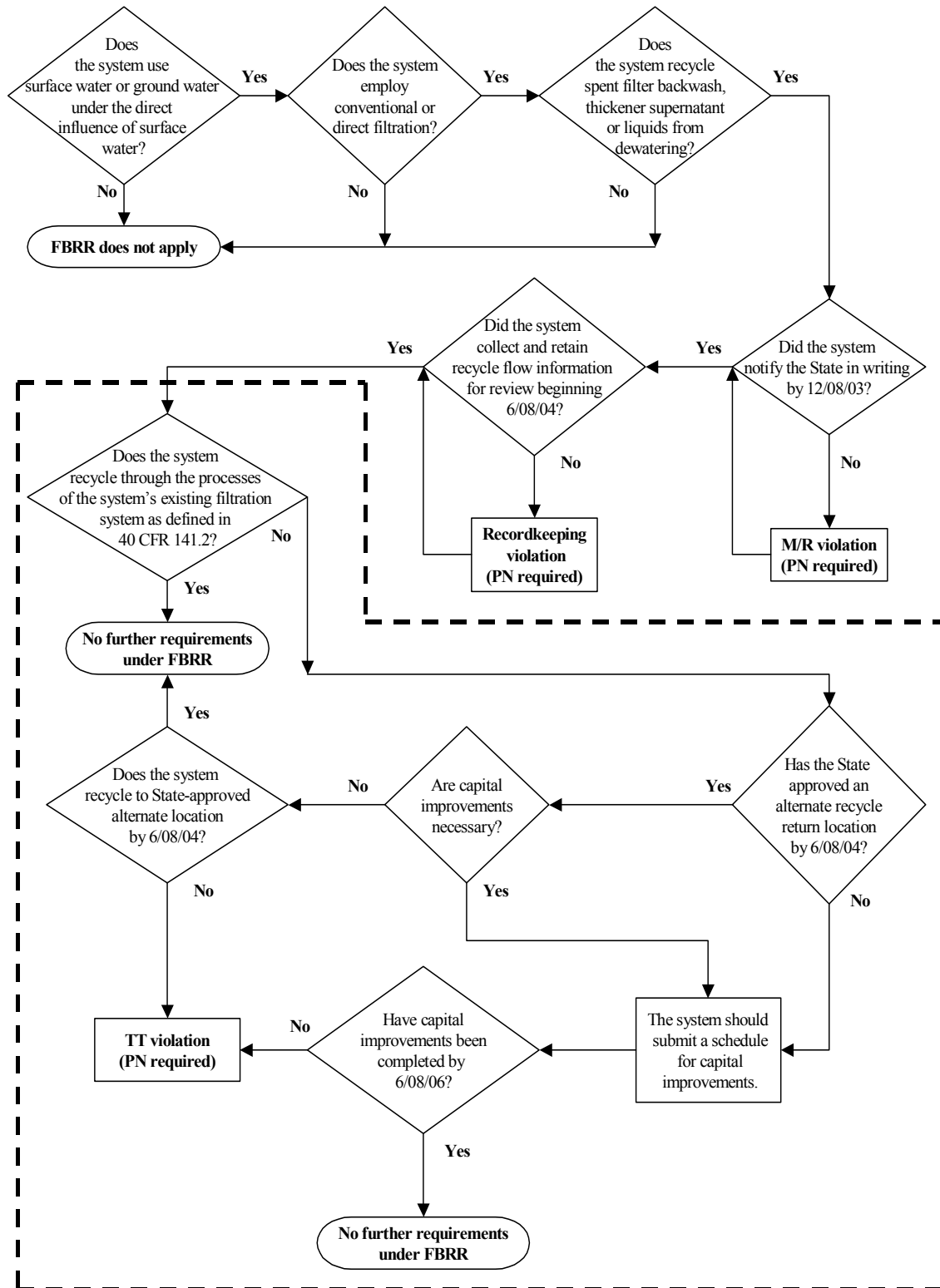
If the State does not approve the alternate location and capital improvements are needed to relocate the recycle return point, or if the State approves an alternate recycle location that requires capital improvements, the system must complete the necessary capital improvements by June 8, 2006.

If the system decides to relocate the existing recycle return point so that recycle is returned through all processes of the system's existing conventional or direct filtration treatment train (as defined in 40 CFR 141.2), capital improvements must be completed no later than June 8, 2006.

Table 4-1 Recycle Return Location Compliance Schedule

If:	The System Must:	By:
No capital improvements are necessary and the system is not seeking approval for an alternate location . . .	meet only the reporting and record-keeping requirements of the FBRR . . .	See Chapters 3 and 5.
The system is planning to request state approval for use of an alternate location . . .	receive approval from the State . . .	June 8, 2004.
The system is planning to request State approval for use of an alternate location AND capital improvements are necessary . . .	receive approval from the State for alternate recycle return location . . .	June 8, 2004; and,
	complete all improvements . . .	June 8, 2006.
Capital improvements are necessary to relocate the point of recycle return . . .	complete all improvements . . .	June 8, 2006.

Figure 4-2. Filter Backwash Recycling Rule Provisions- Recycle Return Location



Systems seeking approval of an alternate recycle return location should consider submitting:

- T A written request explaining the reason and/or rationale for using the alternate recycle location (such as if the plant requires recycle to an alternate location to maintain optimal finished water quality, or other reason), including an explanation of why the alternate recycle location would not or does not cause a negative impact upon the finished water quality.
- T A plant schematic identifying the alternate recycle location (which may be the schematic required in 40 CFR 141.76(b) if the alternate location is currently used).
- T Demonstration of compliance with IESWTR/LT1ESWTR turbidity limits through submission of combined filter effluent and/or individual filter effluent data.
- T A description of the type of treatment(s) applied to the recycle stream (if any).
- T A comparison of plant influent water quality to the recycle stream water quality. Data for comparison may include, but are not limited to:
- Turbidity;
 - Cysts and oocysts;
 - Cyst and oocyst-sized particles;
 - Iron and/or manganese;
 - Disinfection Byproduct (DBP) levels;
 - Level of organic matter (TOC, DOC, UV₂₅₄); and,
 - pH.
- T Information on sedimentation performance (as evidenced by settled water turbidity as related to recycle practices).
- T Design and monitoring data for the alternate recycle location.
- T Information on the current loading rates of unit processes, and the impact to the loading rates caused by the alternate location.
- T Information on flow control during recycle.
- T An analysis of other impacts that the alternate location may have on finished water quality.

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5. RECORDKEEPING REQUIREMENTS

5.1 INTRODUCTION

The FBRR has specific recordkeeping requirements in addition to the reporting requirements (see Chapter 3) and recycle return location requirements (see Chapter 4).

For FBRR compliance, a system must collect and retain the following information for review and evaluation by the State beginning June 8, 2004 (see Figure 5-1):

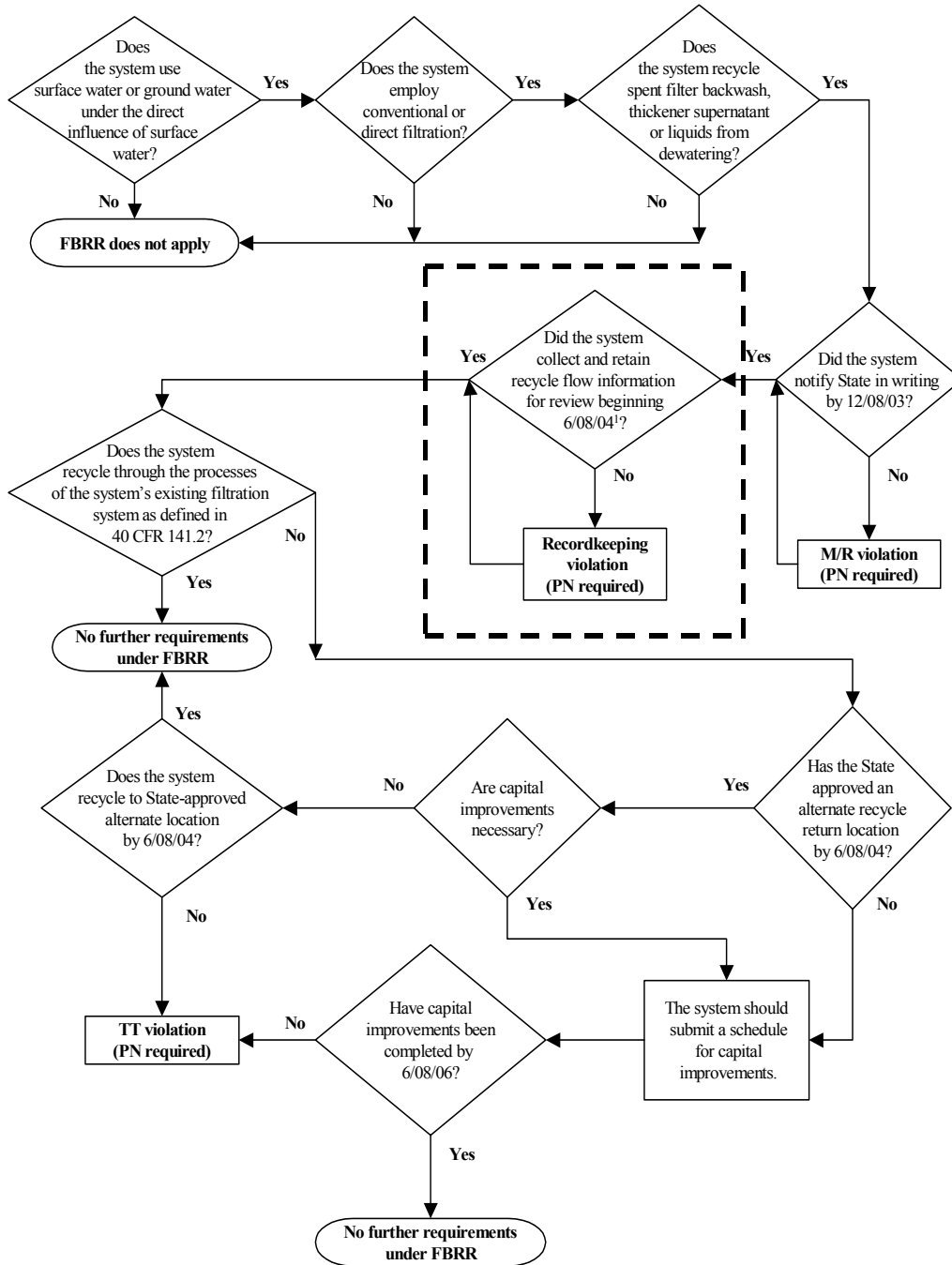
Rule Reference:
40 CFR 141.76 (d)

(d) Recordkeeping. The system must collect and retain on file recycle flow information specified in paragraphs (d)(1) through (6) of this section for review and evaluation by the State beginning June 8, 2004.

- A copy of the Recycle Notification (see Chapter 3);
- A list of all recycle flows and the frequency at which they are returned;
- Average and maximum backwash flow rates through the filters and the average and maximum duration of the filter backwash process, in minutes;
- Typical filter run length and a written summary of how filter run length is determined (e.g., headloss, turbidity, time, etc.);
- If applicable, the type of treatment provided for the recycle stream before it re-enters the conventional or direct filtration process; and,
- If applicable, data about the physical dimensions of the equalization and/or treatment units, typical and maximum hydraulic loading rates, types of treatment chemicals used, average dose of chemicals, frequency of chemical addition, and frequency of solids removal.

With the exception of the Recycle Notification, systems are not required to submit this information unless requested to do so by the State. However, all of the information must be made available by the system for State review during sanitary surveys, Comprehensive Performance Evaluations, or other inspections or activities. After the State reviews this information, a system may be required to modify its recycling practices or undertake other activities. Failure to comply with the recordkeeping requirements is a recordkeeping violation, which requires Tier 3 public notification. Failure to notify the public of the violation within the appropriate time frame is a public notification violation. The worksheet in Appendix B (Recordkeeping Form) can be used for collecting data (if this form is acceptable to the State). A completed example of this form is included at the end of this chapter. Appendices C, D, and E contain examples that may be helpful when completing the forms.

Figure 5-1. Filter Backwash Recycling Rule Provisions- Recordkeeping Requirements



1. System must collect and retain the following information: a copy of the Recycle Notification; a list of all recycle flows and the frequency with which they are returned; average and maximum backwash flow rates through the filters and the average and maximum durations of the filter backwash process, in minutes; typical filter run length and a written summary of how filter run length is determined (e.g. headloss, turbidity, time, etc.); if applicable, the type of treatment provided for the recycle flow before it re-enters the conventional or direct filtration process; if applicable, data about the physical dimensions of the equalization or treatment units, typical and maximum hydraulic loading rates, type of treatment chemicals used, average dose of chemicals, frequency of chemical addition, and frequency of solids removal.

5.2 REQUIRED RECORDKEEPING INFORMATION

The following sections provide information on the required recordkeeping information the system must collect. Systems should consult the State on frequency of data collection. The State could require a system to collect data as operating conditions change, such as on a seasonal basis.

5.2.1 Recycle Notification

Systems must maintain a copy of all information that is submitted to the State, as described in Chapter 3.

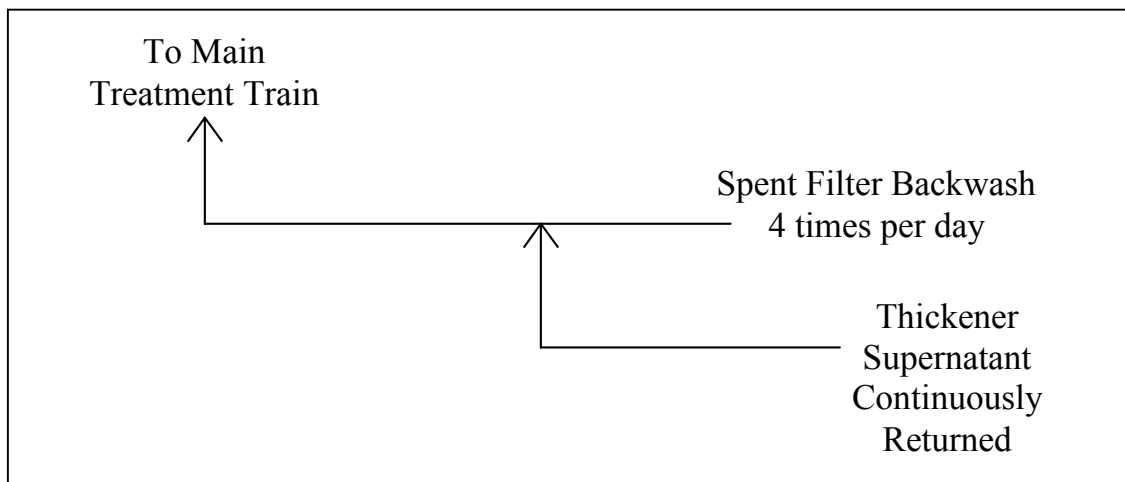
5.2.2 Recycle Flows

The system must retain a list of all recycle flows (regulated and non-regulated) and the frequency of return of each flow. Recycle streams are often generated at varying frequencies and flow rates. It is important to recognize that the rate at which each recycle stream is generated may differ from the rate at which these flows are returned to the treatment train if equalization and/or treatment of recycle streams is provided. The FBRR requires systems to record the frequency at which recycle flows are returned. If allowed by the State, the Recordkeeping Form can be used to record recycle flow information (see Appendix B). A completed example of this form is included at the end of this chapter. Examples in Appendices C, D, and E provide examples of ways to collect recycle flow information.

Recycle without Treatment or Equalization

If recycle streams are returned to the main treatment train without equalization and/or treatment, then the system must record the frequency at which the flows are returned to the main treatment train (see Figure 5-2).

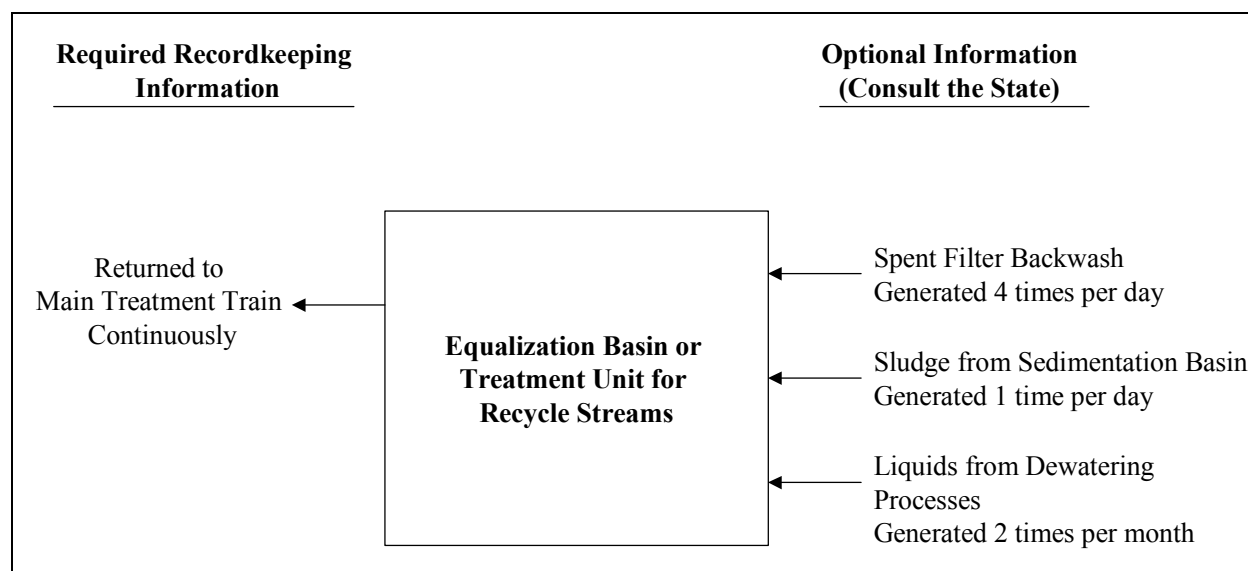
Figure 5-2. Example of Recycle Flow Frequency Recordkeeping Information (No Equalization or Treatment of Recycle Streams Provided)



Recycle with Treatment and/or Equalization

If recycle streams are discharged to an equalization basin or treatment unit, then the frequency at which these flows are returned to the main treatment train must be recorded. States may want systems to also record the frequency at which recycle flows are generated if equalization and/or treatment is provided to the recycle flows. Knowing the frequency at which recycle flows are generated and returned will assist systems and States in assessing recycle practices. Figure 5-3 provides a schematic that illustrates the required information that systems must record and some of the types of optional information States could request.

Figure 5-3. Example of Recycle Flow Frequency Information (Equalization and/or Treatment Provided)



5.2.3 Backwash Information

Systems must collect the following backwash information for the filter(s):

- Average backwash flow rate through the filter;
- Average duration of filter backwash;
- Maximum backwash flow rate through the filter; and,
- Maximum duration of filter backwash.

Filters tend to be backwashed in a highly regulated and well-monitored manner. The plant records should be specific about the filter backwash process. Some systems may not vary the backwash rate throughout the backwash process, so that the average and maximum backwash rates are the same. Other systems may vary the backwash rate throughout the backwash process. For instance, a system may use air scour or surface wash in addition to

backwashing. The average and maximum backwash rates are different in this case because of the varying backwash rate. Also, some systems may vary the backwash rates seasonally based on changing water temperature or system loading rates. States may require systems to collect backwash information for different operating conditions. Systems should check with the State to determine the frequency of data collection. Backwash flow rates can be reported based on metered values, rise-rate tests, pump records, or other means.

The Recordkeeping Form in Appendix B can be used to record backwash information. A completed example of this form is included at the end of this chapter. Examples in Appendices C, D, and E illustrate how backwash information can be collected and recorded.

5.2.4 Filter Run Length and Termination of Filter Run

Systems must provide to the State the typical filter run length (typical time that a filter is operated before it is backwashed). The filter run length is the sum of the time that the filter is operating between backwashes. As water passes through, a filter becomes clogged with particles that eventually could begin to compromise the treatment ability of the filter. Systems may have different methods for determining typical filter run length.

Systems must maintain a written summary of the methods used to determine the run time along with the typical filter run time. If turbidity, head loss, or filter effluent turbidity thresholds are used to determine the filter run time, these thresholds should be provided. If the filter run is terminated based on a pre-determined time established by the system or other means, this determination should also be noted.

The Recordkeeping Form in Appendix B can be used to record this information. A completed example of this form is included at the end of this chapter. Examples in Appendices C, D, and E provide an example of how to report the information.

5.2.5 Recycle Stream Treatment

If a system treats or equalizes its recycle streams, then information about these processes must be included in records maintained for the FBRR. The system must record information on the type of treatment that is provided.

5.2.6 Equalization and Treatment Information

If equalization or treatment of the recycle stream is provided, systems must collect the following information on the units:

- Physical dimensions of the equalization and/or treatment units. A sketch of the unit with dimensions may be helpful. This information will be used to determine the capacity of the unit;
- Typical and maximum hydraulic loading rates. This could include generated rates for each recycle stream (see Figure 5-3);

5. Recordkeeping Requirements

- Type of treatment chemical(s) used, if the recycle stream is chemically treated. It may be useful to note whether the chemical is introduced to the recycle stream prior to entering the unit or directly into the unit;
- Average dose rate of the treatment chemical and frequency of chemical use must be provided; and,
- Frequency of solids removal. Solids removal is important because solids can reduce the equalization/treatment capability of the unit by occupying a significant volume in the unit. Systems will need to record the frequency of solids removal (for example, once a month).

The Recordkeeping Form in Appendix B can be used to record this information. A completed example of this form is included at the end of this chapter. Examples in Appendices D and E illustrate how this information can be collected and recorded.

FILTER BACKWASH RECYCLING RULE RECORDKEEPING FORMSYSTEM NAME Example 3.0 MGD PlantPWSID _____ **Operating Period**¹ Jun 2003-Jun 2004

Check with your State or Primacy Agency to make sure this form is acceptable.

Type of Recycle Stream	Frequency at which flow is returned ²
Spent Filter Backwash	4 times/day returned to main treatment train
Thickener Supernatant	
Liquids from Dewatering Process	
Other	
Other	

Filter Information	Filter Number ³			
	1-8, all filters the same			
Average Duration of Backwash (in minutes)	15 minutes			
Maximum Duration of Backwash (in minutes)	15 minutes			
Average Backwash Flow ⁴ (in gpm)	1,500 gpm			
Maximum Backwash Flow ⁴ (in gpm)	1,500 gpm			
Run Length Time of Filter ⁵ (include units)	48 hrs			
Criteria for Terminating Filter Run ⁶	Time, unless individual filter turbidity exceeds 0.2 NTU.			

Is treatment or equalization provided for recycle flows? _____ Yes No

If yes, complete the following table.

Type of Treatment Provided		
Physical Dimensions of Unit		
Typical Hydraulic Loading Rate		
Maximum Hydraulic Loading Rate		
Type of Chemical Used		
Average Dose of Chemical (mg/L)		
Frequency of Chemical Addition		
Frequency of Solids Removal		

See instructions on back.

Instructions

1. Note the operating period for the information provided. Check with your State or Primacy Agency for required operating period.
2. The frequency at which the recycle stream is returned can be described as continuous, once a day, or as another frequency.
3. Fill out all information for each of your filters. If some or all filters are operated the same, note the appropriate filter numbers.
4. The backwash flow is obtained by multiplying filter surface area (in ft²) by backwash rate (gpm/ft²). Use the average backwash rate to get the average flow and the maximum backwash rate to get the maximum flow. If the flow is varied throughout the backwash process, then the average can be computed on a time-weighted basis as follows:

$$\frac{(\text{Backwash Rate 1 X Duration 1}) + (\text{Backwash Rate 2 X Duration 2}) + \dots}{\text{Duration 1} + \text{Duration 2} + \dots}$$

5. The filter run length time is the sum of the time that the filter is producing water between backwashes.
6. Describe how run length time is determined. For example, is the run length based on head loss across the filter, turbidity levels of filter effluent, a predetermined amount of time, or another method?

PART II

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6. PART II OVERVIEW

Water treatment systems typically recycle residual streams for one or both of the following reasons:

- Water resources are limited, such as in the arid southwest, and the system may not be able to access additional water. Therefore, certain residual streams (such as spent filter backwash) are recycled to maximize production.
- Recycling of residual streams may be more cost-effective than disposal, such as discharge to a storm sewer or sanitary sewer. Therefore, the system recycles the residual stream.

For those systems regulated by the FBRR, specific reporting, recycle return location, and recordkeeping requirements apply (as described in Chapters 3, 4, and 5). States will most likely evaluate the information collected and submitted by systems and decide if recycle practices are impacting finished water quality. If the State identifies problems with recycle practices or the recycle return location, then States and systems should revise or alter main treatment plant processes and/or recycle practices to minimize impacts on finished water. For instance, an exceedance of turbidity limits may be linked to recycle practices. Part II of this document provides information on how States and systems can evaluate recycle practices, recycle stream characteristics, and alternatives to consider to minimize the impacts of recycle practices on treatment plant performance and in particular, finished water quality. **States and systems should note that the information presented in Part II is provided as an additional resource and is not required by the FBRR. In some instances the information is very site specific. Therefore, if systems are considering modifying their treatment process or recycle practices, the State should be consulted prior to any modification.**

Part II contains the following chapters:

- **Chapter 7. Recycle Streams:** This chapter describes different recycle streams (regulated and non-regulated) and characteristics of recycle streams.
- **Chapter 8. Operational Considerations and Modifications:** This chapter presents information on how to modify the main treatment train process or better manage recycle streams to minimize the impacts of recycle streams on finished water.
- **Chapter 9. Equalization:** This chapter describes equalization of recycle streams and discusses the advantages and disadvantages of equalization. Case studies are presented.
- **Chapter 10. Treatment of Recycle Streams:** This chapter describes the concept of treatment and discusses the advantages and disadvantages of treating recycle

streams. This chapter also describes specific treatment options and the issues associated with each treatment option. Case studies are presented.

States and systems can also refer to the references listed at the end of each chapter and AWWA's *Self Assessment of Recycle Practices* (2002) for more detailed information on a specific case study or evaluation of recycle practices.

7. RECYCLE STREAMS

7.1 INTRODUCTION

Water treatment plants throughout the United States recycle or reintroduce a variety of residual streams back into their treatment plants. Some of these flows may contain *Cryptosporidium* oocysts and other contaminants, while others may be quite harmless. As indicated elsewhere in this document, only three recycle streams (spent filter backwash water, thickener supernatant, and liquids from dewatering processes) are regulated by the FBRR. (Note: The FBRR only applies to conventional and direct filtration systems that recycle one or more of the regulated recycle streams.) These streams are regulated because they are the recycle streams most likely to contain *Cryptosporidium* oocysts (and other contaminants) and may represent a large percentage of overall plant production. Spent filter backwash water data indicates that both *Cryptosporidium* and *Giardia* cysts can occur in greater concentrations than raw water concentrations. Thickener supernatant and liquids from dewatering processes both result from sludge that may contain elevated *Cryptosporidium* and *Giardia* cyst concentrations in comparison to raw water concentrations. Data show that microbial contaminants, in addition to other contaminants, can be released from the sludge into the recycle stream if the sludge is not properly settled, treated, and/or removed. In addition to contaminants, the volume and/or flow rates of the recycle stream are also of concern. Two of the regulated streams- spent filter backwash water and thickener supernatant- can be produced at sufficient rates to create hydraulic surges or cause a water treatment plant to exceed operating capacity.

Regulated Recycle Streams

Spent filter backwash water
Thickener supernatant
Liquids from dewatering processes

Unregulated Residual Streams (not all-inclusive)

Filter-to-waste
Membrane concentrate
Ion exchange regenerate
Sludge
Diatomaceous earth slurry

In addition to the regulated recycle streams, water treatment plants produce other streams that, as of yet, are not regulated. Examples of typical unregulated streams are filter-to-waste, membrane concentrate, ion exchange regenerate, and sludge. These streams were not regulated in the FBRR because of one or more of the following:

- The quality of the stream was of high quality and probably would not adversely impact overall treatment plant efficiency (such as filter-to-waste);
- The stream was of such small volume that the chance of hydraulic surge was minimal (such as waste flows from turbidimeters); or,
- The stream was not typically recycled due to the quality of the stream (such as ion exchange regenerate).

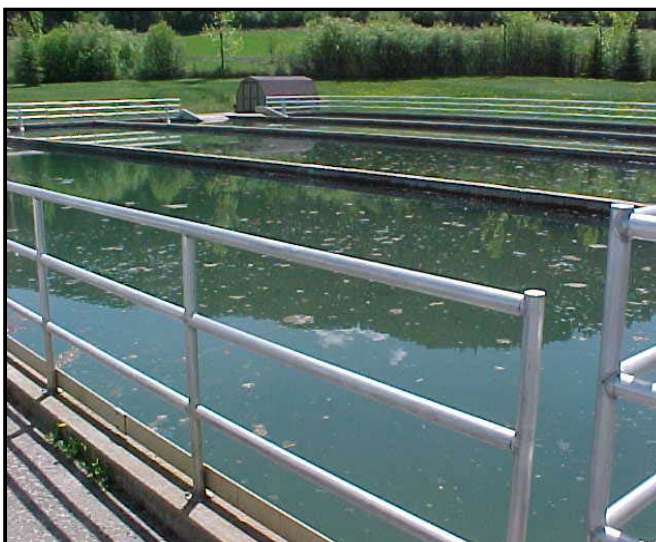
This chapter provides a discussion of each of the regulated recycle streams and a brief discussion of some recycle streams not regulated by the FBRR.

7.2 SPENT FILTER BACKWASH WATER

Filter backwashing is an integral part of treatment plant operation. Filters are typically cleaned by flushing them with water in the reverse direction to normal flow. The water flow must have sufficient force to separate particles from the filter media, so a greater than normal flow is used. The resulting water, which carries particles flushed from the filters including microbes (such as *Cryptosporidium*), raw water particles, and particles from the coagulation process, is called waste or spent filter backwash water. The backwash period generally lasts for 10-25 minutes at a rate of approximately 15 to 20 gpm/ft², and produces a significant volume of spent filter backwash. Of all the processes that produce residual streams, filter backwash typically produces the largest volume of water and at the highest rate.

7.2.1 Frequency and Quantity

Filter runs generally last between 24 and 72 hours in length, but vary from plant to plant. Filters are taken off-line for backwashing based on time (hours of filter run time), turbidity and/or particle counts in filter effluent, head loss across the filter, or other system-specific methods. A typical backwashing operation lasts for 10-25 minutes with maximum rates of 15 to 20 gpm/ft², but the backwash rate varies for each plant and filter type. Since a high water flow is used, a large volume of spent filter backwash water is produced in a relatively short amount of time. Some plants only produce spent filter backwash sporadically (small plants), but larger plants with numerous filters may produce it continuously as filters are rotated for backwashing. Medium and small plants typically produce spent filter backwash as an intermittent stream in large volumes over a short time span. The return of the spent filter backwash to the main treatment train without treatment or equalization is known as direct recycle. Direct recycle could result in the plant exceeding its operating capacity or experiencing hydraulic disruptions if the raw water flow is not properly managed during recycle.



This backwash holding basin is used to allow settling of spent filter backwash.

Spent filter backwash can comprise 2% to 10% of the total plant production, but on the average accounts for 2.5% of average plant production (Environmental Engineering and

Technology, 1999). Recycled spent filter backwash can represent a significant percentage of plant instantaneous flow during recycle events, particularly if no equalization is provided. High recycle flows can result in hydraulic surges and possibly upset treatment plant performance. For instance, the spent filter backwash scenario presented in the example in Appendix C illustrates that the spent filter backwash recycle volume constitutes 4% of the total plant production, but during periods of recycle it constitutes 60% of the plant instantaneous flow.

7.2.2 Quality

The quality of spent filter backwash varies from plant to plant. Spent filter backwash quality has been analyzed in several studies. One research project funded by the American Water Works Association Research Foundation (AWWARF) surveyed 25 representative water treatment plants to compare the differences in microbial, physical, and chemical water quality of raw waters to untreated spent filter backwash (Cornwell et al., 2001). Of the 146 raw water samples collected, *Giardia* and *Cryptosporidium* were detected in 30% and 11% of samples, respectively. The observed geometric mean levels of *Giardia* and *Cryptosporidium* in the raw water samples for the detections were 89 and 108/100 L, respectively. For the 148 spent filter backwash samples, 8% and 5% were positive for *Giardia* and *Cryptosporidium*, respectively. The geometric mean levels of *Giardia* and *Cryptosporidium* in the spent filter backwash samples with detections were 203 and 175/100 L, respectively. All of the data were collected by means of the immunofluorescence assay method. Concentrations of *Giardia* and *Cryptosporidium* in spent filter backwash were observed to be approximately 16 and 21 times higher than corresponding raw water samples, respectively, after adjusting for recovery efficiency. Infectious *Cryptosporidium* was observed in six raw water samples (4.9%) and nine spent filter backwash samples (7.4%). Other water quality parameters were also sampled, including dissolved organic carbon (DOC), TTHMs, HAA5s, and metals. DOC and zinc concentrations showed a three-fold increase and TTHMs had a 92-fold increase in concentration in spent filter backwash when compared to raw water samples after chemical addition. Appendix F has additional information on contaminants in spent filter backwash.

Kawamura (2000) indicates that spent filter backwash water from a conventional treatment plant generally has a turbidity of 150 to 250 NTU. Other data shows a range from 7 to 148 NTU for spent filter backwash turbidity from conventional treatment plants (HDR, 1997). Data from another study (Cornwell and Lee, 1993) showed that turbidity during backwash at one plant varied between 0.57 and 97 NTU (See Table F-1, Appendix F). A study by Tobiason et al.,



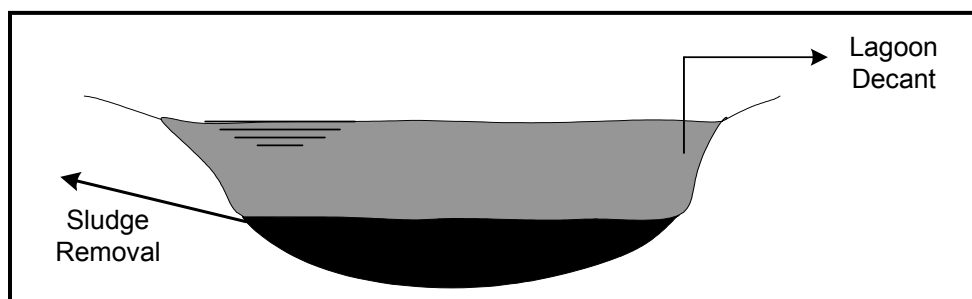
This newly constructed lagoon will be used to equalize and settle spent filter backwash prior to recycling.

(1999) found high peak turbidity levels of 150 to 400 NTU that fell to 1 to 7 NTU at later stages of recycle. The peak turbidity levels were associated with the settling of solids in the backwash storage tank after the flow of spent filter backwash water into the tank ended. The variability of the spent filter backwash turbidity is due to the variability of raw water, upstream treatment processes, filter design and operation, and backwashing practices. For example, the amount of solids trapped in a filter will be highly dependent upon the amount of solids in the raw water, the amount and type of coagulant used, whether lime softening is used (as it can add greatly to the solids load), and the efficiency of the sedimentation unit process (in conventional treatment systems). The quality of the spent filter backwash water also depends on the volume of backwash water used. The more water used, the more diluted the spent backwash water will become (HDR, 1997).

Other contaminants contained in the spent filter backwash can impact plant performance and finished water. TOC, aluminum, manganese, and iron concentrations in the spent filter backwash can be higher than those found in both the raw water and raw water after chemical addition. In a study by Levesque, et al., (1999) a facility with flow equalization but no solids removal had peak grab sample concentrations of 143 mg/L TOC, 158 mg/L total aluminum, and 1.23 mg/L total manganese. These contaminants are typically more of a concern when thickener supernatant is recycled in combination with the spent filter backwash (HDR, 1997). Total suspended solids (TSS) may also be a concern. TSS in the spent filter backwash varies between plants and during the backwash cycle. A study by Bashaw et al., (2000) indicated that TSS was very high, with a peak of approximately 300 mg/L and an average TSS of 71 mg/L, during the first three minutes of backwash. Another study by Myers et al., (2000) showed an average TSS of backwash water of 300 mg/L. A study by Tobiason et al., (1999) found high peak levels of 600 to 7,000 mg/L TSS in recycled spent filter backwash water. These peak levels were associated with the settling of solids in the backwash storage tank after the flow of spent filter backwash water into the tank ended. The recycled spent filter backwash from a backwash holding tank may have lower TSS values since solids are settled in the holding tank. However, if the backwash holding tank is mixed, no solids removal will occur and TSS could be high in the recycle stream.

7.3 THICKENER SUPERNATANT

Thickener supernatant results from gravity thickening of solids. In the gravity thickener unit, solids in the water stream settle out as a result of gravity. Gravity-thickeners can consist of clarifiers, sedimentation basins, backwash holding tanks, lagoons, and other similar units. After settling, the clarified water or decant that exits the unit is called thickener supernatant (see Figure 7-1). The sludge at the bottom of the sedimentation basin and other sludge-holding units could contain elevated levels of microbial (such as *Cryptosporidium* and *Giardia* cysts), organic, and inorganic contaminants as compared to the raw water. These contaminants can remain in the supernatant if the sludge is not properly settled, treated, and/or removed. The supernatant should be removed from the thickener unit in a manner such that the settled solids are not disturbed to minimize contamination issues.

Figure 7-1. Lagoon Used to Settle Solids

7.3.1 Frequency and Quantity

Thickener supernatant can be recycled continuously or intermittently. The frequency of thickener supernatant recycling depends on the quantity of sludge that is produced and thickener supernatant recycle practices. Thickener supernatant is often combined with other plant flows (such as spent filter backwash, filter-to-waste, or liquids from dewatering processes).

Approximately 65% to 75% or more of the sludge generated at a treatment facility settles out in sedimentation basins at a conventional alum coagulant plant. Generally, the sludge is 0.05% to 3% solids and the remainder is water. Sludge volumes are typically 0.1% to 3% of the plant flow (Environmental Engineering and Technology, 1999). The volume of sedimentation basin sludge supernatant is dependent on sludge production, sludge solids content, and method of thickener operation. Sludge production is a function of plant production, raw water suspended solids, plant process (such as lime softening), coagulant type and coagulant dose. The quantity of sedimentation basin thickener supernatant is approximately 75% to 90% of the original volume of sedimentation basin sludge produced (Environmental Engineering and Technology, 1999). The volume of lagoon decant depends on the volume of influent waste streams, concentration of solids in the waste stream, loading duration and frequency, drainage rates, overflow rates, and evaporation rates (Environmental Engineering and Technology, 1999).

7.3.2 Quality

Contaminant concentrations in thickener supernatant depend on the raw water characteristics, thickener design, thickener loading rate, and the type and amount of coagulant added.

Data for *Giardia* and *Cryptosporidium* in untreated sedimentation basin sludge showed concentrations of 3,000 to 5,000 cysts/100 L in a plant with two sampling points (Environmental Engineering and Technology, 1999). In another study, the *Giardia* concentration was 40 cysts/L and the *Cryptosporidium* concentration was 80 cysts/L in the sludge (Cornwell and Lee, 1993). The same study indicated that recycling the supernatant did not impact finished water quality. More detailed influent water, sludge, and supernatant data can be found in Table G-1, Appendix G, Characteristics of Thickener Supernatant.

Residual characteristics in lagoon decant are altered due to treatment in the lagoon and storage. Anaerobic conditions may occur, promoting the release of some metals from solid state to dissolved form. This may also occur for organics, and could result in taste and odor problems. However, anaerobic biological decomposition may reduce virus, parasite, or pathogenic microbial concentrations. Data on lagoon decant characteristics are presented in Table G-2, Appendix G.

A study by Hoehn, et al., (1987) reported significant release of manganese, iron, and TOC from sludges held in manually cleaned, anaerobic sedimentation basins (sedimentation basins that receive sludge and act as gravity thickeners). The study also concluded that sludge stored in lagoons can also be expected to degrade the overlying water, a consideration when recycling thickener supernatant.

Another study confirmed Hoehn's observations that manually-cleaned sedimentation basins caused more manganese to be released than mechanically cleaned basins (Cornwell and Lee, 1993). As the sludge accumulated in a manually cleaned basin, manganese levels in the clarified water gradually increased. Generally, if solids were removed from the waste stream prior to recycle, TTHM formation potential and TOC in the recycle stream was no higher than in the raw water.

7.4 LIQUIDS FROM DEWATERING PROCESSES

Some filtration plants prepare waste solids (sludge) for disposal by concentrating solids and removing excess water, which reduces the volume of waste that must be disposed. The sludge typically comes from sedimentation basins, clarifiers, backwash holding tanks, or other units, and contains only 1% to 2% solids. Removing liquids from these waste solids can concentrate the sludge up to 50% solids (Kawamura, 2000). The liquids that are removed are referred to as liquids from dewatering processes.

Liquids from dewatering can be produced from a lagoon or sludge drying bed as decant and underflow, from monofill as leachate, or from mechanical dewatering devices as pressate, filtrate, or centrate. If recycled, these liquids are subject to the FBRR.

7.4.1 Quantity and Quality

Liquids from dewatering processes can be of reduced quality since they consist of water extracted from thickened sludge. Most of the *Cryptosporidium* oocysts that are removed from raw water by treatment are concentrated, first as sludge in the sedimentation basin, clarifier, or other treatment processes. They can be settled a second time in a gravity thickener and then dewatered. The recycle stream created by the dewatering process typically has a smaller volume than spent filter backwash, but its size depends on the volume of sludge produced in the plant, and on the solids content of the sludge. Most plants will produce a small, intermittent stream as a result of the dewatering process.

Non-mechanically Dewatered Sludge Recycle Streams

Sludge drying beds, lagoons, and monofills can be used as non-mechanical processes to dewater sludge. Each of these dewatering processes creates a waste stream. Sludge drying beds are used for dewatering sludge through draining, percolation, decanting, and evaporation (see Figure 7-2). The quantity of decant and underflow depends on the volume of sludge applied to a bed, the sludge solids content, loading duration and frequency, and drainage and evaporation rates. The underflow and decant account for 50% to 75% of applied volume. If a thickener is not used, the underflow and decant volume would be in the range of 0.3% to 0.4% of plant production based on average sludge volumes reported elsewhere (Environmental Engineering and Technology, 1999). No published data exists that demonstrates the potential impact of recycling sludge drying bed decant and underflow. See Appendix H, Table H-1, for data on sludge drying bed underflow. Lagoons can be designed and operated in a manner similar to a sludge drying bed for dewatering.

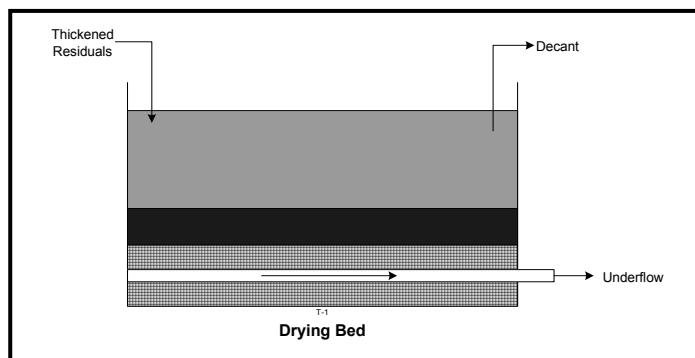


Figure 7-2. Sludge Drying Bed

Monofill (sludge-only landfill) is available in some States as a means of disposal of dewatered plant residuals from a water treatment plant. Water percolates through the monofill and is a potential recycle stream if it is collected by an underdrain (see Figure 7-3). The quantity of monofill leachate is dependent on the quantity and quality of dewatered residuals and the quantity of rainfall entering the monofill. The rate of seepage through the monofill is a function of sludge permeability and hydraulic gradient (Environmental Engineering and Technology, 1999). Three sets of pilot data from a study are presented in Table H-1, Appendix H. The leachate was generated by constructing pilot-scale monofills using two alum sludges and one ferric sludge. Although none of the metals concentrations shown in Table H-1 exceed primary MCLs, dissolved iron and manganese concentrations for a few of the data sets exceeded secondary MCLs. Metals and pH are typically the constituents of concern in leachate.

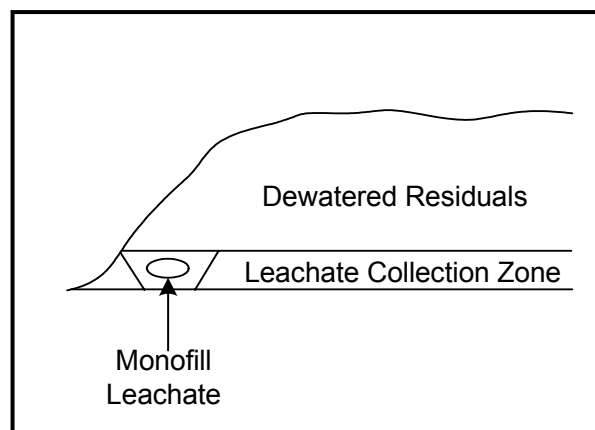
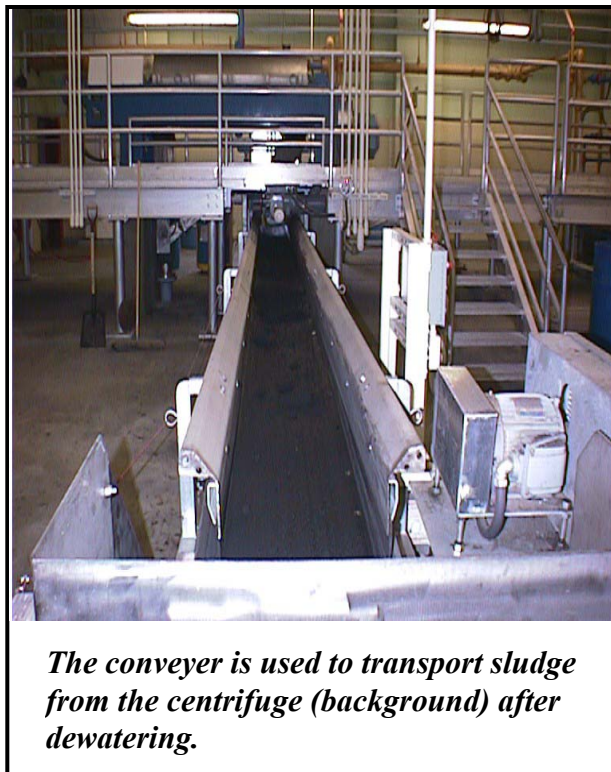


Figure 7-3. Monofill used for Dewatering Residuals

Mechanically Dewatered Sludge Recycle Streams

Water treatment plant residuals can also be dewatered by mechanical means, such as a centrifuge or belt filter press. The quantity depends on the volume and solids content of the thickened residuals feed. If the sedimentation basin average sludge flow is 0.6% of plant production, the dewatering device concentrate flow may be approximately 0.1% to 0.2% of plant flow. Belt filter presses and centrifuges, particularly at smaller facilities, are typically operated for only 8 to 12 hour shifts per day, often only five days per week. Operating routines would also affect potential recycle rates (Environmental Engineering and Technology, 1999). Data presented in Table H-2, Appendix H, shows that turbidity, TOC, and TTHMs can be high in liquids from mechanically dewatered sludge. Both total and dissolved aluminum and manganese concentrations may also be high. Elevated aluminum is expected to be present in waste streams of water plants practicing alum coagulation, and release of significant levels of manganese from residuals has been demonstrated. No published data exists on the potential impacts of recycling mechanical dewatering device concentrates. Plants generally dilute the dewatered residuals stream with other recycle streams prior to return to the main treatment train. The concentrates may often undergo further settling when put into thickeners prior to recycle.



7.5 NON-REGULATED RECYCLE STREAMS

The FBRR only regulates spent filter backwash water, thickener supernatant, and liquids from dewatering processes at conventional and direct filtration systems. However, other residual streams are produced at treatment plants. Table 7-1 provides a summary of some common residual streams produced by water treatment plants.

Table 7-1. Commonly Produced Non-Regulated Residual Streams

Residual Stream	Description
Filter-to-Waste	Generated by filters when the filter is placed back on-line after backwashing and prior to discharging to the clearwell. Typically of high quality since the stream has been treated by all treatment processes. Typically 0.5% of total amount of filtered water and second largest potential waste stream (after spent filter backwash) generated at a plant (HDR, 1997). Can be recycled or disposed.
Membrane Concentrate Reject Stream	Generated when the source water is passed through the membrane for treatment. Either returned back through the membrane for treatment or disposed (discharged to surface water, sanitary sewer, or land-applied).
Ion Exchange Residual Streams	Generated when the resins are regenerated, rinsed, or backwashed. Quality may be of concern if recycled.
Sludge from Softening Plants and Contact Clarifiers	Solids generated in the sedimentation basin or contact clarifiers. Recycled as an intrinsic part of the treatment process.
Slow Sand Filter-to-Waste	Generated over 1 to 2 days during the slow sand filter ripening period. Quality and volume may be of concern if recycled.
Diatomaceous Earth (DE) slurry	Generated when the DE filter is cleaned. Consists of filter medium and particles removed from the source water. Quality and volume may be of concern if recycled.
Minor Streams	Streams that result due to spills, laboratory analyses, washdown of plant facilities, and leaks. Typically of small volume, but quality may be a concern if recycled. AWWA's <i>Self-Assessment of Recycle Practices</i> (2002) provides more information on minor streams.

7.6 REFERENCES

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8. OPERATIONAL CONSIDERATIONS AND MODIFICATIONS

8.1 INTRODUCTION

As States and systems evaluate recycle practices, there are operational considerations and modifications that can be employed by water systems to minimize the impacts that the recycle of process flows and backwashing practices have on treatment. They all may not be appropriate for any given system; however, they have been proven appropriate in site specific situations. Operational considerations that systems may investigate include the following:

- Adjust chemical feed practices in the main treatment train during recycle events;
- Return recycle stream(s) to presedimentation basin;
- Control raw water or recycle stream flow to avoid unmanageable hydraulic surges;
- Reduce the amount of spent filter backwash generated through backwash modifications or increased filter run times;
- Reduce the filter-to-waste volume if filter-to-waste flows are recycled; and,
- Equalize (see Chapter 9) and/or treat (see Chapter 10) recycle stream(s) prior to returning stream(s) to the main treatment train.

While these operational considerations and modifications are not required by the FBRR, they are practices that can help systems optimize treatment and minimize the impact of recycle on treatment plant performance. Modifications can be implemented with or without pretreatment and/or equalization of the recycle stream. In addition, system modifications may or may not involve capital improvements at the plant. **Each operational consideration and modification is site-specific and pilot- or full-scale testing is recommended prior to modifying plant operations. Also, the State should be consulted prior to modifying any processes.** The operational considerations and modifications presented in this section are not all-inclusive.

8.2 ADJUST CHEMICAL FEED PRACTICES DURING RECYCLE EVENTS

Some plants have successfully tracked influent changes by streaming current readings, zeta potential readings, or other means and adjusted the chemical feed rate and type accordingly during recycle events. Jar testing prior to any modifications will be important to identify the

Jar Testing References

- ❑ Draft LT1ESWTR Turbidity Provisions Technical Guidance Manual (under development by EPA)
- ❑ Operational Control of Coagulation and Filtration Processes, AWWA M37, 1992 [Denver, CO] (available from AWWA)

type and amount of chemicals that perform best when recycle streams are introduced to the plant. Most systems will want to develop a Standard Operating Procedure (SOP) to assist operators with proper chemical feed operations during recycle events. Also, maintaining the recycle stream flow at a certain percentage of the total plant flow may be essential to properly implement this operational modification without major plant upsets. Equalization of the recycle stream may be necessary to maintain the target recycle percentage (see Chapter 9). The case studies presented in this section illustrate successes and concerns with modifying chemical feed practices during recycle events.

Case Study- Success with chemical feed modifications (Moss, 2000)

The Salt Lake City Public Utilities Department (SLCPUD) noticed an increase in particle counts and decrease in streaming current values during spent filter backwash recycle events. Operators were able to adjust coagulant feed rates to compensate for influent water quality variations such that finished water was not effected during recycle. In addition, SLCPUD fed polymer (high charge anionic polymer) to the spent filter backwash clarifier to increase sedimentation of the spent filter backwash prior to recycling.

Case Study- Issues with chemical feed modifications (Goldgrabe-Brewen, 1994)

A study of three plants in northern California reported coagulant underdosing when a streaming current detector was used in coagulant dosage control mode. Positively charged particles contained in the spent filter backwash caused the streaming current monitor reading to increase, resulting in chemical underdosing. This same study also demonstrated that using polymer exclusively for coagulation had negative impacts on clarification when the recycle percentage exceeded five percent of the total raw water treated.

This option may be complicated due to residual chemicals contained in the recycle stream and the intermittent nature of some recycle streams. These residuals can cause a fluctuation of chemical demands at the head of the plant when mixed with raw water. Also, determining the appropriate chemical dose may be difficult, as presented in the case studies. A polymer feed system may need to be installed for successful treatment if one does not already exist. EPA estimates the cost of installing a polymer feed system on a 1.8 MGD plant was \$8,900 in capital costs and \$4,000 in operation and maintenance costs (EPA, 2000).

8.3 RETURN RECYCLE STREAM(S) TO PRESEDIMENTATION BASIN

If presedimentation basins are available, the recycle stream can be returned to the presedimentation basin prior to coagulation. Additional settling prior to the main treatment train may reduce particle loading onto the filters. Another added benefit of discharging recycle streams to a presedimentation basin, if configured to avoid short-circuiting, is the mixing that will occur with the raw water. A more consistent influent water quality to the plant allows for more uniform chemical feed operations and overall improved treatment plant efficiency. A disadvantage with this operational consideration is that more frequent sediment/solids removal will be required.

8.4 CONTROL RAW WATER FLOW OR RECYCLE RETURN FLOW

Systems should be careful to avoid unmanageable hydraulic surges or plant capacity exceedances during recycle events. Two options systems may want to consider to avoid unmanageable hydraulic surges or plant capacity exceedances are:

- Control raw water flow during recycle events such that the raw water flow plus recycle flow will not create a hydraulic surge or plant capacity exceedance.
- Control the rate of return of recycle flows by providing equalization of recycle streams (see Chapter 9).

Maintaining the recycle flow at or below 10 percent of the plant influent (raw water flow plus recycle flow) should be sufficient (SPHEM, 1992; Kawamura, 2000; Cornwell and Lee, 1994). The appropriate recycle flow percentage will vary from system to system depending on site specific water quality and treatment conditions.

8.5 REDUCE THE AMOUNT OF GENERATED SPENT FILTER BACKWASH

Several options are available for reducing the amount of generated spent filter backwash, including:

- Using air scour or surface wash to supplement the backwash process;
- Determining the minimum backwash duration necessary to produce optimum filtered water; and,
- Increasing filter run times and decreasing the frequency of backwashes.

Systems should be careful, when modifying backwash practices, to monitor the resulting impact on filtered water quality. Modifying backwash practices can affect filtered water turbidity (causing either increases or decreases in turbidity) and systems must maintain compliance with all filter effluent turbidity standards. The LT1ESWTR Turbidity Provisions Technical Guidance Manual has additional information on filter assessments and backwash practices (under development by EPA).

8.5.1 Air Scour with Backwash

Air scour can be used in conjunction with backwash and in some instances has been shown to provide better cleaning than water-only backwash, and saves on backwash water. A water works in southern Nevada that upgraded to an air/water backwash system was able to reduce its backwash water volume by 500 million gallons per year (Logsdon et al., 2000).

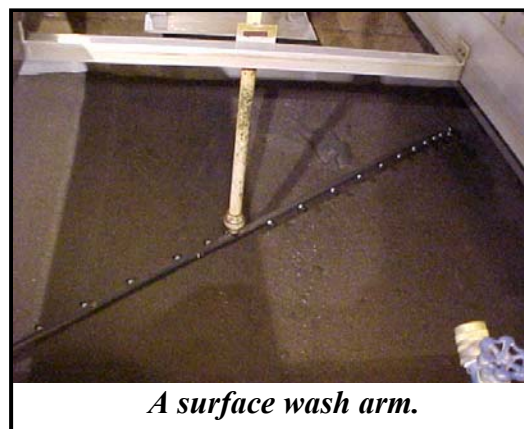
The process can consist of three scenarios (AWWA, 1999):

- **Air scour alone before backwash.** This process is recommended for fine sand, dual media, and triple media filters.
- **Simultaneous air scour and backwash during rising water level but before overflow.** Air scour and backwash can be done simultaneously, with air scour terminating before overflow. This process is recommended for fine sand, dual media, triple media, and coarse monomedium anthracite.
- **Simultaneous air scour and water backwash during overflow.** This process consists of air scour with water backwash throughout the overflow period. This process is recommended for coarse monomedium sand or anthracite filters. Special baffled overflow troughs are essential for anthracite filters to prevent loss of anthracite.

The use of air scour in the backwash process may allow a reduction in the backwash rate and duration, producing less spent filter backwash.

8.5.2 Surface Wash with Backwash

Surface wash systems inject jets of water from orifices located about 1 to 2 inches above the surface of the fixed bed. Surface wash jets are operated for 1 to 2 minutes before the upflow wash and usually are continued during most of the upflow wash. Surface wash is terminated 2 or 3 minutes before overflow to prevent media loss. Surface wash may allow the time of backwash to be decreased and result in less generated spent filter backwash. EPA estimates that the cost of installing a surface wash system at a 1.8 MGD plant was \$159,400 in capital costs and \$5,700 in operation and maintenance costs (EPA, 2000).



A surface wash arm.

Case Study (Myers, et al., 2000)

The Ann Arbor Water Treatment Plant (WTP) (50 MGD lime softening plant) evaluated four backwash durations: 5, 8, 10, and 15 minutes. Particle counts were measured in the subsequent filter run for each backwash duration. The results indicated the 8- or 10-minute backwash duration produced the best particle removal for their system configuration in the subsequent filter run. Eight minutes produced the lowest particles in the first hour and 10 minutes produced the lowest particles over the filter run. A backwash duration of 8 minutes was selected, resulting in approximately 20% reduction in backwash volume as opposed to a 10-minute backwash duration.

8.5.3 Reduce the Length of Backwash

Under some conditions, it may be possible to reduce the time of backwash and still comply with turbidity standards. In fact, backwashing for too long can be detrimental to the media and filter performance. Backwashing should typically be terminated when the filter backwash turbidity is between 10 and 15 NTU (Kawamura, 2000); however, the optimum filter backwash turbidity value will vary from system to system. Full-scale tests are necessary to determine the backwash duration that minimizes the filter ripening time when the filter is placed back on-line and results in the optimum filtered water quality.

8.5.4 Increase Filter Run Times

Evaluating an increase in the filter run time may be worthwhile and can result in a significant reduction in generated spent filter backwash volume over time. **Caution should be exercised so as not to compromise finished water by operating a filter to or past the point of breakthrough.** Chemical feed practices can also be modified to optimize coagulation, flocculation, and sedimentation, resulting in increased filter run times.

Case Study (Myers, et al., 2000)

Pilot and full-scale tests were conducted on extending filter run times at the Ann Arbor WTP (50 MGD lime softening plant). The addition of a fine garnet layer to the filters allowed the filter run times to be increased from 75 hours to 96 hours. Headloss in all the extended filter runs did not exceed three feet. Extending the filter runs resulted in a 30% decrease in backwash volume and also eliminated about 700 filter backwashes per year, simplifying operations and reducing costs.

8.6 REDUCE THE AMOUNT OF FILTER-TO-WASTE

If filter-to-waste flows are recycled, several options exist to reduce this particular stream. Although this stream is not regulated by the FBRR, systems may be concerned about its potential for causing hydraulic surge. Such systems may consider terminating the filter-to-waste process when the filtered water turbidity level reaches a predetermined level, as opposed to terminating the filter-to-waste process after a preset time. For example, some systems may filter-to-waste for a preset time limit of 15 minutes on all filters during initial filter start-up. Systems may want to re-evaluate the filter-to-waste procedure. Evaluation of filter-to-waste practices may reveal that desired turbidity or particle count levels in the filtered water may be achieved prior to the preset time limit.

Another option is to reduce the filter ripening period, which will in turn reduce the filter-to-waste volume. The following practices have been demonstrated in certain systems to decrease the initial turbidity spike that occurs when a filter is placed back on-line:

- **Delayed start.** The delayed start consists of letting the filter rest for a period of time between backwashing and placing the filter back into service. This option may not be possible during peak flow periods, but is a good option to consider for reducing initial turbidity spikes.
- **Slow start.** The slow start is a technique that involves a gradual increase of flow to the filter until the desired hydraulic loading rate is achieved. Again, this option can potentially reduce initial turbidity spikes but may require modification of the system to properly control the flow to the filter.
- **Add a coagulant or polymer during the backwash process.** Some studies have shown that coagulants added to the backwash water during the later stages of the backwash process could accelerate the filter ripening process (Hess et al., 2000).
- **Add polymer during initial start-up of filter.** A polymer can be fed to the filter influent during the initial start-up period to enhance initial filtration performance. Polymer feed is then terminated once the filter has reached optimal performance. Systems should be careful when adding polymer during initial filter start-up. Polymer addition can create mud balls and other problems in the filter.

Systems should exercise caution when modifying filter-to-waste practices. Systems will need to verify that their filter-to-waste practices maintain compliance with finished water turbidity standards.

Case Study (Carmichael, Lewis, and Aquino, 1998)

The Milwaukee Water Works compared filter performance for three different scenarios:

- Backwash with no polymer addition;
- Backwash with cationic polymer (Cat-Floc T) added to the backwash water; and,
- Adding cationic polymer to the filter influent water for the last hour of a filter run and then adding it again during the first hour of the following run.

The strategy of adding polymer to the filter influent water both before and after backwash at a dosage of 0.4 mg/L controlled the initial spike better than adding polymer to the backwash water. Filter performance was measured based on particle counting. Full-scale practice has been modified to include the addition of a slug dose (0.4 mg/L) of undiluted cationic polymer in the filter box in front of the influent valve as the settled water flows into the filter box after the influent valve is opened. Then during the first hour of the filter run, polymer is fed at a dose of 0.4 mg/L. Polymer is no longer fed in the last hour of a filter run before backwash, as this did not improve filter performance.

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9. EQUALIZATION

9.1 INTRODUCTION

Water treatment plants are designed to treat up to a specific flow rate and water is typically introduced to the plant via pumps at a controlled rate. When additional flows during recycle events are introduced, the recycle stream may cause one or more of the following:

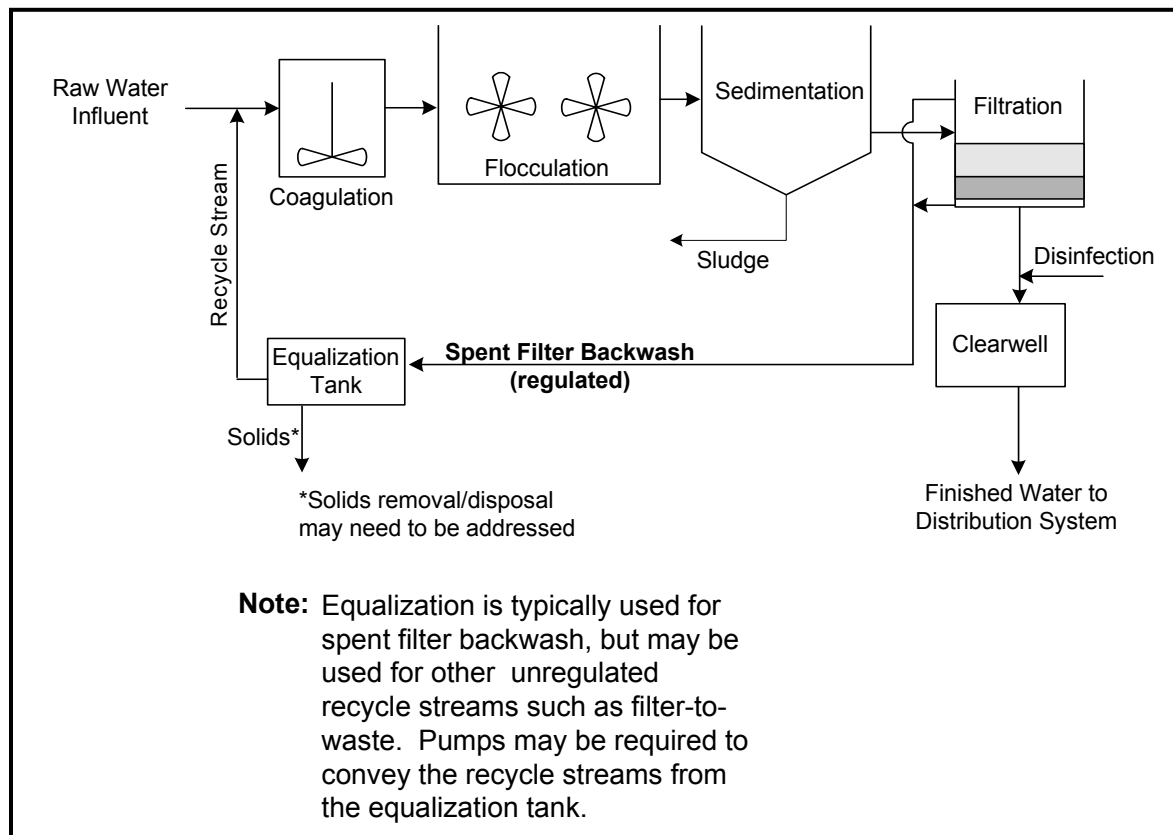
- The plant exceeds the design capacity. Recycle streams (spent filter backwash water in particular) can be generated rapidly and in large volumes, and have the potential to cause a plant to exceed its design capacity.
- Hydraulic surge. The introduction of recycle streams can cause the flow to the plant to increase suddenly, which can disrupt treatment processes.
- The influent water quality is significantly altered by the recycle stream. The potential exists for recycle streams to contain higher concentrations of contaminants, particularly pathogens, than the raw water. Also, the chemistry of the recycle stream may influence water quality such that the overall treatment efficiency of the plant may be affected.

Equalization of recycle streams can be provided to help reduce the impacts of recycle streams on plant processes. Equalization consists of providing storage or detention of the recycle stream and returning the recycle stream at a rate different than the generated rate. For instance, spent filter backwash is generated at a particular plant at a rate of 2,000 gpm. Equalization is provided in a spent filter backwash holding tank, and the holding is operated such that the spent filter backwash is returned at a rate of 500 gpm. Figure 9-1 provides a schematic for equalization of spent filter backwash. With equalization, flows can be returned at a rate less than the generated flow rate. Equalization of recycle streams can be provided by basins similar to sedimentation basins, lagoons, or other similar units. The case studies presented in this chapter provide information on equalization tank design considerations.

When determining the rate of return from the equalization basin, the rule of thumb has been to maintain the recycle flow at or below 10% of the plant flow (SPHEM 1997; Kawamura, 2000; Cornwell and Lee, 1994). However, the actual percentage varies from plant to plant and systems need to evaluate the percentage of recycle stream that creates the minimal impacts on finished water. In addition, a continuous recycle return flow (as opposed to intermittent recycle return flow) has been recommended for optimum plant performance (McGuire, 1997; Petersen and Calhoun, 1995).

This chapter discusses the advantages and disadvantages of equalization and methods for assessing the impacts of equalization or lack of equalization at a system. Two case studies are presented later in this chapter to provide real-life scenarios and concerns.

Figure 9-1. Example of Equalizing Recycle Streams



9.2 ADVANTAGES

Flow equalization provides hydraulic stabilization that can help to maintain optimal finished water quality.

Equalization of recycle streams can provide the following benefits:

- Minimize hydraulic surges and the possibility of hydraulic overload of sedimentation basins, filters, and other treatment units. Settled water quality has been shown to deteriorate as surface-loading rates of the sedimentation basin increase (AWWA, 1999). Hydraulic overload can compromise overall treatment plant efficiency and removal of pathogens and other contaminants. Hydraulic surges can also result in a plant exceeding its design or State-approved capacity. Equalization can help eliminate the situation where clarification and filtration operating rates may be exceeded at precisely the time recycle streams may be returning large numbers of oocysts to the treatment process. Example 9-1 illustrates a situation where direct recycle practices resulted in a plant exceedance and other plant process impacts.
- Allow better flow pacing of chemicals at the head of the treatment plant when the flow is more consistent. Recycle streams vary with quality as the stream is produced. For instance, spent filter backwash typically contains more particles during the beginning of filter backwash than at the end of the backwash process. Equalization can allow the spent filter backwash to be mixed (if mixing is provided in the equalization basin) and of a more consistent quality, in addition to controlling the flow. A more consistent recycle stream, both in quantity and quality, will allow for consistent chemical feed operation.
- Equalization can allow a reduction in the size of a recycle stream treatment unit (if provided) by reducing the peak recycle stream flow.

Benefits of Equalization

- ✓ Minimize hydraulic surge
- ✓ Better flow pacing of chemicals
- ✓ Subsequent recycle stream treatment processes may be downsized

Equalization basins can be operated such that settling of particles can occur. Chapter 10 has more information on treatment through sedimentation.

Example 9-1. Evaluating Recycle Practices

Note: The following example is intended to illustrate how a system or State could evaluate recycle practices and resulting modifications. This example is not intended to establish plant operation or modification criteria.

Using the example and information for the 3.0 MGD plant presented in Appendix C, recycle practices were evaluated. Following is a quick summary of the plant information:

- Plant design flow: 3.0 MGD (2,080 gpm);
- Observed Peak Plant Influent: 2,500 gpm, consisting of 1,000 gpm raw water flow and 1,500 gpm spent filter backwash recycle flow; and,
- Typical Recycle Flow: 1,500 gpm- This flow represents spent filter backwash. Backwash is conducted at a rate of 15 gpm/ft² and each filter has a surface area of 100 ft². Filters are backwashed individually, four filters per night. Filters were backwashed for a duration of 15 minutes.

To evaluate their recycle practices, the system determined the percent of peak plant influent flow that was recycle flow on an instantaneous basis:

$$\% \text{ Recycle flow} = \frac{\text{Recycle Flow}}{\text{Total Plant Flow}} = \frac{1,500 \text{ gpm}}{2,500 \text{ gpm}} = 60\%$$

The percent recycle flow on an instantaneous basis of 60% was rather high. Also, the peak plant influent flow of 2,500 gpm exceeds the plant design flow of 2,080 gpm. Further evaluation of plant flows during recycle indicated the design flow was typically exceeded during recycle events. The sedimentation basin and filters were both subjected to hydraulic surges during recycle. Turbidity and particle counts in the finished water were recorded at 30-second intervals as another means of evaluating impact of recycle practices. The results indicated substantial increases in both turbidity and particle counts during recycle events as opposed to periods where recycle was not occurring.

The system decided to install a lagoon to provide equalization. The lagoon was sized for two backwash volumes plus adequate freeboard. The lagoon was operated such that recycle flows were reduced from 1,500 gpm under direct recycle practices to 500 gpm. The lagoon was allowed to fill completely during backwash (15 minutes) to allow mixing and then pumped back to the plant before the next backwash commenced.

9.3 DISADVANTAGES

Few disadvantages are associated with flow equalization, however, as with any water treatment plant improvement, costs are a consideration. Multiple or redundant facilities may be required for adequate operation. Should the equalization basin not be operated on a continuous basis or operation suspended for an extended time (2 to 3 days), sludge may form in the bottom and be subsequently discharged to the plant influent. Sludge can taint the equalized flow, create objectionable tastes and odors, and carry other undesirable substances in the recycle stream. Another disadvantage is the required amount of space needed to accommodate the equalization basin.

Case Study (Myers, et al., 2000)

Four alternatives for handling spent filter backwash at the Ann Arbor WTP (50 MGD lime softening plant) were evaluated:

- Discharge to a storm sewer (equalization required to meet discharge permit flow requirements);
- Discharge to a sanitary sewer (equalization required by receiving wastewater plant);
- Discharge to a lime sludge lagoon; and,
- Equalization with recycle.

The system evaluated all four alternatives for feasibility, flexibility, and cost-effectiveness. For this particular plant, equalization with recycle in conjunction with discharge to the lime sludge lagoon was the most feasible and cost-effective option. Discharge to the lime sludge lagoon was recommended to be included as a back-up and added operational flexibility.

The conceptual equalization basin design included an equalization basin with a capacity of at least two backwash volumes and variable speed pumps to maintain the recycle flow between 5% and 10% of the raw water flow. Equalization of recycle provided the following benefits for the Ann Arbor WTP:

- Reduced the possibility of plant capacity exceedance during recycle;
- Reduced hydraulic surge through the plant, resulting in better settling and particle removal through the filters; and,
- Allowed for more consistent chemical feed, which resulted in more consistent water quality.

The conceptual design also included a recommendation that the equalization basin allow for future chemical addition if treatment becomes necessary in the future.

9.4 COSTS

Costs are associated with both the construction and operation and maintenance (O&M) of equalization basins. EPA developed a range of costs as part of the FBRR making process. Capital costs associated with equalization basins for design recycle flows into the equalization basins of 0.59 MGD and 83.59 MGD were \$317,000 per MGD and \$14,360 per MGD, respectively. O&M costs associated with equalization basins for design flows of 0.59 MGD and 83.59 MGD were \$11,000 per MGD and \$130 per MGD, respectively (EPA, 2000).

9.5 EVALUATING EQUALIZATION

Evaluating existing equalization or evaluating the need for equalization is an important step in examining the effects of recycle practices on a system, particularly when a plant is out of compliance (for example, unable to meet current turbidity standards). In order to evaluate if equalization improvements would be beneficial, the following information and plant performance data should be assessed:

- Evaluate the data collected on recycle practices, as discussed in Chapters 3, 4, and 5. Systems may want to examine frequency of recycle streams, recycle stream flow rates, backwash practices, and other information. Systems may be able to determine that plant capacity and individual treatment unit process loading rates are exceeded during recycle events. The system should then evaluate the impact to finished water quality as a result of recycle practices.
- Evaluate loading rates to treatment units (specifically clarifiers, sedimentation basins, and filters) during recycle events. Compare the loading rates during recycle events to the design loading rates. In order to ensure finished water quality meets all standards, the design loading rates should rarely be exceeded.
- Examine turbidity and/or particle count levels in finished water during recycle events. If turbidity and particle counts increase during recycle events, equalization may be one option to reduce these impacts (see Example 9-1).
- Examine daily operation information and assess the chemical feed practices during recycle events. If the system must modify chemical feed practices during recycle events, equalization may allow a more consistent chemical feed practice.

Again, equalization can allow the recycle stream to be returned at a more controlled rate and at a more consistent quality. As the system evaluates equalization, treatment options may also be considered. Chapter 10 provides more information on treatment for recycle streams. If treatment is not installed at the time the equalization units are installed, the system may want to allow room in the design for future treatment.

Case Study (Bashaw, et al., 2000)

The James E. Quarles WTP is a 64 MGD conventional filtration treatment plant located in Marietta, Georgia. The recycle practices were evaluated as part of the expansion process (upgrade to a capacity of 96 MGD) and recycle stream equalization and treatment alternatives were investigated. As seen in Figure 9-2, the existing system recycles spent filter backwash, thickener supernatant, filtrate, and filter-to-waste. All recycle streams are treated in a clarifier, equalized in a recycle tank, and then recycled to the raw water reservoir.

Four alternatives were evaluated for the recycle streams:

1. Adding polymer to flocculate the solids in the spent filter backwash water before settling. Jar tests were conducted to determine the type and dose of polymer needed.
2. Equalizing backwash flows and thickener overflows prior to settling. Flows to the clarifier during backwash were 2.7 times the average flow to the clarifier. Equalization would provide a consistent flow to the backwash clarifier for better detention and treatment. Also, the suspended solids in the spent filter backwash varied greatly over the backwash cycle. With mixing the full backwash flow volume in the equalization tank, a more uniform concentration of solids is obtained. The added benefit of mixing is that the polymer feed rate could be maintained at a more uniform rate.
3. Discharge filter-to-waste flows downstream of the clarifier. Since filter-to-waste contains almost no solids, little treatment is accomplished in the clarifier. By-passing the clarifier reduces the loading to the clarifier and provides better detention and treatment (removal of solids) of spent filter backwash flow.
4. Provide additional treatment after the clarifier.

The following options were selected for final design and are presented in Figure 9-3:

- Two new equalization tanks will be installed to receive spent filter backwash and thickener supernatant. The equalization tanks were designed to accommodate two backwash volumes plus thickener overflows. Each tank will be equipped with submersible mixers for blending contents and with vertical, mixed flow transfer pumps that will discharge to a flocculation tank.
- The discharge piping from the equalization tanks will be equipped with polymer feed injection capabilities.
- A two-stage flocculation tank will be installed downstream of the equalization tanks and will provide 10 minutes of detention time at peak flow rate.
- Filter-to-waste flows will be discharged downstream of the clarifier.
- The existing clarifier capacity will not be modified due to the elimination of filter-to-waste flows and longer filter runs (to be achieved with deep-bed filters that will be installed as part of the plant upgrades). The clarifier will be able to provide 4.2 hours of detention time.
- Treatment of the flow exiting the clarifier was not included as part of the final design, but the final design allows for installation of treatment if needed in the future.

Figure 9-2. Existing Layout of James E. Quarles Water Treatment Plant

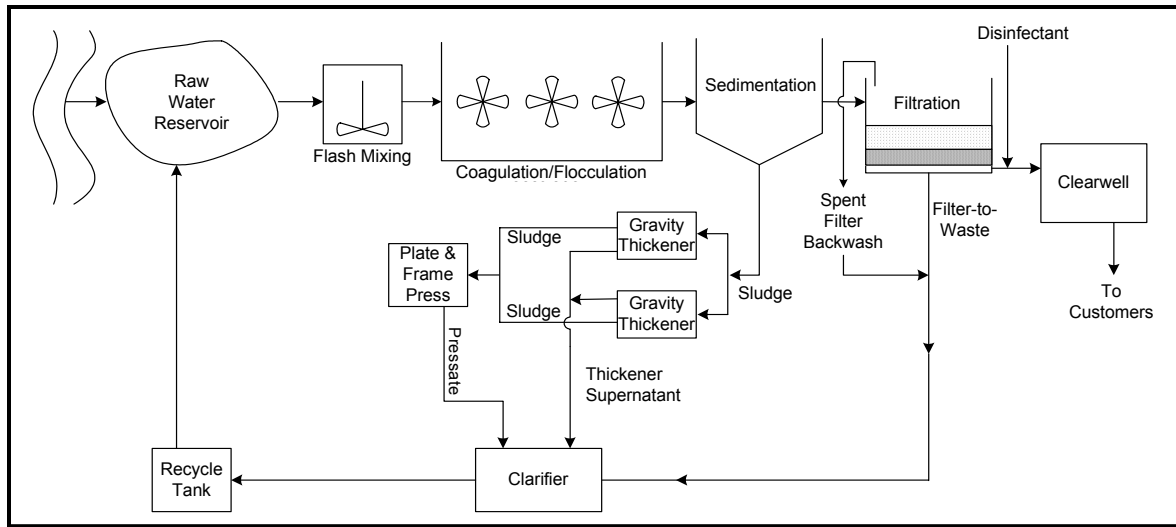
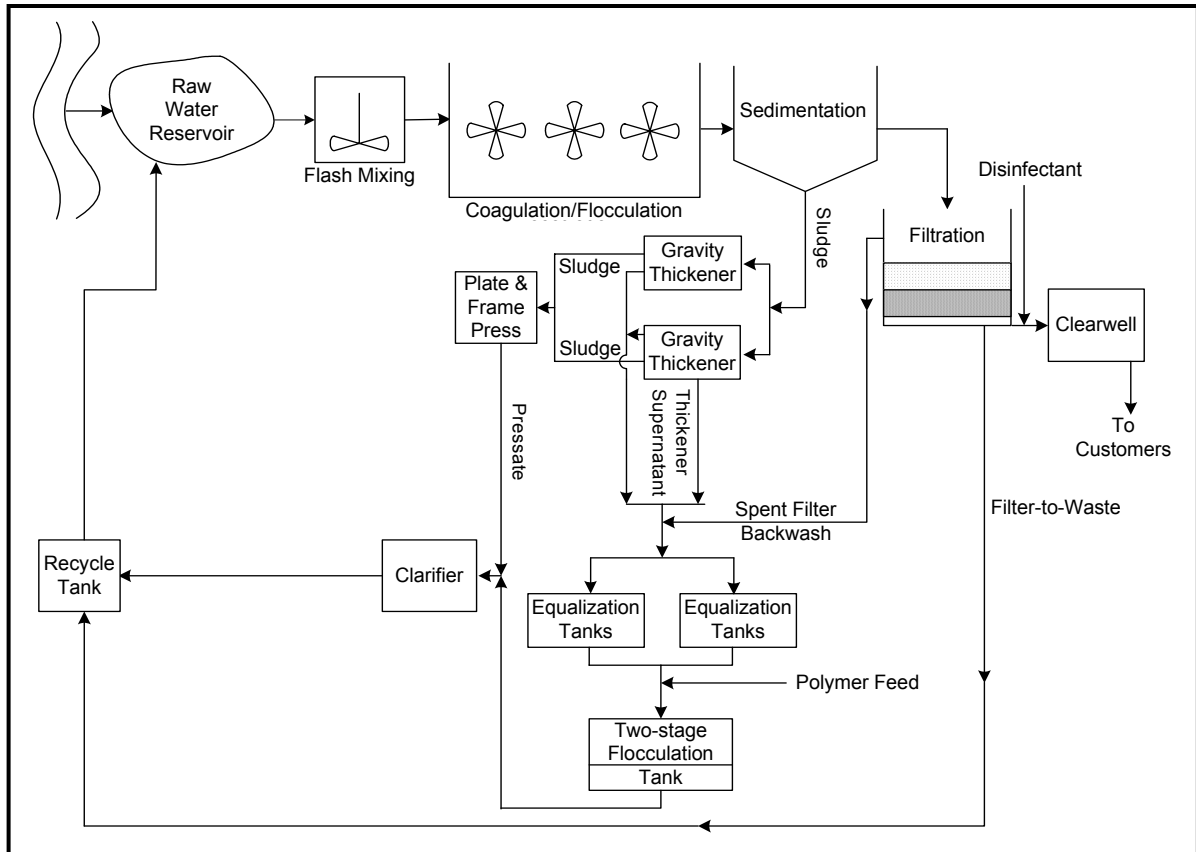


Figure 9-3. Proposed Improvements for Recycle Streams at the James E. Quarles Water Treatment Plant



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10. TREATMENT OF RECYCLE STREAMS

10.1 INTRODUCTION

Residual streams are often high in particulates, solids, and other contaminants. It may be necessary to treat residual streams prior to recycling so finished water quality is not compromised. An AWWA FAX survey taken in 1998 found that the majority of systems that recycle (approximately 70%) treat and/or equalize the stream prior to its return to the main treatment train (AWWA, 1998). The most common type of treatment is sedimentation. See Table 10-1 for the results of the AWWA FAX survey.

The FBRR does not require treatment of recycle streams beyond returning flows through the processes of a system's existing conventional or direction filtration system. However, EPA recognizes that additional treatment of recycle streams may be appropriate to reduce risks of microbial contamination and optimize the operational performance of the system. As systems and States begin to evaluate recycle practices, they may decide that treatment of recycle streams or modifications to existing recycle stream treatment processes is warranted.

Table 10-1. Results of AWWA FAX Survey on Systems that Recycle

TREATMENT TYPE	PERCENTAGE OF SYSTEMS
No Treatment	30
Sedimentation	38
Equalization	14
Sedimentation and Equalization	10
Lagoon	3
Other	5

Some systems may decide that recycle of residual streams is not cost-effective and may elect to dispose of residual streams. Disposal of residual streams may need to meet requirements under other Federal and State statutes and regulations. Some options that may be available include:

- Discharge to the sanitary sewer;
- Discharge to a surface or ground water body; or,
- Irrigation/land application.

Systems should check with their State and EPA regional offices to determine what restrictions or permit requirements apply to any of these disposal options. This document will not cover disposal options.

This chapter presents a description of recycle stream treatment concepts, the advantages and disadvantages associated with treatment, guidelines for treatment, methods for assessing existing recycle stream treatment or the need for treatment, and a brief description of different treatment options. Case studies are also provided that give examples of different recycle stream treatment options.

10.2 ADVANTAGES

Treatment processes for recycle streams that are properly designed and operated can reduce levels of *Cryptosporidium* and *Giardia*, contaminants of concern in recycle streams. Treatment processes can also be designed and operated to remove other contaminants, such as solids, particulates, DBP precursors, TOC, aluminum, iron, and manganese. These contaminants can create aesthetic and health issues in the finished water if not removed from recycle streams. Other benefits of treatment are as follows:

- Treatment of recycle streams may be cheaper and less time-intensive for the operator than modifying main treatment train processes during recycle events. Because both quantity and quality of plant influent change during recycle events, operators may need to modify chemical feed processes and other main treatment plant processes to ensure that finished water quality is not compromised. Treatment of recycle streams can allow more consistent operation of the main treatment train processes.
- Treatment of recycle streams can reduce particle loading on sedimentation basins (in conventional filtration plants) and filters in the main treatment train, thus possibly extending the useful life of these units.

Benefits of Treating Recycle Streams

- ✓ Removal of contaminants, particularly *Cryptosporidium* and *Giardia*.
- ✓ Allows more consistent operation of main treatment train, resulting in saved money and operator time.
- ✓ May extend useful life of sedimentation basins and filters in main treatment train.

It may be necessary to equalize flow in addition to providing treatment to control the recycle stream flow. The use of equalization may also reduce the size of the treatment unit required to handle the recycle flow.

10.3 DISADVANTAGES

There are some disadvantages associated with treatment of recycle streams. As with any other treatment plant improvement, more equipment requires more maintenance. Again, when compared to other residual management options (such as disposal), the O & M of treatment units may be a more cost-effective option.

10.4 COSTS

The costs will vary depending on the type of treatment, flows, level of treatment, and other site-specific issues. However, treatment may be cheaper than other alternatives (such as discharge to a surface water body or wastewater treatment plant). EPA estimated a sedimentation basin with polymer feed and tube settlers to have a capital cost of \$228,000 and \$1,560,000 for design loading rates to the sedimentation basin of 0.022 MGD and 19.87 MGD, respectively (EPA, 2000). Annual operation and maintenance costs were estimated to be \$4,600 and \$34,700 for design loading rates to the sedimentation basin of 0.022 MGD and 19.87 MGD, respectively (EPA, 2000).

10.5 RECOMMENDED DESIGN GOALS

The FBRR does not provide specific requirements for treatment. Some States and professionals have developed treatment guidelines that are presented for consideration in the following sections. Systems should check with their State on specific treatment requirements or guidelines when considering treatment for recycle streams.

10.5.1 Ten States Standards

The Great Lakes Upper Mississippi River Board of State Public Health and Environmental Managers, (or Ten States Standards) (SPHEM, 1997), recommend that spent filter backwash be returned at a rate less than 10% of the raw water flow entering the plant. Spent filter backwash should not be recycled when raw water contains excessive algae, when finished water taste and odor problems occur, or when trihalomethane levels in the distribution system exceed allowable levels.

10.5.2 California

California recommends that treatment plants establish an operational goal for turbidity of less than 2.0 NTU for recycled spent filter backwash and other recycle streams. If this turbidity limit cannot be achieved, the system should treat the recycle stream to a quality equal to the average raw water quality. In addition, new facilities should remove 80% of solids before recycle and the recycle flow should be less than 10% of the plant flow.

10.5.3 Maryland

Maryland has a policy for both new and existing surface water treatment plants. New surface water plants should provide treatment for recycle streams. Existing systems can continue to recycle under the following controlled circumstances:

- The recycle ratio should be less than 5%;
- A minimum of two hours of polymer-enhanced sedimentation should be provided; and,
- Sedimentation should be provided with very low, continuous overflow rates (0.3 gpm/ft²).

10.5.4 Ohio

Ohio recommends recycle streams be treated prior to their return to the main treatment train. In addition, the recycle flow should be less than 10% of the plant flow.

10.5.5 Cornwell and Lee (1993)

Based on an evaluation of eight systems, Cornwell and Lee (1993) made the following observations which may minimize impacts on finished water quality:

- Equalization should be provided so that recycle is continuous rather than intermittent.
- The recycle stream should be properly treated for cyst removal with an 80 percent treatment efficiency.
- Overflow rates from the backwash water clarifier should be less than 0.07 gpm/ft² to achieve the 80% treatment efficiency (when chemical addition is not used).

10.5.6 United Kingdom Water Industry Research (UKWIR) (1998)

The UKWIR developed a water treatment guidance manual that addresses recycling of spent filter backwash water (Logsdon, et al., 2000). The UKWIR recognized the risk posed by concentrated suspensions of *Cryptosporidium* oocysts in spent filter backwash. UKWIR developed the following guidelines to prevent passing oocysts into finished water:

- Backwash water should be settled to achieve a treatment objective of greater than 90% solids removal before recycling.

- Recycle flows should be at less than 10% of raw water flow and continuous rather than intermittent.
- Continuous monitoring of the recycle stream with on-line turbidimeters should be conducted.
- Jar tests should be conducted on plant influent containing both recycle streams and raw water to properly determine coagulant demand.
- Polymers should be considered if high floc shear or poor settling occurs.
- The recycle of liquids from dewatering processes should be minimized, particularly when quality is unsuitable for recycling.

10.6 EVALUATING TREATMENT

The evaluation of existing treatment processes used for recycle streams or evaluating the need for treatment is an important process. The following checklist can be used to conduct the evaluation:

- ✓ Compare finished water quality during periods of recycle to periods when recycling is not occurring. Contaminants of concern are *Cryptosporidium*, *Giardia*, DBPs, DBP precursors, TOC, iron, aluminum, and manganese. Other water quality parameters that could be examined are pH, turbidity, particle counts, and taste and odor. If contaminant concentrations increase during recycle events as compared to periods when recycling is not occurring, then treatment (or improvements to existing recycle stream treatment processes) may be warranted. Also, if treatment technique violations or MCL violations occur during recycle events, then treatment (or improvements to existing recycle stream treatment processes) should seriously be considered.
- ✓ Perform a similar process as previously described on individual treatment unit processes in the main treatment train for more information on how individual units are being impacted during recycle events.
- ✓ Examine flows and hydraulic loading rates during periods of recycle events. Make sure that hydraulic surge, plant capacity exceedance, and/or hydraulic loading rates of individual treatment units in excess of design rates are not occurring.

As a system considers treatment options for recycle streams, the following items should be considered:

- ✓ Estimate or measure the amount of residuals produced by the plant. Mass balance calculations can be used to determine residual stream loading rates. The

liquid and solid residual stream quantities (peak and overall volume) should be obtained to properly size treatment units.

- ✓ Consider the benefits of adding equalization. Equalizing the recycle stream may allow a reduction in the required treatment unit loading rates.
- ✓ When designing any treatment process, allow for future modifications- flexibility is key.

The AWWA *Self-Assessment of Recycle Practices* provides additional information on how to evaluate existing recycle stream treatment facilities or the need for treatment (AWWA, 2002).

The case study (Bashaw, et al., 2000) presented in Chapter 9 (page 65) provides information on how treatment and equalization options for recycle streams can be evaluated. The following case study presents additional information on evaluating treatment.

Case Study (Nielson, et al., 1995)

The Cleveland Division of Water (CDW) is upgrading one of its four water treatment plants (Crown WTP) from 50 MGD to 125 MGD capacity. The upgrade will involve modifying existing conventional unit treatment processes (coagulation, flocculation, sedimentation and filtration) to high-rate processes. As part of the upgrades, the system evaluated recycle practices. Figure 10-1 contains a schematic of the existing system and residual streams. The Crown WTP handles residual streams as follows:

- Spent filter backwash is either equalized and recycled to the head of the plant or sent to the gravity thickeners for ultimate discharge to Lake Erie.
- Solids are thickened, dewatered, and the filter cake disposed in sanitary landfills. The pressate is sent to the sanitary sewer after pH adjustments. Thickener supernatant is discharged to Lake Erie.

In evaluating recycle practices, CDW developed a residual solids management plan. CDW considered the following to develop this plan:

- Existing data on both the quantity and quality of residual streams. An important part of this process was identifying additional data collection needs.
- Solids production throughout the treatment process. A mass balance was conducted to identify the point in the treatment train where solids were generated. The mass balance showed how residual solids were processed, and checking the results against existing data enabled the identification of erroneous data. Average quantity and average quality of residual streams in addition to maximum day, maximum week, and maximum monthly values were calculated.
- Cost and non-cost issues associated with each residual solids management alternative.
- The impacts on individual treatment processes or operational practice in the main treatment train during recycle events. For instance, the TOC concentrations in water leaving clarifiers and filters during recycle events was compared to periods of no recycling. In addition, DBP levels in the distribution system were monitored.
- Future needs and flexibility for future upgrades and expansions.

CDW selected the following options for residual solids management as part of the overall plant upgrade (see Figure 10-2):

- Filter-to-waste capabilities would be installed and filter-to-waste streams would be recycled directly to the head of the plant. This alternative was selected based on costs, the fact that the stream would be treated again by plant processes, and that the stream's quantity and quality would have little impact on operation of the expanded WTP.
- Spent filter backwash would be discharged to Lake Erie after being equalized and clarified. Spent filter backwash would not be recycled (and would not undergo chemical treatment). This alternative was selected to reduce solids loading on treatment units and eliminate water quality issues in the finished water (taste and odor, iron, manganese, TOC, DBP and DBP precursor concentrations, *Giardia*, and *Cryptosporidium*).

Figure 10-1. Crown Water Treatment Plant – Existing

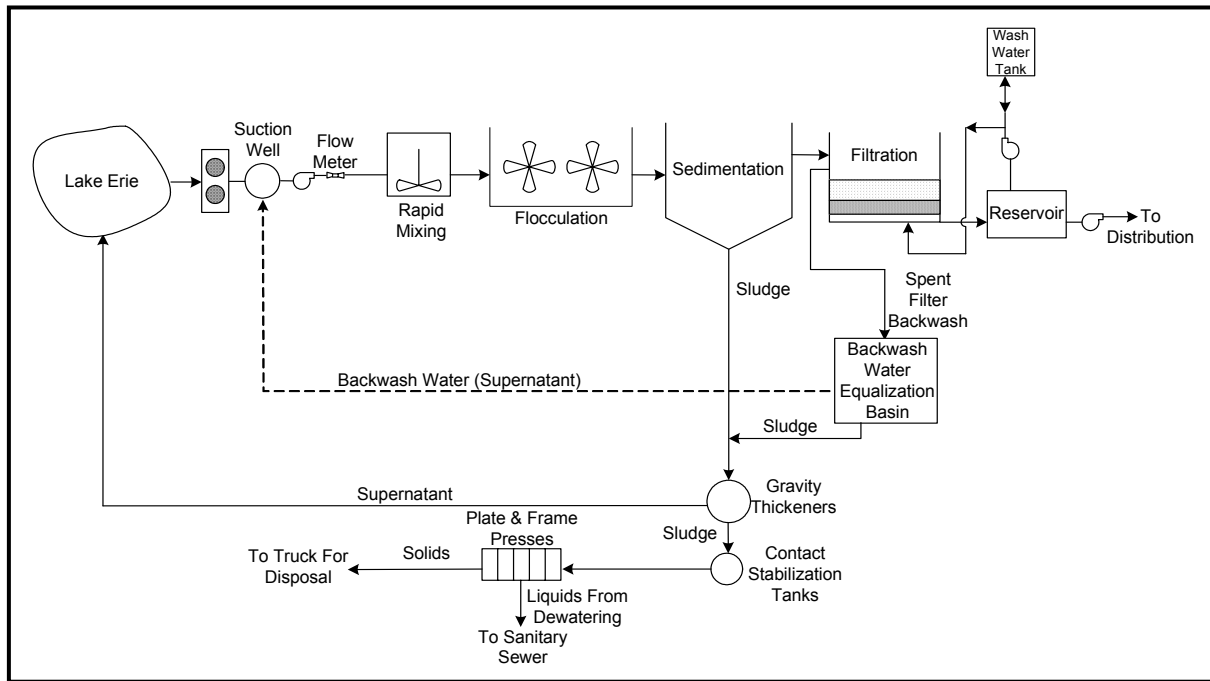
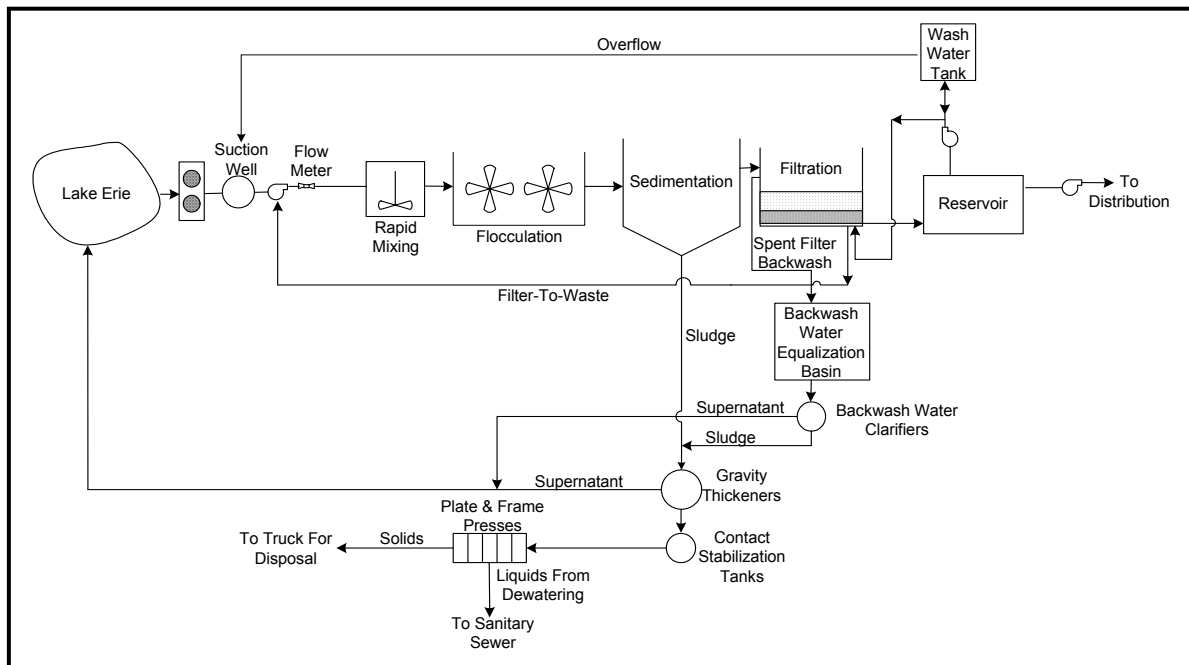


Figure 10-2. Crown Water Treatment Plant – Proposed



10.7 TREATMENT OPTIONS

Treatment options for recycle streams are similar to the treatment options used for raw water at a water treatment plant. Treatment can consist of solids removal and/or disinfection.

There are several options for solids separation from spent filter backwash water and other recycle streams: sedimentation, granular-bed filtration, and membrane filtration.

Disinfection can also be employed for treatment of recycle streams to provide inactivation of pathogens. This chapter presents general treatment capabilities, advantages, disadvantages, operational considerations, and case studies (where available) for each treatment type. Not all aspects of recycle stream treatment are discussed.

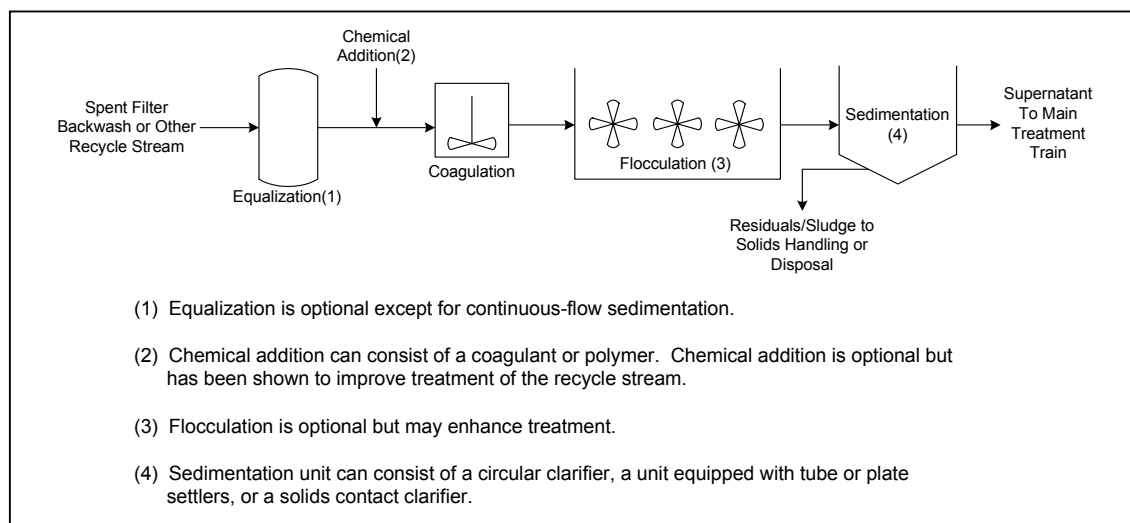
10.7.1 Sedimentation

General

Sedimentation is a process for removal of solids from liquids either by gravity or physical separation. The use of sedimentation on recycle streams has been shown to be effective in removing particles and pathogens. An example of a typical sedimentation process for recycle streams (in addition to the main treatment train) is shown in Figure 10-3.

Sedimentation can either be batch-flow or continuous-flow. Batch-flow sedimentation processes combine equalization and treatment in a single unit, and for this reason, are commonly used to treat recycle streams. Generally, batch flow systems consist of one or more basins sized to receive a large volume of flow, such as spent filter backwash water, in a short period of time.

Figure 10-3. General Sedimentation Process for Treatment of Recycle Streams (In Addition to the Main Treatment Train)



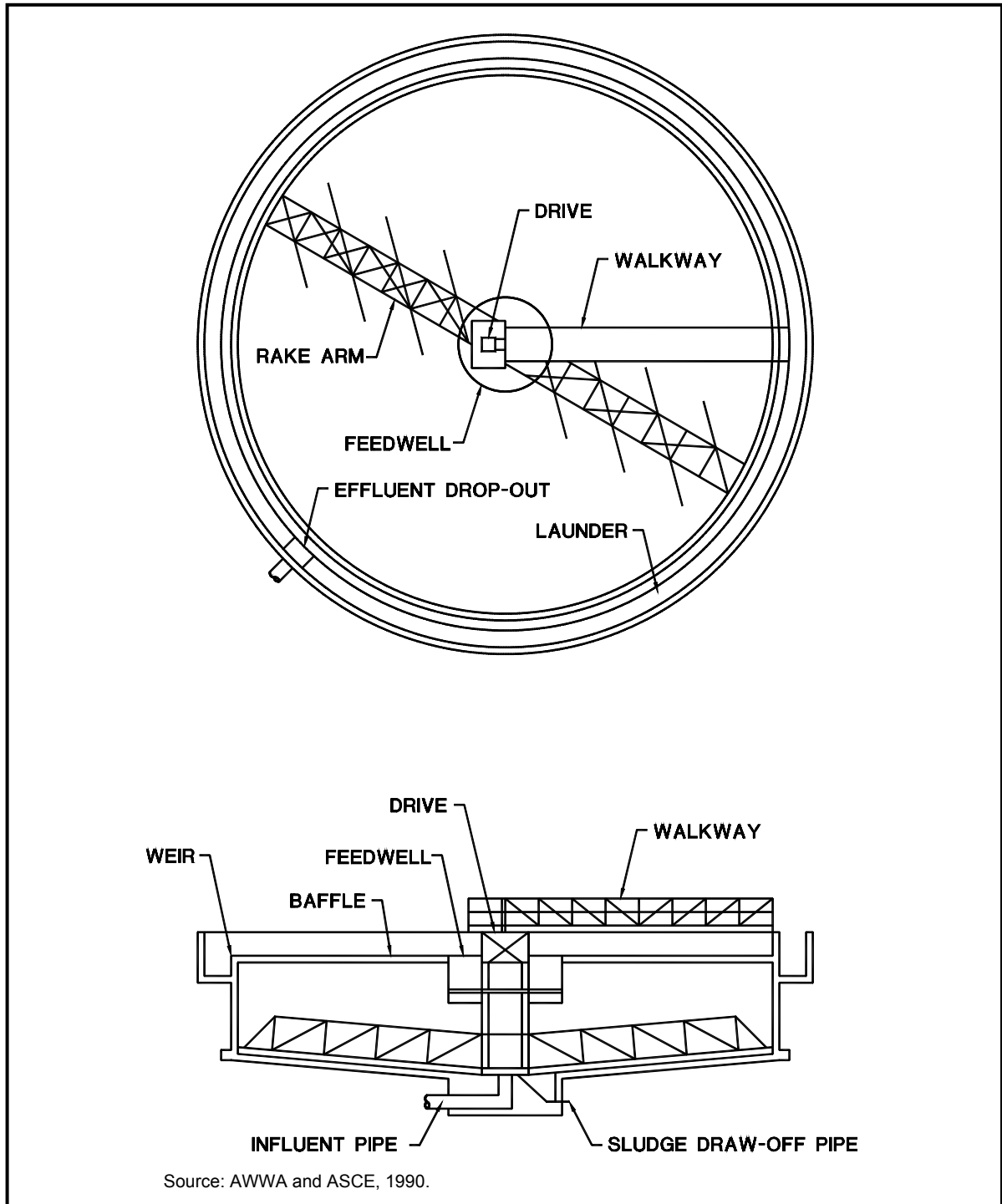
Continuous flow sedimentation basins (both circular and rectangular), similar to those used to treat the main process flow, may also be considered for recycle stream treatment. It is best to avoid operating continuous-flow systems intermittently. If generation of the recycle stream is too variable, then accommodation in the design for operational flexibility (e.g., variable flow rate from pumps) may be needed to maintain continuous flow.

A sedimentation basin typically consists of an inlet, an outlet for clarified water, and a solids collector and removal mechanism (see Figure 10-4). Clarified water may be removed by a floating decanter or from one or more fixed outlets above which all water is collected. The recycle stream can either be pumped or conveyed by gravity to the main treatment train. A pretreatment chemical may or may not be added to the flow before it enters the basin. The chemical mixing process could use a static in-line mixer or rapid-mix basin depending on the plant layout, hydraulic grade line, and capacity.

If recontamination of the recycle flow by the settled sludge is a concern, the system should employ a method to remove the solids frequently. This contamination could lead to objectionable taste, odors, and other undesirable qualities in finished water. Sludge removal should also be conducted at an appropriate frequency to avoid compromising the active storage and treatment capability in the sedimentation basin. Systems should use sedimentation basins with automatic sludge removal since manual cleaning has been shown to release significant amounts of manganese, iron, and TOC into the supernatant (Cornwell and Lee, 1993). For continuous-flow units, sludge removal should be automatic and continuous so as not to disrupt the continuous-flow process.

The remainder of this section provides information on three types of sedimentation processes: lagoons, chemical additions, and tube and plate settlers. Advantages and disadvantages of sedimentation are also provided and case studies of each type of sedimentation are included to further describe each.

Figure 10-4. Circular Radial-flow Clarifier



Lagoons

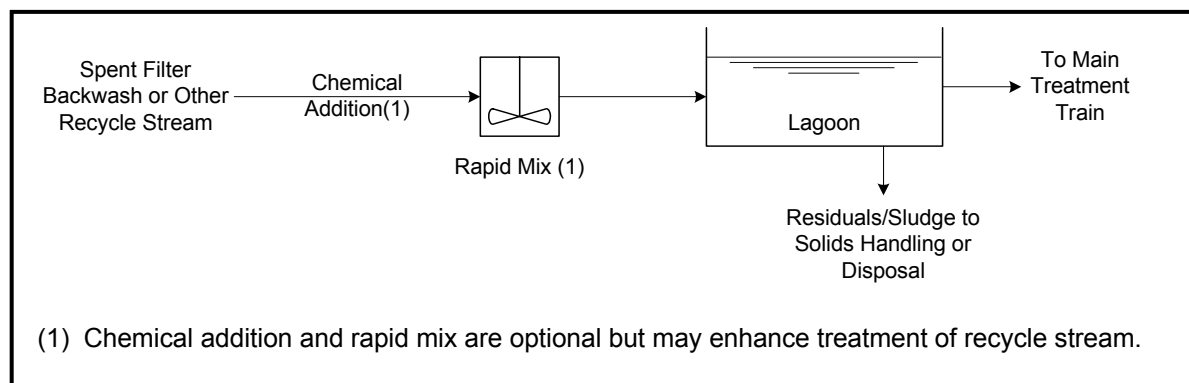
Where adequate land is available, lagooning may be an economical alternative for treating spent filter backwash water and other recycle streams. Lagoons are relatively simple earthen structures for sedimentation. They have an inlet for the recycle stream, an outlet for the settled water, access to remove the settled solids, and (typically) drain and overflow provisions. A generic schematic diagram for treating recycle streams in lagoons is presented in Figure 10-5.

Lagoons do not require a separate tank to equalize the incoming flow. However, the potential mixing effect created by a high rate of incoming flow does require special consideration. To minimize resuspension of settled solids by the influent, Kawamura (2000) recommends that the lagoon be sized to contain at least 10 backwashes. A series of three or more smaller lagoons, each holding three or four filter backwash volumes, may also be used.

All lagoons should be elongated in shape to maximize the distance between the inlet and outlet, and the inlet should be provided with an energy dissipator. The outlet should be designed to decant as well as drain the lagoon, and should act as an overflow facility. Depending on the design conditions, either a mixing device or a static in-line mixer that uses the turbulence of the influent flow may provide chemical mixing when chemical addition is used.

Additional considerations when using lagoons are the release of contaminants by the settled sludge, contamination by outside sources, or contamination to the local environment from the lagoon. Lagoons are often designed for infrequent sludge removal by equipment such as a front loader. If recontamination of the recycle flow from constituents of the stored sludge (e.g., manganese) is a concern, then the design should incorporate a method of frequent sludge removal. Also, contamination of the recycle flow by sources outside the lagoon, such as chemical delivery trucks, should be considered. The lagoon should be lined with an impervious liner to prevent contamination to the ground water. Another option is to install underdrains to collect leachate. Underdrains may be included in the lagoon design to collect and recycle the leachate, although quality of this water may be of concern. All of these considerations add costs to the installation of a lagoon.

Figure 10-5. Lagoon Process for Recycle Streams



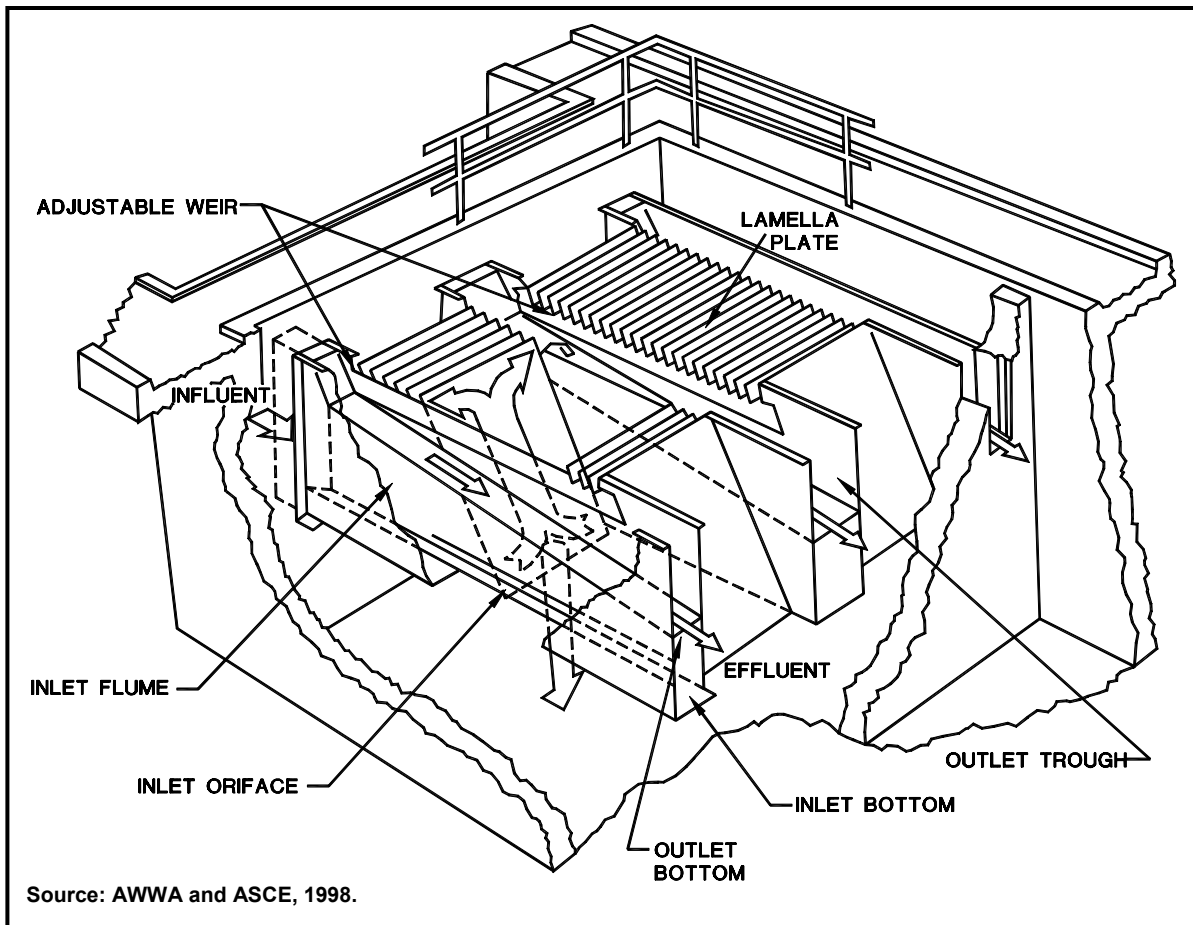
Chemical Addition

The sedimentation process can be enhanced by the addition of chemicals. The use of flocculation prior to sedimentation is recommended when the settling characteristics of the spent filter backwash water are less than desired unless conventional flocculation and sedimentation are implemented (Kawamura, 2000). A schematic diagram of this treatment train is shown in Figure 10-3. The optimal chemical type and dose should be determined based on jar tests and the particular application. The overflow rate should also be based on the desired amount of sedimentation. The case studies presented in this section demonstrate the benefits that can be realized with chemical addition.

Tube and Plate Settlers

Inclined tubes and plates can be used in sedimentation basins to allow greater loading rates than conventional sedimentation. Figure 10-6 shows a typical plate settler design. This technology relies on the theory of reduced-depth sedimentation: particles need only settle to the surface of the tube or plate for removal from the process flow. Generally a space of two inches is provided between tube walls or plates to maximize settling efficiency. The typical

Figure 10-6. Typical Plate Settler Design



angle of inclination is about 60 degrees, so that settled solids slide down to the bottom of the basin. The disadvantages of these processes are that the tubes and plates can become easily clogged in some applications, can serve as a surface for biological growth (often algae when uncovered), and can be difficult to clean. Uneven flow distribution at the inlet and inadequate spacing of the discharge flumes can create inefficiencies.

A generic process schematic diagram for tube and plate settling is shown in Figure 10-3. Flocculation may be beneficial for recycle streams, depending on the settling characteristics of the recycle stream. The type of chemical mixing used, if necessary, depends on factors such as the plant layout, hydraulic grade line, and design flow rate.

Tube and Plate Settler Case Study (Ashcroft, et al., 1997)

A full-scale plant was using both tube and plate settlers. The tube settlers were installed in an existing circular clarifier and the plate settlers were installed in a new circular basin. The spent filter backwash water was pumped to the clarifiers from an equalization basin. No separate flocculation facilities were provided.

Both clarifiers consistently achieved greater than 90% reductions in turbidity and 2- to 5- μ m particles with the addition of 0.7 mg/L anionic polymer. Treated turbidities were in the range of 2.0-3.6 NTU. Loading rates of 0.20-0.38 gpm/ft² were tested with little variation in performance. These loading rates are very low when compared to the typical rates of 2-3 gpm/ft² used in treating main process flows.

TTHMs and TTHM formation potential were also measured in the untreated and treated backwash waters. TTHMs were about 40 μ g/L in the untreated water, and were not significantly affected by treatment. Total TTHM formation potential, however, was reduced by 45% to 55%, to approximately 100 μ g/L. Little difference between the performance of the tube and plate settlers was shown.

Plate Settler Case Study (Narasimhan, 1997)

Two full-scale WTPs in metropolitan Phoenix, AZ- the Verde and Mesa plants- have plate-settling facilities that include polymer feed, rapid mix, flocculation, and plate settlers to treat recycle streams. At the Verde plant, a combination of spent filter backwash water, centrate, and gravity thickener overflow is treated; the Mesa plant treats only spent-filter backwash water. Facilities at both plants are operated continuously for six to eight hours per day.

Results from the Verde plant showed consistent treated turbidities of less than 25 NTU with the addition of 0.4 mg/L polymer and loading rates of up to 0.39 gpm/ft² (0.95 m/h). At the Mesa plant, treated turbidities were consistently below 20 NTU at loading rates of up to 0.6 gpm/ft². Polymer addition did not have much impact on turbidity removal at Mesa. Turbidities of the influents to the recycle treatment facilities at both plants ranged from below 20 NTU to about 100 NTU.

Tube Settler Case Study (Cornwell, et al., 2001)

A full-scale study on a Central Utah Water Conservancy District direct filtration plant was conducted. The plant was equipped with a sidestream plant to treat spent filter backwash prior to recycle. The sidestream was equipped with rapid mix, flocculation, and sedimentation with tube settlers. The tube settler overflow rate range investigated in the plant was 0.19 to 0.37 gpm/ft² and treatment was compared with and without polymer. Average settled turbidities without and with polymer were 2.4 NTU and 1.2 NTU, respectively. The addition of 0.1 mg/L of the appropriate polymer resulted in 50% reduction in average settled turbidities. This study also demonstrated that the turbidity levels from the sedimentation basin increased steadily as the overflow rate was increased from 0.19 to 0.37 gpm/ft² when no polymer was added. In contrast, the turbidity levels from the sedimentation basin only increased marginally as overflow rates were increased when polymer was added.

Plate Settler Case Study (Hess, et al., 1993)

Plate settlers were used to treat spent filter backwash water from a direct filtration plant. The backwash solids were of low density, were highly organic, and had poor settling characteristics. The plate settlers were operated at a maximum of 0.25 gpm/ft² with polymer addition. The treated water averaged less than 1.5 NTU and was returned to the headworks, where the raw water is typically less than 1.0 NTU.

Advantages

When properly designed and operated, the sedimentation unit can remove significant amounts of turbidity and particles, including *Cryptosporidium* and *Giardia*. If overflow rates are low enough, additional contaminants, such as disinfection byproduct precursors, may also be removed.

Disadvantages

If not properly designed and operated, solids removal capabilities will be compromised. Adequate equalization and storage should be provided to avoid this situation. Sludge removal should be conducted frequently enough to avoid compromising the active storage and treatment capability of the sedimentation basin.

Sedimentation with Polymer Addition Case Study (Moss, 2000)

The Salt Lake City Public Utilities Department (SLCPUD) examined optimization of its recycle practices. SLCPUD recycles spent filter backwash at all three of its plants. The spent filter backwash passes through clarifiers prior to its return to the plant headworks. Turbidity levels in filtered water did not exhibit significant changes during recycle; however, increased particle counts in filtered water were very noticeable during recycle events. At one plant, particle counts in the filtered water (measured as particles greater than 2 μm) went from approximately 1,800 prior to recycle to greater than 8,000 during recycle. Recycle of spent filter backwash also resulted in an increase of *Cryptosporidium* and *Giardia* in plant influent as compared to raw water. SLCPUD examined a combination of treatment strategies to reduce the impacts of recycle on its plants. Optimization consisted of increasing settling time, polymer addition, adjusting rate of return at one of the plants, and adjusting coagulant dose at one of the plants in response to streaming current monitoring data. SLCPUD conducted jar testing to determine which polymer to feed to the spent filter backwash. A high charge anionic polymer was selected for two plants and a medium charge anionic polymer was selected for the other plant. The polymer dose at all plants was 0.1 mg/L. All plants exhibited a decrease in particle counts in filtered water due to optimization of recycle practices. Also, turbidity and TOC concentrations in the recycled spent filter backwash decreased as a result of optimization.

10.7.2 Microsand-Assisted Sedimentation

Microsand-assisted settling is not a new principle. The process has been used in the water treatment industry since the 1970's and has been identified by numerous names such as ballasted floc, ballasted sand, and Actiflo®. Microsand-assisted sedimentation relies on improved settling through the addition of microsand and a coagulant chemical to improve flocculation and clarification. The microsand is separated and recycled through the system numerous times. Figure 10-7 shows the typical process of microsand-assisted sedimentation. This process may have application in facilities that need clarification and do not have the space for conventional sedimentation or that need rapid startup clarification ability for variable source water qualities.

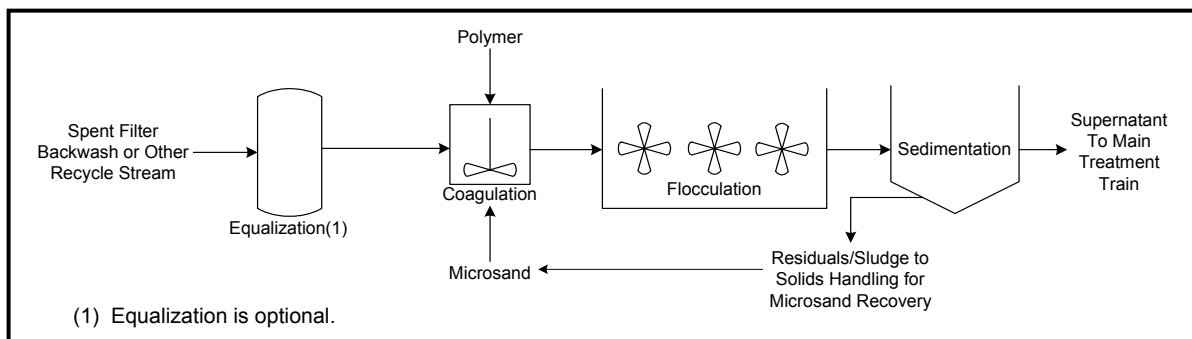
Advantages

According to Kawamura (2000) the advantages of this process are: requires a small footprint, has good performance, has a very quick process start up time, and may have reduced capital costs. As a result, systems may want to consider microsand-assisted sedimentation versus other sedimentation processes if space or money is limited.

Disadvantages

The disadvantages include heavy dependence on mechanical equipment and short processing time, dependence upon power, and may require higher dosage of coagulant.

Figure 10-7. Microsand-Assisted Sedimentation Process for Recycle Streams (In Addition to the Main Treatment Train)



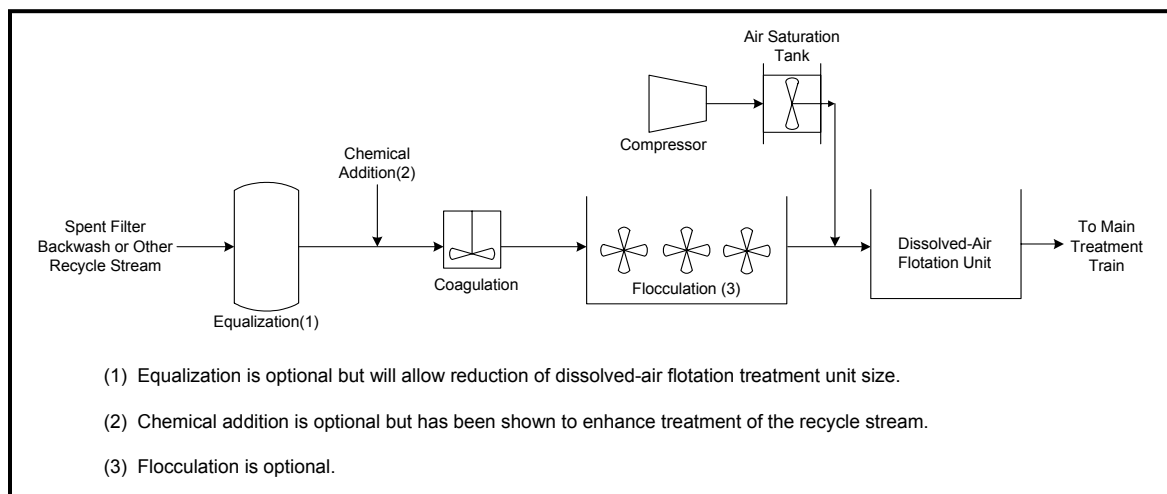
10.7.3 Dissolved-Air Flotation

Dissolved-air flotation (DAF) is most commonly used in two applications: potable water treatment as a clarification step prior to filtration, and wastewater treatment for sludge thickening. The DAF process is another form of solids separation and may be an appropriate technology for treating recycle streams.

In a typical water treatment system installation, DAF replaces sedimentation in a conventional treatment train. The upstream and downstream processes are similar; the raw

water is coagulated and flocculated, and the DAF effluent is sent to the filters. A similar process train is likely to be used for treating recycle streams, as shown in Figure 10-8, where the treated stream is recycled to the head of the plant.

Figure 10-8. Dissolved-Air Flotation Process for Recycle Streams (In Addition to the Main Treatment Train)



In the DAF process itself, a side-stream is saturated with air at high pressure and then injected into the flotation tank to mix with the incoming recycle stream. As the side-stream enters the flotation tank, the pressure drop releases the dissolved air. The air bubbles then rise, attaching to floc particles and creating a layer of sludge (also called float) at the surface of the tank. The float is removed either by a mechanical scraper or by flooding the tank over a weir. The clarified water is collected near the bottom of the tank.

DAF can be highly effective at removing low-density particles such as algae, protozoan cysts, coagulated natural organic material, and alum floc from low-turbidity, soft waters. In a bench-scale study on *Cryptosporidium* removal, DAF was shown to achieve at least 2-log removal of oocysts under most process conditions (Plummer, et al., 1995). In a pilot-scale study of DAF and lamella sedimentation, the average log removals by DAF for *Giardia* and *Cryptosporidium* were 2.4 and 2.1 respectively, compared to 1 to 1.2 and 0.91 to 1.1, respectively, for lamella sedimentation (Edzwald, et al., 2000). However, this study was conducted on a main treatment process rather than a recycle stream. These results were included in another study by Edzwald, et al., (2001). The same considerations for sludge removal, storage, and equalization apply to DAF, as discussed in Section 10.7.1.

Advantages

DAF has several advantages over sedimentation:

- *More compact:* DAF loading rates are high, so that much smaller tanks can be used than in sedimentation.

- *Shorter startup time:* The smaller tanks result in good effluent quality in less time.
- *Lower chemical dose:* In many cases DAF requires less coagulant than sedimentation.
- *Shorter flocculation time:* Flocculation times for DAF are normally one-half to one-fifth of those for sedimentation.
- *Thicker sludge:* The floated sludge from a DAF unit typically has a much higher solids concentration than does sludge from a sedimentation basin.

Disadvantages

The main disadvantage of DAF compared to sedimentation is that it requires more complex equipment, particularly the air saturation and recycle control equipment. A higher level of skill is needed to operate and maintain this equipment than is needed for equipment associated with sedimentation facilities.

As with sedimentation, the need for chemical pretreatment and flocculation prior to DAF treatment of the recycle stream is uncertain. DAF normally requires less coagulant and shorter flocculation times than does sedimentation, and particles in spent filter backwash water have already been coagulated and flocculated to some degree in the main treatment train. If DAF can provide adequate treatment without pretreatment, then DAF becomes a cost-effective option to treat recycle streams.

DAF Case Study (Cornwell, et al., 2001)

A bench-scale study was conducted using DAF with polymer addition to treat spent filter backwash. The pilot DAF plant could treat spent filter backwash at a rate between 36 and 54 gpm and had varying surface overflow rates and recycle ratio range capabilities. The spent filter backwash fed to the pilot plant had turbidity levels ranging from 30 to 300 NTU. The DAF was able to produce clarified effluent with turbidities of 1 to 2 NTU (99% or 2-log turbidity reduction) with 0.3 mg/L of polymer at surface overflow rates of 4 to 5 gpm/ft². A DAF recycle ratio of 10% was found to be adequate for effective treatment.

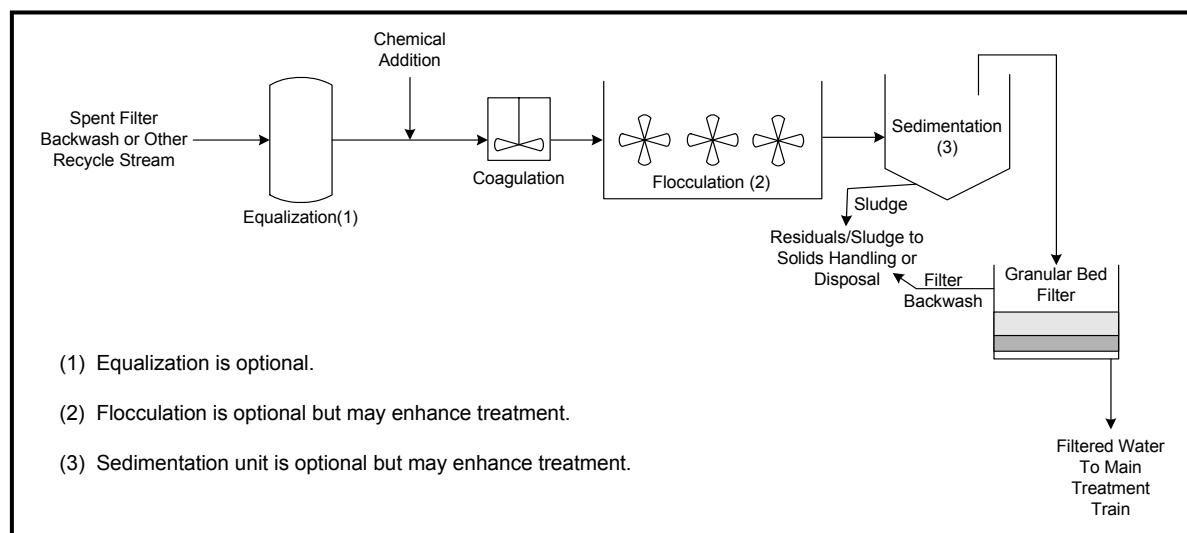
DAF Case Study (Lew and Patawaran 2000)

The Betasso Water Treatment Plant (Boulder, CO) selected DAF as the best treatment technology for spent filter backwash after assessing six alternative treatment types. The DAF process was able to achieve turbidity levels of 1 NTU on a consistent basis without extensive chemical manipulation. With consistent dosage of polymer, DAF was able to adsorb significant turbidity spikes and varying loading rates without compromising effluent water quality.

10.7.4 Granular Bed Filtration

Granular bed filtration may be an effective treatment method for spent filter backwash water and other recycle streams. Pretreatment by chemical addition with or without flocculation prior to the filter should be practiced. The high solids content of some backwash waters may result in unacceptable short filter runs, suggesting that clarification is needed prior to filtration, but higher-quality spent filter backwash waters may be quite amenable to filtration without sedimentation. A process schematic diagram for granular bed filtration, with pretreatment by chemical mixing, flocculation, and sedimentation, is shown in Figure 10-9. Pumping facilities may be required to convey the treated recycle stream depending on site-specific conditions.

Figure 10-9. Granular Bed Filtration Process for Recycle Streams (In Addition to the Main Treatment Train)



Advantages

The expected advantage of granular bed filtration over sedimentation and DAF is that it has a much higher rate of particle removal. Depending on water quality, pretreatment, filter media, and loading rates (among other factors), filtration of recycle streams may remove particles at or above the level achieved by the main treatment train.

Disadvantages

The disadvantages of filtration, compared to either sedimentation or DAF alone, are its high cost, process complexity, and greater volume of waste. Waste would be generated through the backwash of the recycle stream filter.

Granular Filtration Case Study (MacPhee, et al., 2000)

Several treatment scenarios were examined for spent filter backwash. The treatment scenarios consisted of sedimentation with polymer and DAF with polymer followed by granular media filtration. This treatment scenario provided 2.2 to 3.0 log reduction of turbidity and 2.4 to 4.4 particle log reduction of the spent filter backwash.

10.7.5 Membrane Filtration

A membrane treatment process, such as microfiltration (MF) or ultrafiltration (UF), is capable of very high levels of particle removal. MF has been used for a variety of industrial applications and, in recent years, has been used for particle removal in potable water treatment. Limited information is available on MF treatment of spent filter backwash water and other recycle streams, but research continues on this technology.

Microfilters provide an absolute barrier to particulates by straining them from the flow stream at the membrane surface. Nominal pore sizes for microfilters fall in the range of 0.05 to 5.0 μm . Microfilters with smaller pore sizes ($\leq 0.2 \mu\text{m}$) can remove virtually all bacteria and protozoa, including *Cryptosporidium* and *Giardia* (Jacangelo and Buckley, 1996). The removal of viruses is more highly dependent upon the specific virus, membrane, and water quality (Jacangelo and Buckley, 1996), though the removal of viruses may be less of a concern because of their high susceptibility to inactivation by most disinfectants.

Depending on the membrane and water quality, MF membranes can remove some natural organic matter (NOM), DBP, and TOC. The removal of NOM by MF membranes can also be improved by coagulation. NOM found in spent filter backwash water, having previously been coagulated to an extent, may be removed to a good degree by MF. Some membranes are susceptible to fouling by chemicals and chemical use should be carefully evaluated for each membrane type. A simple process schematic diagram for membrane filtration of recycle streams is shown in Figure 10-10. As noted above, microfiltration may require chemical pretreatment, depending on the recycle stream characteristics and treatment goals. Also, facilities for membrane cleaning would be required.

Advantages

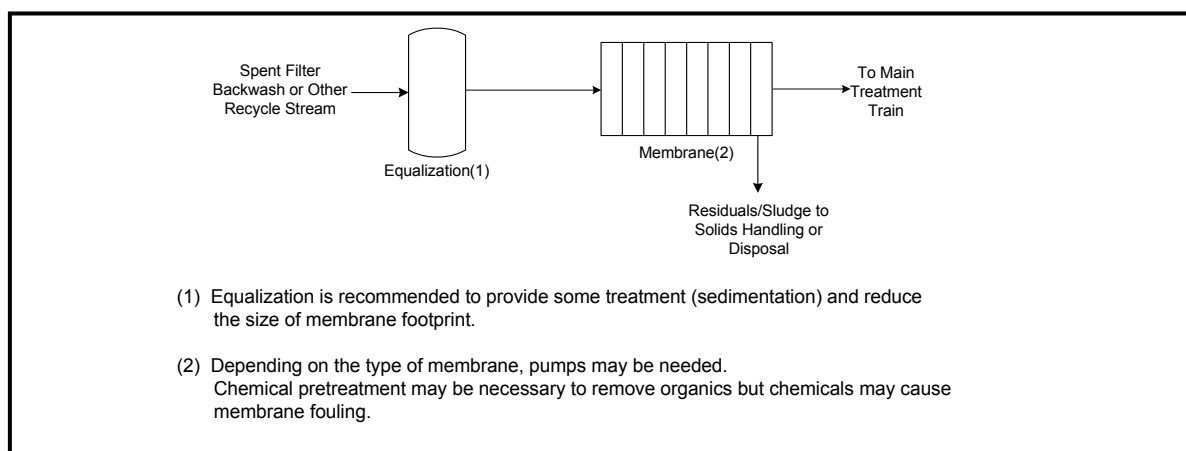
One advantage of MF for recycle stream treatment is that it can normally treat wide variations in influent water quality with little or no adjustment to the process. Another advantage is that MF systems are compact and available as prefabricated, modular units that can easily be expanded. Also, hydraulic head is not typically “broken” in membrane systems, so a unit may be located at any elevation and require only one pumping facility.

Disadvantages

The primary disadvantage of a MF system, when compared to sedimentation or DAF, is the greater complexity of its equipment. Another disadvantage is that membranes are subject to fouling from bacteria, chlorine residual, coagulants, and polymers. The contaminants contained in the recycle stream may be substantial enough to foul the membranes.

Therefore, extensive pilot testing should be conducted on the membrane for each type of recycle stream to evaluate potential fouling.

Figure 10-10. Membrane Treatment Process for Recycle Streams (In Addition to the Main Treatment Train)



Microfiltration (MF) Case Study (Thompson, et al., 1995)

Thompson, et al. (1995) reported on pilot-scale testing of MF for recycle stream treatment. A membrane with a nominal pore size of 0.2 μm was used in all tests. In these tests, spent filter backwash water with turbidities around 500 NTU were reduced to less than 5 NTU. At another plant, MF was used to treat a combination of spent filter backwash water and clarifier sludge blowdown from a conventional treatment train. The recycle stream was spiked with *Giardia* cysts and *Cryptosporidium* oocysts before MF treatment. No cysts, oocysts, or coliforms were detected in the MF-treated water, and turbidities were consistently 0.1 NTU. High levels of particle removal were also shown using particle counters.

Ultrafiltration (UF) Case Study (Shealy, et al., 2000)

Several recycle water treatment alternatives were evaluated at the Orangeburg, SC plant. After narrowing the alternatives, the system chose to pilot test micro/ultrafiltration membrane treatment. The main objectives of the study were: contaminant removal and membrane flux rate, feasibility of full-scale application, and potential capital and operating costs. After months of research and evaluation, membrane treatment with immersed UF technology was selected for full-scale implementation. The conclusion was that, coupled with equalization basins, UF membranes produced excellent treated water quality. The permeate from the membrane unit is proposed to discharge to the head of the plant.

Microfiltration Case Study (Taylor, et al., 2000)

Bench-scale testing of MF to treat spent filter backwash water was conducted at the University of Central Florida. Backwash waters from nine water treatment plants across the United States were used in the testing. The treatment unit used in the study was an MF unit fitted with a single microfilter membrane (surface area of 1 m²). One liter of filtrate water was collected approximately five minutes into filtration for chemical water quality analysis. True color, UV-254, total suspended solids (TSS), turbidity, and particle counts were the parameters measured. The changes in UV-254 and true color were not significant and therefore not considered a consequence of treatment. However, turbidity and TSS were significantly reduced by MF. Water turbidity was reduced from 31-168 NTU to 0.02-0.16 NTU. TSS was reduced from 66-206 mg/L to 1-3 mg/L (the limit of accurate TSS measurements).

A cost estimate for applying membrane filtration (MF and UF) to the treatment and recovery of spent filter backwash water was included in the study. Estimates for flows of 0.01, 0.1, 1.0, and 10.0 MGD were developed. The membrane system cost included feed water pumps, backwash and recycle pumps, air compressor, membrane modules and racks, piping and valves, instrumentation and controls, and the membrane cleaning system. The researchers found that unit capital and O & M costs decreased significantly by capacity and varied significantly by source. Unit capital costs varied from \$10.35/gpd at 0.01 MGD to \$0.38/gpd at 10 MGD. Unit O & M costs varied from \$2.68/Kgal at 0.01 MGD to \$0.16/Kgal at 10 MGD.

10.7.6 Disinfection

Disinfection can be a barrier to the recycling of pathogens from recycle streams. Results from the AWWA utility survey show that a small percentage of plants that do recycle practice disinfection of those streams (Pedersen and Calhoun, 1995). The most common disinfectant used by far was chlorine. The California Department of Health Services recommends that disinfection be considered for recycle streams (CDHS, 1995).

The main issues to be addressed when considering disinfection of recycle streams are:

- The level of inactivation to be provided for specific organisms;
- Whether disinfection is to be used alone or with a solids removal process; and,
- The potential impacts of recycle stream disinfection on finished water quality, particularly the formation of DBPs.

If disinfection is to be applied to recycle streams, the required level of disinfection and inactivation must be known in order to size the facility. No guidelines have yet been issued in regard to pathogen inactivation or removal from recycle streams. Under the current SWTR, IESWTR, and LT1ESWTR, the amount of disinfection provided to water supplies is determined by the inactivation and removal of *Giardia* and viruses. Credit is given for the removal of pathogens by properly operated treatment processes, such as filtration, and credit for inactivation is given based on the disinfectant concentration and contact time provided.

For the treatment of recycle streams, the removal and/or inactivation of *Cryptosporidium*, *Giardia*, and viruses is a concern.

Disinfection options and inactivation levels are well known for *Giardia* and viruses. Ozone and UV both appear to provide inactivation of *Cryptosporidium*.

Disinfection Case Study (Cornwell, et al., 2001)

The oxidant demand of both potassium permanganate and chlorine dioxide was examined for spent filter backwash samples from five participating water utilities. Overall, the potassium permanganate demands were approximately 5.5 times higher for spent filter backwash with particles than in samples without particles. Potassium permanganate disinfection at 2,400 mg-min/L (CT value) with and without particles resulted in *Cryptosporidium* inactivations of 0.21 and 0.27-log, respectively. The presence of particles in spent filter backwash increased the chlorine dioxide demand by a factor of four when compared to samples without particles. Chlorine dioxide dosed at 115 mg-min/L (CT value) produced 2.7 and 2.1-log inactivation of *Cryptosporidium* for spent filter backwash with and without particles, respectively. Ultraviolet (UV) treatment was also examined for its effectiveness on *Cryptosporidium* in clarified spent filter backwash with turbidities between 10 and 14 NTU. UV doses as low as 3 milliJoules per square centimeter used in collimated beam experiments resulted in *Cryptosporidium* inactivations greater than 4 logs.

Advantages

Pathogens are contaminants of concern in recycle streams. Depending on the type and amount of disinfectant used, *Cryptosporidium*, *Giardia*, and/or viruses can be inactivated. More advantages may be realized through disinfection of recycle streams as more studies are conducted on this practice.

Disadvantages

Recycle stream disinfection should be examined for its potential effects on the main treatment train and finished water quality. Untreated recycle streams can have significant concentrations of TTHM precursors and TOC (Cornwell and Lee, 1993). If the recycle stream is treated with chlorine, then recycling may cause problems for the treatment plant in meeting DBP limits. The potential formation of DBPs through disinfection should be considered. Chapter 7 provides more information on DBP and DBP precursor levels in recycle streams.

10.8 COMPARISON OF TREATMENT OPTIONS

Seven different treatment scenarios for spent filter backwash at seven different treatment plants were examined (Cornwell, et al., 2001). Table 10-2 presents the turbidity and particle log reductions obtained from each treatment type. The results in Table 10-2 are based on both pilot-scale and full-scale plants. Sedimentation with polymer, DAF with polymer, granular media filtration with pretreatment, and membrane microfiltration appear to provide the best turbidity and particle reduction. Table 10-2 also presents relative costs of each treatment type. Membrane microfiltration was the most expensive treatment option based on this study. However, costs will vary from plant to plant depending on site-specific conditions, recycle stream characteristics, and desired level of treatment.

Table 10-2. Spent Filter Backwash Turbidity and Particle Log Reductions by Treatment Type

Treatment Process¹	Turbidity Log Reduction	Particle Log Reduction	Relative Cost Ranking²
Sedimentation without polymer³	0.1 to 0.8	0.2 to 0.9	1
Dissolved Air Flotation (DAF) without polymer	0.7 to 1.4	0.8 to 1.7	-----
Sedimentation with polymer³	1.4 to 2.3	1.9 to 3.3	2
DAF with polymer	1.7 to 2.7	1.9 to 3.5	3
Coagulation/ Flocculation followed by Sedimentation³	0.5 to 1.7	0.4 to 2.1	-----
Granular Media Filtration with pretreatment⁴	2.2 to 3.0	2.4 to 4.4	4
Membrane Microfiltration	2.6 to 3.9	1.6 to 3.5	5

¹Treatment processes were conducted at seven different sites and consisted of both pilot-scale and full-scale studies.

²Relative costs are presented with 1 being the lowest-cost treatment process and 5 being the highest-cost treatment process. Costs were not available for DAF without polymer and coagulation/flocculation followed by sedimentation.

³Sedimentation consisted of either tube settlers or plate settlers.

⁴Pretreatment consisted of either sedimentation with polymer or DAF with polymer.

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APPENDIX A.

GLOSSARY

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Glossary of Terms Used in this Manual:

air scour- Introduction of air to the full filter area from orifices located under the filter medium, in order to improve the effectiveness of the backwashing operation and to improve cleaning of media during filter backwash.

backwash- The process of reversing the flow of water back through the filter media to remove the entrapped solids.

batch-flow sedimentation- One or more basins sized to receive a volume of flow, such as spent filter backwash water, in a specific period of time. The flow is detained for a specific period of time to allow sedimentation, and then the tank is emptied.

best available technology (BAT)- As defined in 40 CFR 141.2, the best technology, treatment techniques, or other means which the [U.S. EPA] Administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking cost into consideration).

breakthrough- A condition whereby filter effluent water quality deteriorates (as measured by an increase in turbidity, particle count, or other contaminant). This may occur due to excessive filter run time or hydraulic surge.

centrate- Water separated from the solids by a centrifuge.

clarifier- A large circular or rectangular tank or basin in which water is held for a period of time, during which the heavier suspended solids settle to the bottom by gravity. Clarifiers are also called settling basins and sedimentation basins.

coagulant- A chemical added to water that has suspended and colloidal solids to destabilize particles, allowing subsequent floc formation and removal by sedimentation, filtration, or both.

coagulation- As defined in 40 CFR 141.2, a process using coagulant chemicals and mixing by which colloidal and suspended materials are destabilized and agglomerated into flocs.

contact clarification- A water treatment process in which flocculation and clarification (and often the rapid mix) are combined in one unit, such as an upflow solids contactor or contact clarifier.

continuous flow sedimentation- A process by which flow is received on a continuous basis at its normal flow rate and solids are allowed to settle.

conventional filtration treatment- As defined in 40 CFR 141.2, a series of processes including coagulation, flocculation, sedimentation, and filtration resulting in substantial particulate removal.

Cryptosporidium- A disease-causing protozoan widely found in surface water sources. *Cryptosporidium* is spread as a dormant oocyst from human and animal feces to surface water. In its dormant stage, *Cryptosporidium* is housed in a very small, hard-shelled oocyst form that is resistant to chlorine and chloramine disinfectants. When water containing these cysts is ingested, the protozoan causes a severe gastrointestinal disease called cryptosporidiosis.

decant- To draw off the liquid from a basin or tank without stirring up the sediment in the bottom.

dewatering processes- Mechanical and non-mechanical methods used to remove excess liquids from residual solids in order to concentrate the solids. These methods include belt presses, centrifuges, filter presses, vacuum presses, lagoons, and monofill.

diatomaceous earth filtration- As defined in 40 CFR 141.2, a process resulting in substantial particulate removal in which (1) a precoat cake of diatomaceous earth filter media is deposited on a support membrane (septum), and (2) while the water is filtered by passing through the cake on the septum, additional filter media known as body feed is continuously added to the feed water to maintain the permeability of the filter cake.

direct filtration- As defined in 40 CFR 141.2, a series of processes including coagulation and filtration but excluding sedimentation resulting in substantial particulate removal.

direct recycle- The return of recycle flow within the treatment process without first passing the recycle flow through treatment or equalization.

disinfectant- As defined in 40 CFR 141.2, any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms.

disinfection- As defined in 40 CFR 141.2, a process which inactivates pathogenic organisms in water by chemical oxidants or equivalent agents.

disinfection by-products (DBPs)- Organic compounds formed by the reaction of the disinfectant, natural organic matter, and the bromide ion during water disinfection process. Regulated DBPs include TTHMs, HAA5s, bromate, and chlorite.

dissolved-air flotation- A method of solids separation, whereby a side stream is saturated with air at high pressure and then injected into the flotation tank to mix with the incoming water stream. As the air bubbles rise to the surface they attach to floc particles and create a sludge layer at the surface of the tank, which is then removed for disposal.

equalization- A method used to control the flow of water or residual stream by providing storage and detention time between the point of origin and the return location of the water or

residual stream. The water or residual stream is then removed from the storage unit at a controlled, uniform rate.

filter-to-waste- The practice of discarding filter effluent that is produced during the “filter ripening” period immediately after backwash due to its impaired quality.

filtrate- The water separated from the solids by a belt filter press or the liquid that has passed through a filter.

filtration- As defined in 40 CFR 141.2, a process for removing particulate matter from water by passage through porous media.

floc- Collections of smaller particles that have come together (agglomerated) into larger, more settleable particles as a result of the coagulation-flocculation process.

flocculation- As defined in 40 CFR 141.2, a process to enhance agglomeration or collection of smaller floc particles into larger, more easily settleable particles through gentle stirring by hydraulic or mechanical means.

Giardia lamblia- Flagellated protozoan which is shed during its cyst-stage with the feces of man and animals. When water containing these cysts is ingested, the protozoan causes a severe gastrointestinal disease called giardiasis.

ground water under the direct influence of surface water (GWUDI)- As defined in 40 CFR 141.2, any water beneath the surface of the ground with significant occurrence of insects or other macroorganisms, algae, or large-diameter pathogens such as *Giardia lamblia* or *Cryptosporidium*, or significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions. Direct influence must be determined for individual sources in accordance with criteria established by the State. The State determination of direct influence must be based on site-specific measurements of water quality and/or documentation of well construction characteristics and geology with field evaluation.

haloacetic acids (HAA5)- As defined in 40 CFR 141.2, the sum of the concentrations in milligrams per liter of the haloacetic acid compounds (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid), rounded to two significant figures after addition.

hydraulic surge- A sudden increase in flow to the plant or treatment process.

influent water- Raw water plus recycle streams.

ion-exchange regenerant- A chemical solution used to restore an exhausted bed of ion exchange resins to the fully ionic (regenerated) form necessary for the desired ion exchange to again take place effectively.

jar test- A laboratory procedure that simulates a water treatment plant's coagulation, rapid mix, flocculation, and sedimentation processes. Differing chemical doses, energy of rapid mix, energy of slow mix, and settling time can be examined. The purpose of this procedure is to estimate the minimum or optimal coagulant dose required to achieve certain water quality goals. Samples of water to be treated are commonly placed in six jars. Various amounts of a single chemical are added to each jar while holding all other chemicals at a consistent dose, and observing the formation of floc, settling of solids, and resulting water quality.

lagooning- The placement of solid or liquid material in a basin, reservoir, or artificial impoundment for purposes of storage, treatment, or disposal.

leachate- The underflow from a dewatering unit such as a sludge-drying bed or monofill.

liquids from dewatering processes- A stream containing liquids generated from a unit used to concentrate solids for disposal.

membrane concentrate- The reject stream generated when the source water is passed through a membrane for treatment.

membrane filtration- A filtration process (e.g., reverse osmosis, nanofiltration, ultrafiltration, and microfiltration) using tubular or spiral-wound elements that exhibits the ability to mechanically separate water from other ions and solids by creating a pressure differential and flow across a membrane with an absolute pore size <1 micron.

micron- A unit of length equal to one micrometer (μm). One millionth of a meter or one thousandth of a millimeter. One micron equals 0.00004 of an inch.

microsand- A small-grain sand used to improve settling.

minor streams- Waste streams that result due to spills, laboratory analyses, washdown of plant facilities, leaks, and other similar streams that are small in volume.

monofill- An ultimate disposal technique for water treatment plant sludge in which the sludge is applied to a landfill for sludge only.

operating capacity- The maximum finished water production rate approved by the State drinking water program.

pH- pH is an expression of the intensity of the basic or acid condition of a solution. Mathematically, pH is the negative logarithm (base 10) of the hydrogen ion concentration, $[\text{H}^+]$. $[\text{pH} = \log (1/\text{H}^+)]$. The pH may range from 0 to 14, where 0 is most acidic, 14 most basic, and 7 neutral. Natural waters usually have a pH between 6.5 and 8.5.

pilot plant- A small-scale water treatment plant set up on a raw water source to determine the feasibility and impacts of a treatment scheme for a given water supply. Pilot plants are

used to test alternative technologies and experiment with chemical dosages for new water treatment plants or upgrades to existing plants.

polymer- A synthetic organic compound with high molecular weight and composed of repeating chemical units (monomers). Polymers may be polyelectrolytes (such as water-soluble flocculants), water-insoluble ion exchange resins, or insoluble uncharged materials (such as those used for plastic or plastic-lined pipe).

pressate- The water separated from the solids by a filter press.

presedimentation- A water treatment process in which solid particles are settled out of the water in a clarifier or sedimentation basin prior to entering the treatment plant.

raw water- Source water prior to any treatment or addition of chemicals.

recycle- The act of returning a residual stream to a plant's primary treatment process.

recycle stream- Any water, solid, or semi-solid generated by a plant's treatment processes, operational processes, and residual treatment processes that is returned to the plant's primary treatment process.

recycle notification- Information on recycling practices that must be provided to the State by conventional and direct filtration water treatment plants that recycle spent filter backwash, thickener supernatant, or liquids from dewatering processes, as required in 40 CFR 141.76 (b).

schmutzdecke- The surface dirt cake of accumulated particulates, including a variety of living and non-living micro- and macroorganisms, on top of a slow sand filter, that assists in turbidity removal.

sedimentation- As defined in 40 CFR 141.2, a process for removal of solids before filtration by gravity or separation. (Note: The Federal definition refers to the sedimentation process used in the main treatment train, but sedimentation can also be used for recycle streams.)

slow sand filtration- As defined in 40 CFR 141.2, a process involving passage of raw water through a bed of sand at low velocity (generally less than 0.4 m/h) resulting in substantial particulate removal by physical and biological mechanisms.

sludge thickener- A tank or other piece of equipment designed to concentrate water treatment sludges.

spent filter backwash water- A stream containing particles that are dislodged from filter media when water is forced back through a filter (backwashed) to clean the filter.

State- As defined in 40 CFR 141.2, the agency of the State or Tribal government which has jurisdiction over public water systems. During any period when a State or Tribal government does not have primary enforcement responsibility pursuant to Section 1413 of the Safe Drinking Water Act, the term “State” means the Regional Administrator, U.S. Environmental Protection Agency.

streaming current- A current gradient generated when a solution or suspension containing electrolytes, polyelectrolytes, or charged particles passes through a capillary space, as influenced by adsorption and electrical double layers. This phenomenon is used in monitoring and controlling coagulation and flocculation processes.

subpart H systems- As defined in 40 CFR 141.2, public water systems using surface water or ground water under the direct influence of surface water as a source that are subject to the requirements of subpart H of the Code of Federal Regulations.

suspended solids- Solid organic and inorganic particles that are held in suspension by the action of flowing water and are not dissolved.

thickener supernatant- A stream containing the decant from a sedimentation basin, clarifier, or other unit that is used to treat water, solids, or semi-solids from the primary treatment processes. The clarified water that exits the units after particles have been allowed to settle out is thickener supernatant.

total organic carbon (TOC)- As defined in 40 CFR 141.2, total organic carbon in mg/L measured using heat, oxygen, ultraviolet irradiation, chemical oxidants, or combinations of these oxidants that convert organic carbon to carbon dioxide, rounded to two significant figures.

total trihalomethane precursors- Organic materials in the raw water that promote the formation of trihalomethanes.

total trihalomethanes (TTHM)- As defined in 40 CFR 141.2, the sum of the concentration in milligrams per liter of the trihalomethane compounds (trichloromethane [chloroform], dibromochloromethane, bromodichloromethane and tribromomethane [bromoform]), rounded to two significant figures.

total trihalomethanes formation potential (TTHMFP)- A measure of the ability of a water to create trihalomethanes.

trihalomethane (THM)- As defined in 40 CFR 141.2, one of the family of organic compounds, named as derivatives of methane, wherein three of the four hydrogen atoms in methane are each substituted by a halogen atom in the molecular structure.

tube settlers- Bundles of small-bore (2 to 3 inches or 50 to 75 mm) tubes installed on an incline as an aid to sedimentation. As water rises in the tubes, settling solids fall to the tube surface. As the sludge (from the settled solids) in the tube gains weight, it moves down the

tubes and settles to the bottom of the basin for removal by conventional sludge collection means. Tube settlers are sometimes installed in sedimentation basins and clarifiers to improve settling of particles.

turbidimeter- A device that measures the amount of light scattered by suspended particles in a liquid under specified conditions.

turbidity- The cloudy appearance of water caused by the presence of suspended and colloidal matter which cause the scattering and adsorption of light. In the waterworks field, a turbidity measurement is used to indicate the clarity of water. Technically, turbidity is an optical property of the water based on the amount of light reflected by suspended particles. Turbidity cannot be directly equated to suspended solids because white particles will reflect more light than dark-colored particles and many small particles will reflect more light than an equivalent large particle.

zeta potential- The electric potential arising due to the difference in the electrical charge between the dense layer of ions surrounding a particle and the net charge of the bulk of the suspended fluid surrounding the particle. The zeta potential, also known as the electrokinetic potential, is usually measured in millivolts and provides a means of assessing particle destabilization or charge neutralization in coagulation and flocculation procedures.

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APPENDIX B.

WORKSHEETS

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The following pages contain worksheets with guidelines that can be used to collect recycle information and, if necessary, report it to the State/Primacy Agency. The worksheets provided are:

- Recycle Notification Form
- Recordkeeping Form

**FILTER BACKWASH RECYCLING RULE
RECYCLE NOTIFICATION FORM**

SYSTEM NAME _____

PWSID _____ DATE _____

Check with your State or Primacy Agency to make sure this form is acceptable.

Does your system use conventional or direct filtration? _____

Does your system recycle spent filter backwash water, thickener supernatant, or liquids from dewatering processes? _____

If you answered yes to both questions, please report the following:

1. What is the typical recycle flow (in gpm)? _____

2. What was the highest observed plant flow for the system in the previous year (in gpm)?

3. What is the design flow for the treatment plant (in gpm)? _____

4. Has the State determined a maximum operating capacity for the plant? If so, what is it?

5. Please include a plant schematic that shows:

- the origin of **all** recycle flows (spent filter backwash, thickener supernatant, liquids from dewatering processes, and any other);
- the location where **all** recycle flows re-enter the treatment plant process; and,
- the hydraulic conveyance used to transport **all** recycle flows.

Comments: _____

6. Are you requesting an alternate recycle location? _____ Yes _____ No

An alternate recycle location is one that does not incorporate all treatment processes of a conventional filtration plant (coagulation, flocculation, sedimentation, and filtration) or direct filtration plant (coagulation, flocculation, and filtration). The State or Primacy Agency must approve the recycle location by June 8, 2004. Please contact your State or Primacy Agency on what additional information may be needed.

Comments: _____

FILTER BACKWASH RECYCLING RULE RECORDKEEPING FORM

SYSTEM NAME _____

PWSID _____ Operating Period¹ _____

Check with your State or Primacy Agency to make sure this form is acceptable.

Type of Recycle Stream	Frequency at which flow is returned ²
Spent Filter Backwash	
Thickener Supernatant	
Liquids from Dewatering Process	
Other	
Other	

Filter Information	Filter Number ³			
	<i>Example Filters 1-6</i>			
Average Duration of Backwash (in minutes)	20			
Maximum Duration of Backwash (in minutes)	22			
Average Backwash Flow ⁴ (in gpm)	2,000 gpm			
Maximum Backwash Flow ⁴ (in gpm)	2,000 gpm			
Run Length Time of Filter ⁵ (include units)	36 hrs			
Criteria for Terminating Filter Run ⁶	<i>Taken off-line when filter ef- fluent turbidity =0.2 NTU</i>			

Is treatment or equalization provided for recycle flows? _____ Yes _____ No

If yes, complete the following table.

Type of Treatment Provided	<i>Example Spent filter backwash holding tank</i>	
Physical Dimensions of Unit	<i>100' x 100' x 10' deep</i>	
Typical Hydraulic Loading Rate	<i>20 gpm/ft²</i>	
Maximum Hydraulic Loading Rate	<i>20 gpm/ft²</i>	
Type of Chemical Used	<i>Polymer</i>	
Average Dose of Chemical (mg/L)	<i>0.2 mg/L</i>	
Frequency of Chemical Addition	<i>During backwash events- 4 times per day</i>	
Frequency of Solids Removal	<i>Once per month</i>	

See instructions on back.

Instructions

1. Note the operating period for the information provided. Check with your State or Primacy Agency for required operating period.
2. The frequency at which the recycle stream is returned can be described as continuous, once a day, or as another frequency.
3. Fill out all information for each of your filters. If some or all filters are operated the same, note the appropriate filter numbers.
4. The backwash flow is obtained by multiplying filter surface area (in ft²) by backwash rate (gpm/ft²). Use the average backwash rate to get the average flow and the maximum backwash rate to get the maximum flow. If the flow is varied throughout the backwash process, then the average can be computed on a time-weighted basis as follows:

$$\frac{(\text{Backwash Rate 1 X Duration 1}) + (\text{Backwash Rate 2 X Duration 2}) + \dots}{\text{Duration 1} + \text{Duration 2} + \dots}$$

5. The filter run length time is the sum of the time that the filter is producing water between backwashes.
6. Describe how run length time is determined. For example, is the run length based on head loss across the filter, turbidity levels of filter effluent, a predetermined amount of time, or another method?

Appendix C.
Reporting Example for 3.0
MGD Plant

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A 3.0 MGD plant consists of eight filters and the raw water flow is metered at the plant inlet (see plant schematic in Figure C-1). The flowmeter records total daily flow in million gallons and instantaneous flows in gallons per minute. The system recycles spent filter backwash. The recycled flow is not equalized or treated and is piped directly to the plant headworks. In order to meet daily demands, all eight filters are typically on-line between 7:00 a.m. and 6:00 p.m. The filters are loaded at 2.6 gpm/ft². The design flow for the plant is 2,080 gpm and the State-approved operating capacity is 3.0 MGD (or 2,080 gpm).

The plant is typically operated with one set of four filters being backwashed during late night and early morning hours (between 11:00 p.m. and 5:00 a.m.) of one day and the other set of four filters being backwashed the next day between 11:00 p.m. and 5:00 a.m. Each filter is typically backwashed separately. Recycle flows are not metered but the operator knows the backwash rate (15 gpm/ft²), filter surface area (100 ft² each), and length of backwash (15 minutes).

1. Determine Highest Observed Plant Flow

In order to obtain the highest observed plant flow, the system examined when the highest observed raw water flow occurred and added in any recycle flow and examined when the highest observed recycle flow occurred and added in raw water flow. Then, the two values were compared and the overall highest plant flow was reported to the State.

A. Highest Plant Flow Based on Peak Raw Water Flow

The operator reviewed raw water flow meter records and determined that the peak raw water flow occurred at 5:30 p.m. with a flow of 2,080 gpm. The highest observed raw water flow occurred at a time of day when recycle flows are not produced. Spent filter backwash is only generated during the late night and early morning hours (11:00 p.m. and 5:00 a.m.) when the filters are scheduled for backwashing.

B. Highest Plant Flow Based on Peak Recycle Flow

To account for recycle flows, the backwash information can be used as follows:

$$\text{Backwash rate} = 15 \text{ gpm/ft}^2$$

$$\text{Filter surface area} = 100 \text{ ft}^2$$

$$\text{Backwash flow} = (15 \text{ gpm/ft}^2) \times (100 \text{ ft}^2) = 1,500 \text{ gpm}$$

Since each filter is backwashed separately, the typical recycle flow is 1,500 gpm.

To properly identify the highest observed plant flow, the operator had to identify the raw water flow that occurred during the return of spent filter backwash. The operator reviewed the raw water flow meter records and determined that the raw water flow rate that occurred between 11:00 p.m. and 5:00 a.m. was 1,000 gpm.

C. Compare Plant Flows Calculated Based on Raw Water and Recycle Flows to Obtain Overall Highest Observed Plant Flow

The highest observed raw water flow was 2,080 gpm. This flow occurred between 7:00 a.m. and 6:00 p.m. and does not include any recycle flows since recycling was not conducted during this time period. The highest observed recycle flow was 1,500 gpm. This flow occurred between 11:00 p.m. and 5:00 a.m. when filter backwashing was conducted and the raw water flow during this time period was 1,000 gpm, resulting in a total plant flow of 2,500 gpm. Therefore, the highest observed plant flow occurred between 11:00 p.m. and 5:00 a.m. during backwashing and the flow was estimated to be 2,500 gpm. Note that this flow exceeds the State-approved operating capacity of the plant of 2,080 gpm.

2. Determine Typical Recycle Flow

For this plant, the filters are consistently backwashed in the same manner. Each of 8 filters is backwashed at a rate of 15 gpm/ft² and each filter has a surface area of 100 ft². No equalization or treatment is provided and the flow is recycled directly to the head of the plant. The typical recycle flow is:

$$(15 \text{ gpm/ft}^2) \times (100 \text{ ft}^2) = 1,500 \text{ gpm}$$

3. Complete Recycle Notification Form

The system completed the Recycle Notification Form and it appears on Page 118.

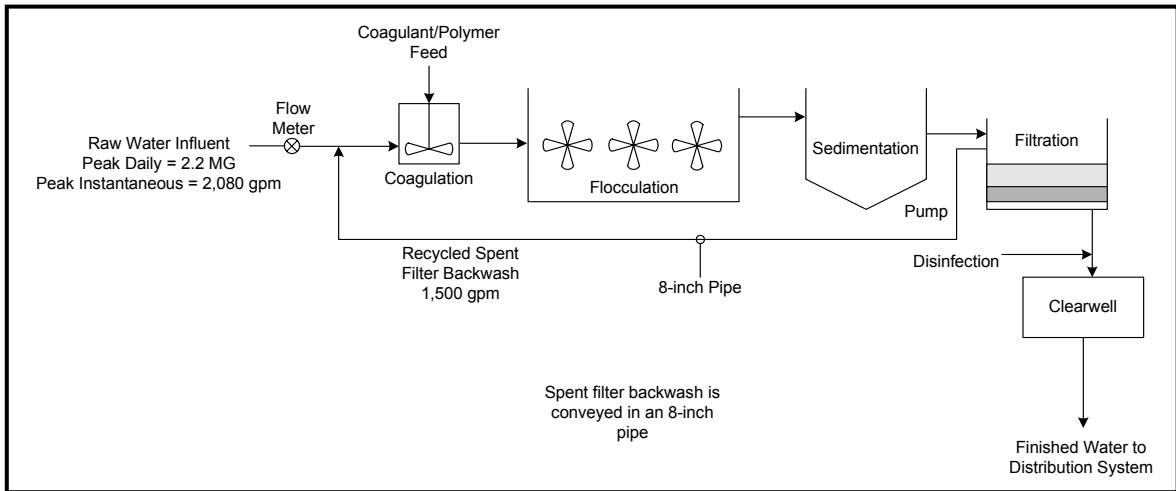
4. Complete Recordkeeping Form

The system completed the Recordkeeping Form and it appears on Page 119.

5. Evaluation of Data

The State may want to request additional information on this system since its highest observed plant flow exceeds the design flow and State-approved operating capacity. The system may want to examine turbidity and/or particle count data (as a starting point) during recycle events and assess if finished water quality is impacted. The system may also want to consider equalization of recycle flows such that the peak spent filter backwash return rate to the main treatment train does not create a plant capacity exceedance.

Figure C-1. Schematic for a 3.0 MGD Plant



**FILTER BACKWASH RECYCLING RULE
RECYCLE NOTIFICATION FORM**

SYSTEM NAME Example 3.0 MGD Plant

PWSID _____ DATE Dec 1, 2003

Check with your State or Primacy Agency to make sure this form is acceptable.

Does your system use conventional or direct filtration? Yes (conventional)

Does your system recycle spent filter backwash water, thickener supernatant, or liquids from dewatering processes? Yes (spent filter backwash)

If you answered yes to both questions, please report the following:

1. What is the typical recycle flow (in gpm)? 1,500 gpm
2. What was the highest observed plant flow for the system in the previous year (in gpm)?
2,500 gpm
3. What is the design flow for the treatment plant (in gpm)? 2,080 gpm
4. Has the State determined a maximum operating capacity for the plant? If so, what is it? 2,080 gpm
5. Please include a plant schematic that shows:
 - the origin of **all** recycle flows (spent filter backwash, thickener supernatant, liquids from dewatering processes, and any other);
 - the location where **all** recycle flows re-enter the treatment plant process; and
 - the hydraulic conveyance used to transport **all** recycle flows.

Comments: The highest observed plant flow of 2,500 gpm exceeds State-approved operating capacity.

-
-
6. Are you requesting an alternate recycle location? _____ Yes No
An alternate recycle location is one that does not incorporate all treatment processes of a conventional filtration plant (coagulation, flocculation, sedimentation, and filtration) or direct filtration plant (coagulation, flocculation, and filtration). The State or Primacy Agency must approve the recycle location by June 8, 2004. Please contact your State or Primacy Agency on what additional information may be needed.

Comments: _____

FILTER BACKWASH RECYCLING RULE RECORDKEEPING FORM

SYSTEM NAME Example 3.0 MGD Plant

PWSID _____ Operating Period¹ Jun 2003-Jun 2004

Check with your State or Primacy Agency to make sure this form is acceptable.

Type of Recycle Stream	Frequency at which flow is returned ²
Spent Filter Backwash	4 times/day returned to main treatment train
Thickener Supernatant	
Liquids from Dewatering Process	
Other	
Other	

Filter Information	Filter Number ³			
	1-8, all filters the same			
Average Duration of Backwash (in minutes)	15 minutes			
Maximum Duration of Backwash (in minutes)	15 minutes			
Average Backwash Flow ⁴ (in gpm)	1,500 gpm			
Maximum Backwash Flow ⁴ (in gpm)	1,500 gpm			
Run Length Time of Filter ⁵ (include units)	48 hrs			
Criteria for Terminating Filter Run ⁶	Time, unless individual filter turbidity exceeds 0.2 NTU.			

Is treatment or equalization provided for recycle flows? _____ Yes ___ X ___ No
 If yes, complete the following table.

Type of Treatment Provided		
Physical Dimensions of Unit		
Typical Hydraulic Loading Rate		
Maximum Hydraulic Loading Rate		
Type of Chemical Used		
Average Dose of Chemical (mg/L)		
Frequency of Chemical Addition		
Frequency of Solids Removal		

See instructions on back.

Instructions

1. Note the operating period for the information provided. Check with your State or Primacy Agency for required operating period.
2. The frequency at which the recycle stream is returned can be described as continuous, once a day, or as another frequency.
3. Fill out all information for each of your filters. If some or all filters are operated the same, note the appropriate filter numbers.
4. The backwash flow is obtained by multiplying filter surface area (in ft²) by backwash rate (gpm/ft²). Use the average backwash rate to get the average flow and the maximum backwash rate to get the maximum flow. If the flow is varied throughout the backwash process, then the average can be computed on a time-weighted basis as follows:

$$\frac{(\text{Backwash Rate 1 X Duration 1}) + (\text{Backwash Rate 2 X Duration 2}) + \dots}{\text{Duration 1} + \text{Duration 2} + \dots}$$

5. The filter run length time is the sum of the time that the filter is producing water between backwashes.
6. Describe how run length time is determined. For example, is the run length based on head loss across the filter, turbidity levels of filter effluent, a predetermined amount of time, or another method?

Appendix D.

Reporting Example for 20 MGD Plant

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A 20 MGD plant records total raw water flow at the plant inlet. The flowmeter can record total daily flow and peak instantaneous flow. The recycle flow is measured separately prior to the point where the recycle flow enters the raw water line (see plant schematic in Figure D-1). The plant was designed for a flow of 14,000 gpm and has a State-approved operating capacity of 20 MGD (or 14,000 gpm based on the design criteria for the plant). The plant recycles spent filter backwash, that is equalized and partially treated, and sludge thickener supernatant.

The system consists of 10 filters and each filter has a surface area of 350 ft². The filters have a maximum loading rate of 4 gpm/ft² and filter run time is typically 48 hours. All filters are on-line during peak demand, which typically occurs between 3:00 p.m. and 6:30 p.m. Filters are backwashed on a rotating schedule, with filter backwash occurring between 9:00 p.m. and 5:00 a.m. Five filters are individually backwashed every night at 2-hour intervals. Filters are backwashed for 10 minutes at 20 gpm/ft² in combination with surface wash. Spent filter backwash recycle flows are equalized and partially treated in a 100,000-gallon backwash holding tank. The outlet rate of the backwash holding tank is controlled with an outlet rate of 1,500 gpm. Thickener supernatant is recycled intermittently during the day (8:00 a.m. to 6:00 p.m.).

1. Determine Highest Observed Plant Flow

In order to obtain the highest observed plant flow, the system examined when the highest observed raw water flow occurred and added in any recycle flow and examined when the highest observed recycle flow occurred and added in raw water. Then, the two values were compared and the overall highest plant flow was reported to the State.

A. Highest Plant Flow Based on Peak Raw Water Flow

A review of the previous year's records indicates the peak plant flow occurred on July 20. The following values were recorded on July 20:

Highest observed raw water flow = 14,100 gpm (metered)

Time of day highest observed raw water flow occurred: 5:30 p.m.

Recycle flow that occurred at 5:30 p.m. = 100 gpm (all sludge thickener supernatant and metered)

Sum raw water flow plus sludge thickener supernatant:

$$14,100 \text{ gpm} + 100 \text{ gpm} = 14,200 \text{ gpm}$$

B. Highest Plant Flow Based on Peak Recycle Flow

Total daily recycle flow = 0.36 MGD (includes both spent filter backwash and sludge thickener supernatant.)

Highest observed recycle flow = 1,500 gpm (constant outflow rate from backwash holding tank. Sludge thickener supernatant flow is not occurring at this time of day.)

Time of day highest observed recycle flow occurred: 9:00 p.m. to 6:00 a.m.

Raw water flow that occurred between 9:00 p.m. and 6:00 a.m. = 10,000 gpm

Sum recycle flow plus raw water flow:

$$1,500 \text{ gpm} + 10,000 \text{ gpm} = 11,500 \text{ gpm}$$

C. Compare Plant Flows Calculated Based on Raw Water and Recycle Flows to Obtain Overall Highest Observed Plant Flow

The highest observed plant flow occurred at 5:30 p.m. when the raw water flow reached a peak of 14,100 gpm plus the recycle of sludge thickener supernatant at 100 gpm, for a total highest observed plant flow of 14,200 gpm.

2. Determine Typical Recycle Flows

The recycle flow for this system varies significantly throughout the day, with 100 gpm being the typical flow during the day (flow generated from the gravity thickener basin) and 1,500 gpm being the typical recycle flow returned to the main treatment train as spent filter backwash (backwash is generated at 7,000 gpm and equalized to 1,500 gpm between 9:00 p.m. and 6:00 a.m.). The State may want to know the time of day these recycle flows occur (not required by the FBRR, but may be useful to the State).

3. Complete Recycle Notification Form

The system filled out the Recycle Notification Form and it appears on Page 127.

4. Recycle Flow Information

A. Sludge Thickener Supernatant

Sludge thickener supernatant is recycled during the day between 8:00 a.m. and 6:00 p.m. The overflow rate is controlled at 100 gpm and the flow is intermittent.

B. Spent Filter Backwash

Spent filter backwash is partially treated and equalized prior to being recycled to the head of the plant. Filters are backwashed individually at a rate of 20 gpm/ft². The spent filter backwash is generated at the following rate:

$$\text{Spent filter backwash flow} = (20 \text{ gpm/ft}^2) \times (1 \text{ filter}) \times (350 \text{ ft}^2/\text{filter}) = 7,000 \text{ gpm}$$

This flow is generated when the filters are backwashed between 9:00 p.m. and 5:00 a.m. The spent filter backwash flow is equalized and partially treated and the return recycle flow is maintained at 1,500 gpm.

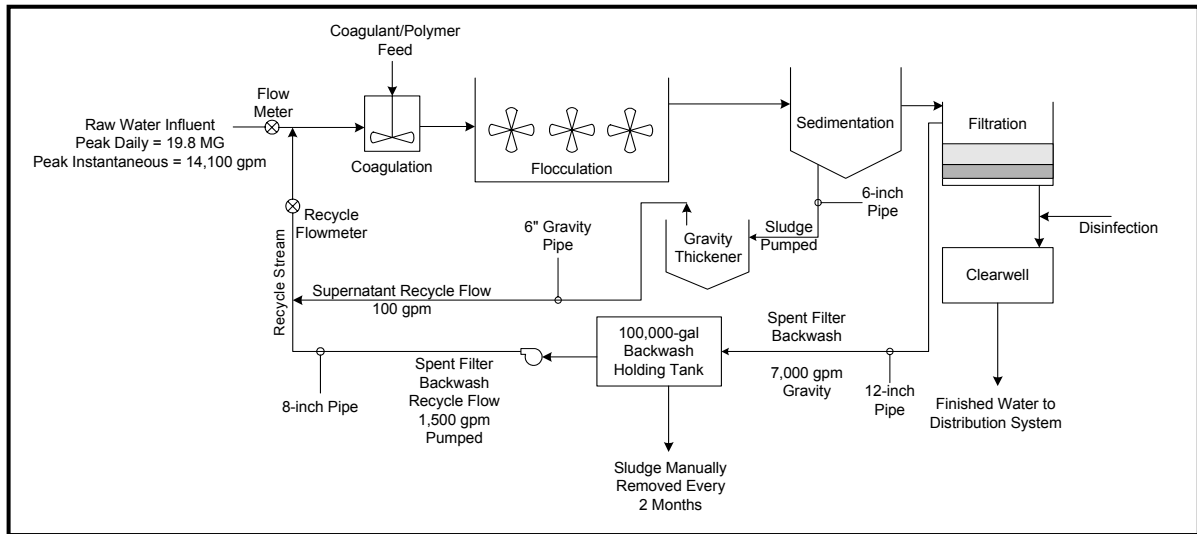
5. Complete Recordkeeping Form

The system completed the Recordkeeping Form and the information appears on Page 129. Equalization information is also included in the Recordkeeping Form.

6. Data Evaluation

The system's highest observed plant flow was slightly greater than the design and State-approved operating capacity. The system has had no treatment technique violations. The equalization basin is working properly. The system will want to monitor peak flows and avoid operating at a rate greater than the design operating capacity.

Figure D-1. Schematic for a 20 MGD Plant



**FILTER BACKWASH RECYCLING RULE
RECYCLE NOTIFICATION FORM**

SYSTEM NAME Example 20 MGD Plant

PWSID _____ DATE Dec 1, 2003

Check with your State or Primacy Agency to make sure this form is acceptable.

Does your system use conventional or direct filtration? Yes (conventional)

Does your system recycle spent filter backwash water, thickener supernatant, or liquids from dewatering processes? Yes (spent filter backwash and thickener supernatant)

If you answered yes to both questions, please report the following:

1. What is the typical recycle flow (in gpm)? 100 gpm for sludge thickener supernatant and 1,500 gpm for spent filter backwash (rate at which spent filter backwash is returned)
2. What was the highest observed plant flow for the system in the previous year (in gpm)?
14,200 gpm
3. What is the design flow for the treatment plant (in gpm)? 14,000 gpm
4. Has the State determined a maximum operating capacity for the plant? If so, what is it?
14,000 gpm or 20 MGD
5. Please include a plant schematic that shows:
 - the origin of **all** recycle flows (spent filter backwash, thickener supernatant, liquids from dewatering processes, and any other);
 - the location where **all** recycle flows re-enter the treatment plant process; and
 - the hydraulic conveyance used to transport **all** recycle flows.

Comments: Sludge thickener supernatant and spent filter backwash are metered at the same location. Spent filter backwash recycle flow is generated at 7,000 gpm, equalized, and returned to the main treatment train at 1,500 gpm.

6. Are you requesting an alternate recycle location? _____ Yes No
- An alternate recycle location is one that does not incorporate all treatment processes of a conventional filtration plant (coagulation, flocculation, sedimentation, and filtration) or direct filtration plant (coagulation, flocculation, and filtration). The State or Primacy Agency must approve the recycle location by June 8, 2004. Please contact your State or Primacy Agency on what additional information may be needed.

Comments: _____

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FILTER BACKWASH RECYCLING RULE RECORDKEEPING FORMSYSTEM NAME Example 20 MGD PlantPWSID _____ **Operating Period**¹ Jun 2003 to Jun 2004

Check with your State or Primacy Agency to make sure this form is acceptable.

Type of Recycle Stream	Frequency at which flow is returned ²
Spent Filter Backwash	Continuously between 9 pm and 6 am
Thickener Supernatant	Intermittently between 8 am and 6 pm
Liquids from Dewatering Process	
Other	
Other	

Filter Information	Filter Number ³			
	Filters 1-10			
Average Duration of Backwash (in minutes)	10 minutes			
Maximum Duration of Backwash (in minutes)	10 minutes			
Average Backwash Flow ⁴ (in gpm)	7,000 gpm			
Maximum Backwash Flow ⁴ (in gpm)	7,000 gpm			
Run Length Time of Filter ⁵ (include units)	48 hrs			
Criteria for Terminating Filter Run ⁶	Time, unless individual filter turbidity exceeds 0.2 NTU.			

Is treatment or equalization provided for recycle flows? Yes No

If yes, complete the following table.

Type of Treatment Provided	Equalization with partial treatment (sedimentation occurs in the backwash holding tank)	
Physical Dimensions of Unit	100,000 gal tank with baffles 70' X 35' X 5.5' active depth	
Typical Hydraulic Loading Rate	2.9 gpm/ft ² from filter backwash	
Maximum Hydraulic Loading Rate	2.9 gpm/ft ² from filter backwash	
Type of Chemical Used	None	
Average Dose of Chemical (mg/L)	None	
Frequency of Chemical Addition	None	
Frequency of Solids Removal	Solids are manually removed every 2 months	

See instructions on back.

Instructions

1. Note the operating period for the information provided. Check with your State or Primacy Agency for required operating period.
2. The frequency at which the recycle stream is returned can be described as continuous, once a day, or as another frequency.
3. Fill out all information for each of your filters. If some or all filters are operated the same, note the appropriate filter numbers.
4. The backwash flow is obtained by multiplying filter surface area (in ft²) by backwash rate (gpm/ft²). Use the average backwash rate to get the average flow and the maximum backwash rate to get the maximum flow. If the flow is varied throughout the backwash process, then the average can be computed on a time-weighted basis as follows:

$$\frac{(\text{Backwash Rate 1 X Duration 1}) + (\text{Backwash Rate 2 X Duration 2}) + \dots}{\text{Duration 1} + \text{Duration 2} + \dots}$$

5. The filter run length time is the sum of the time that the filter is producing water between backwashes.
6. Describe how run length time is determined. For example, is the run length based on head loss across the filter, turbidity levels of filter effluent, a predetermined amount of time, or another method?

Appendix E.

Reporting Example for 48 MGD Plant

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A 48 MGD surface water treatment plant records total daily and peak instantaneous flows at the plant inlet. In addition, the water treatment plant operators analyze raw and filtered water quality daily and record detailed meter readings for flow at many plant locations. The treatment scheme consists of a pre-sedimentation basin and fourteen upflow contact absorption clarifiers, followed by fourteen rapid sand multimedia filters. Chemical addition with coagulant, chlorine, potassium permanganate, and powdered activated carbon is possible before the upflow clarifiers. The tri-media clarifiers are run approximately 24 hours before air scour and backflushing with raw water. Backwashing of clarifiers occurs for 15 minutes at a backwash rate of 15 gpm/ ft². Clarifiers are backwashed individually every 30 minutes between 9:00 p.m. and 4:00 a.m. The clarifiers each have 500 ft² of surface area. The rapid sand multimedia filters are comprised of anthracite, silica, and garnet sands and each have a surface area of 590 ft². They are air-scoured and backwashed with finished water every 80 to 100 hours. A backwash rate of 20 gpm/ ft² is utilized for 15 minutes. Prior to backwashing, the filter is drained down six inches. After backwashing is complete, the first 30 minutes of water produced is wasted. Four filters are typically backwashed each day and individually backwashed every hour between 1:00 a.m. and 5:00 a.m. The filter feed rate is 4 gpm/ ft².

The water treatment plant reuses all of its residual streams (i.e., filter-to-waste water, pre-backwash drain-down, spent filter backwash water, clarifier backwash water, and drying bed leachate). All of the recycle streams are first directed to an equalization basin and the outlet flow rate is regulated at 2,000 gpm. This flow is then treated by four flocculators and four dissolved air flotation units on a continuous basis. Chemical addition with coagulant, chlorine, potassium permanganate, and powdered activated carbon is possible prior to the flocculation basins. Residuals are dewatered using sixteen sludge-drying beds, with the leachate being directed back to the equalization basin. The amount of leachate from the drying beds has been determined to be about 192,000 gpd, which is 0.4% of the finished water production. The treated recycle stream is returned to the presedimentation basin.

1. Determine Highest Observed Plant Flow

A. Highest Plant Flow Based on Peak Raw Water Flow

A review of the water treatment plant's annual records indicates that the peak plant flow occurred on August 15th. The following values were recorded on that day:

Total plant flow = 48 MGD (metered)

Highest observed raw water flow = 35,000 gallons per minute (metered)

Time of day highest observed raw water flow occurred: 5:30 p.m.

Recycle flow that occurred at 5:30 p.m. = 2,000 gpm (regulated by an outlet control valve on the equalization basin)

Sum raw water flow plus recycle flow:

$$35,000 \text{ gpm} + 2,000 \text{ gpm} = 37,000 \text{ gpm}$$

B. Highest Plant Flow Based on Peak Recycle Flow

The quantity of water treatment plant recycle streams was calculated using plant operating parameters and flow estimates.

- Filter backwash:** 708,000 gpd (based on 4 filters backwashed each day for 15 minutes at a rate of 20 gpm/ft²). Filters are backwashed individually at one-hour intervals between 1:00 a.m. and 5:00 a.m. This flow is generated at a rate of 11,800 gpm.
- Clarifier backwash:** 1,575,000 gpd (based on each clarifier backwashed once per day for 15 minutes at a rate of 15 gpm/ft²). Clarifiers are individually backwashed every 30 minutes between 9:00 p.m. and 4:00 a.m. This flow is generated at a rate of 7,500 gpm.
- Filter-to-Waste:** 283,200 gpd (based on disposal of filtered water produced in the first 30 minutes after a filter is backwashed, four filters per day). This flow is generated between 1:00 a.m. and 5:00 a.m. at a rate of 2,360 gpm.
- Pre-backwash draindown:** 8,830 gpd (based on 0.5-foot drawdown of filters prior to backwash, 4 filter backwashed each day). This flow is generated between 1:00 a.m. and 5:00 a.m. at a rate of 200 gpm.
- Sludge drying beds:** 192,000 gpd (based on flow measurement). The leachate is generated at a continuous rate of 140 gpm throughout the day.

Total daily recycle flow = 2.77 MGD (includes all plant waste streams)

Highest observed recycle flow = 2,000 gpm (constant outflow rate from equalization basin)

Highest observed raw water flow = 35,000 gpm

Sum recycle flow plus raw water flow:

$$2,000 \text{ gpm} + 35,000 \text{ gpm} = 37,000 \text{ gpm}$$

C. Compare Plant Flows Calculated Based on Raw Water and Recycle Flows to Obtain Overall Highest Observed Plant Flow

The highest observed plant flow occurred at 5:30 p.m. and is the sum of the highest observed raw water flow (35,000 gpm) and the controlled recycle return flow (2,000 gpm) for a total of 37,000 gpm.

2. Determine Typical Recycle Flows

Recycle flows are generated at different frequencies and at different times during the day. The recycle flow information is contained on the previous page. All generated recycle flows for this system go to the equalization basin and are discharged from the equalization basin at a constant rate of 2,000 gpm continuously throughout the day.

3. Complete Recycle Notification Form

The Recycle Notification Form was completed for this system and is contained on Page 137.

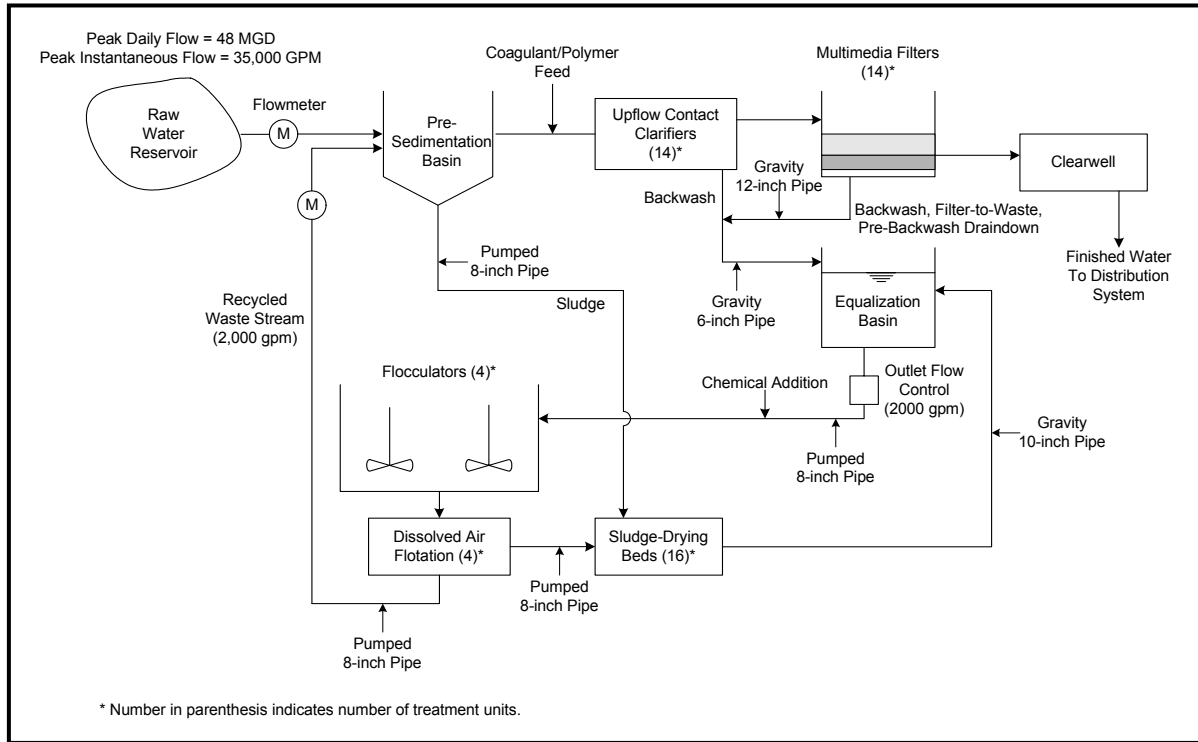
4. Complete Recordkeeping Form

The Recordkeeping Form was completed for this system and is contained on Page 139. Recycle flows were included for each of the recycle streams.

5. Data Evaluation

Based on the information provided, the system exceeds its design and State-approved operating capacity by 3,700 gpm. The system may want to examine finished water quality (such as turbidity and/or particle count data) to assess if recycle practices are impacting finished water quality. If so, the State may request that the system modify its recycle practices.

Figure E-1. Schematic for a 48 MGD Plant



**FILTER BACKWASH RECYCLING RULE
RECYCLE NOTIFICATION FORM**

SYSTEM NAME Example 48 MGD Plant

PWSID _____ DATE Dec 1, 2003

Check with your State or Primacy Agency to make sure this form is acceptable.

Does your system use conventional or direct filtration? Yes (conventional)

Does your system recycle spent filter backwash water, thickener supernatant, or liquids from dewatering processes? Yes (all)

If you answered yes to both questions, please report the following:

1. What is the typical recycle flow (in gpm)? 2,000 gpm (Equalized flow for spent filter backwash, clarifier backwash, filter-to-waste, pre-backwash draindown, and leachate)
2. What was the highest observed plant flow for the system in the previous year (in gpm)?
37,000 gpm
3. What is the design flow for the treatment plant (in gpm)? 33,333 gpm
4. Has the State determined a maximum operating capacity for the plant? If so, what is it? 33,333 gpm or 48 MGD
5. Please include a plant schematic that shows:
 - the origin of **all** recycle flows (spent filter backwash, thickener supernatant, liquids from dewatering processes, and any other);
 - the location where **all** recycle flows re-enter the treatment plant process; and
 - the hydraulic conveyance used to transport **all** recycle flows.

Comments: All residual flows (filter-to-wate water, pre-backwash drain-down, filter backwash, clarifier backwash water, and drying bed leachate) are directed to an equalization basin before treatment. Recycle streams are returned to the main treatment train at a rate of 2,000 gpm.

6. Are you requesting an alternate recycle location? _____ Yes No
- An alternate recycle location is one that does not incorporate all treatment processes of a conventional filtration plant (coagulation, flocculation, sedimentation, and filtration) or direct filtration plant (coagulation, flocculation, and filtration). The State or Primacy Agency must approve the recycle location by June 8, 2004. Please contact your State or Primacy Agency on what additional information may be needed.

Comments: _____

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FILTER BACKWASH RECYCLING RULE RECORDKEEPING FORMSYSTEM NAME Example 48 MGD PlantPWSID _____ **Operating Period¹** Jun 2003 to Jun 2004

Check with your State or Primacy Agency to make sure this form is acceptable.

Type of Recycle Stream	Frequency at which flow is returned ²
Spent Filter Backwash	Continuously (equalized with all recycle streams)
Thickener Supernatant	
Liquids from Dewatering Process	Continuously (equalized with all recycle streams)
Other See attached sheet	
Other	

Filter Information	Filter Number ³			
	Filters 1-14			
Average Duration of Backwash (in minutes)	15 minutes			
Maximum Duration of Backwash (in minutes)	15 minutes			
Average Backwash Flow ⁴ (in gpm)	11,800 gpm			
Maximum Backwash Flow ⁴ (in gpm)	11,800 gpm			
Run Length Time of Filter ⁵ (include units)	80 to 100 hours			
Criteria for Terminating Filter Run ⁶	Time, unless individual filter turbidity exceeds 0.2 NTU			

Is treatment or equalization provided for recycle flows? Yes No

If yes, complete the following table.

Type of Treatment Provided	Equalization with full treatment (flocculation and dissolved air flotation (DAF))
Physical Dimensions of Unit	3.0 MG equalization tank with baffles (200' x 200' X 10'), four flocculation basins (each 13,800 gal), and two DAF basins (each 500 ft ²)
Typical Hydraulic Loading Rate (gpm/ft ²)	0.004 to 0.49 gpm/ft ² to equalization basin and 0.53 gpm/ft ² to DAF basins
Maximum Hydraulic Loading Rate (gpm/ft ²)	0.49 gpm/ft ² (11,800 gpm spent filter backwash plus 7,500 gpm clarifier backwash plus 140 gpm leachate) to equalization basin and 0.53 gpm/ft ² to DAF basins (flow controlled from equalization basin to treatment)
Type of Chemical Used	The DAF chemical feed systems are capable of providing potassium permanganate, caustic soda, polymer, and coagulant
Average Dose of Chemical (mg/L)	None. Operators found that treatment goals could be achieved without chemical addition and so it was dropped.
Frequency of Chemical Addition	None.
Frequency of Solids Removal	Solids are manually removed every 2 months from the equalization basin. Float solids from the DAF units are pumped on a batch basis once a day to the sludge drying beds.

See instructions on back.

Instructions

1. Note the operating period for the information provided. Check with your State or Primacy Agency for required operating period.
2. The frequency at which the recycle stream is returned can be described as continuous, once a day, or as another frequency.
3. Fill out all information for each of your filters. If some or all filters are operated the same, note the appropriate filter numbers.
4. The backwash flow is obtained by multiplying filter surface area (in ft²) by backwash rate (gpm/ft²). Use the average backwash rate to get the average flow and the maximum backwash rate to get the maximum flow. If the flow is varied throughout the backwash process, then the average can be computed on a time-weighted basis as follows:

$$\frac{(\text{Backwash Rate 1 X Duration 1}) + (\text{Backwash Rate 2 X Duration 2}) + \dots}{\text{Duration 1} + \text{Duration 2} + \dots}$$

5. The run length time of the filter starts when filter effluent goes to the clearwell and ends when the filter is taken off-line.
6. Describe how run length time is determined. For example, is the run length based on head loss across the filter, turbidity levels of filter effluent, a predetermined amount of time, or another method?

FILTER BACKWASH RECYCLING RULE RECORDKEEPING FORM

Recycle Stream Attachment

Type of Recycle Stream (Additional Flows)	Frequency at which flow is returned
Other Clarifier Backwash	Continuously (equalized with all recycle streams)
Other Pre-backwash draindown	Continuously (equalized with all recycle streams)
Other Filter-to-waste	Continuously (equalized with all recycle streams)

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Appendix F.

Characteristics of Spent Filter Backwash Water

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The American Water Works Association Research Foundation (AWWARF) funded a study (Cornwell and Lee, 1993) that examined recycle stream effects at eight different utilities throughout the country.

Table F-1 compares data on spent filter backwash (prior to treatment) and plant influent (Cornwell and Lee, 1993). The spent filter backwash had higher TTHM, TTHM formation potential and TOC concentrations than the plant influent. Turbidity and inorganics in the spent filter backwash were also higher than the plant influent. Figure F-1 provides a schematic of one of the studied plants (Mianus Water Treatment Plant) and monitoring locations.

Table F-1. Comparison of Plant Influent to Spent Filter Backwash

Contaminant	Mianus Water Treatment Plant	
	Plant Influent ¹	Spent Filter Backwash ²
TTHM, µg/L	8-19	46-97
TTHM Formation Potential, µg/L	169-200	302-465
Turbidity, NTU	4.5-10.0	0.57-97
TOC, mg/L	2.37-4.4	5.54-7.1
pH	5.5-6.5	6.2-6.8
Aluminum- Dissolved, mg/L	0.026-3.3	0.03-49.6
Aluminum- Total, mg/L	2.2-3.6	55.00-76
Manganese- Dissolved, mg/L	0.04-0.16	0.15-0.75
Manganese- Total, mg/L	0.04-0.24	1.4-12
Iron- Dissolved, mg/L	0.18	2.60
Iron- Total, mg/L	0.23	3.19

¹ Plant influent represents the raw water plus chemicals (chlorine, alum, and lime for this plant) that enters the clarifier filter when recycle was not occurring. This sampling point is just after the recycle return location.

² Spent filter backwash is the backwash directly from the filter that has not been treated or equalized.

Source: Cornwell and Lee, 1993.

Table F-2 presents additional information on contaminants in spent filter backwash (Cornwell et al., 2001). These data are based on samples from 25 systems.

Table F-2. Comparison of Raw Water to Spent Filter Backwash¹

Parameter	Raw Water		Spent Filter Backwash Water		Multiple increase
	Range	Average	Range	Average	
DOC (mg/L)	0.7 - 5.4	2.4	0.8 – 191	8.0	3.3
TTHM (µg/L)	ND - 21.8	0.6	ND – 198	55.0	91.7
HAA6 (µg/L)	ND - 21.5	1.9	ND – 211	46.1	24.3
Br (mg/L)	ND - 0.68	0.038	ND – 0.46	0.033	-0.1
Al (mg/L)	ND - 30	0.72	ND – 145.8	14.7	20.4
Fe (mg/L)	ND - 56.6	1.2	ND – 132	8.7	7.3
Mn (mg/L)	0.01 - 5.5	0.11	0.01 – 17.9	1.4	12.7
Zn (mg/L)	ND - 0.5	0.03	ND – 1.0	0.1	3.3

¹Source: Cornwell et al., 2001.

Figure F-1. Mianus Water Treatment Plant

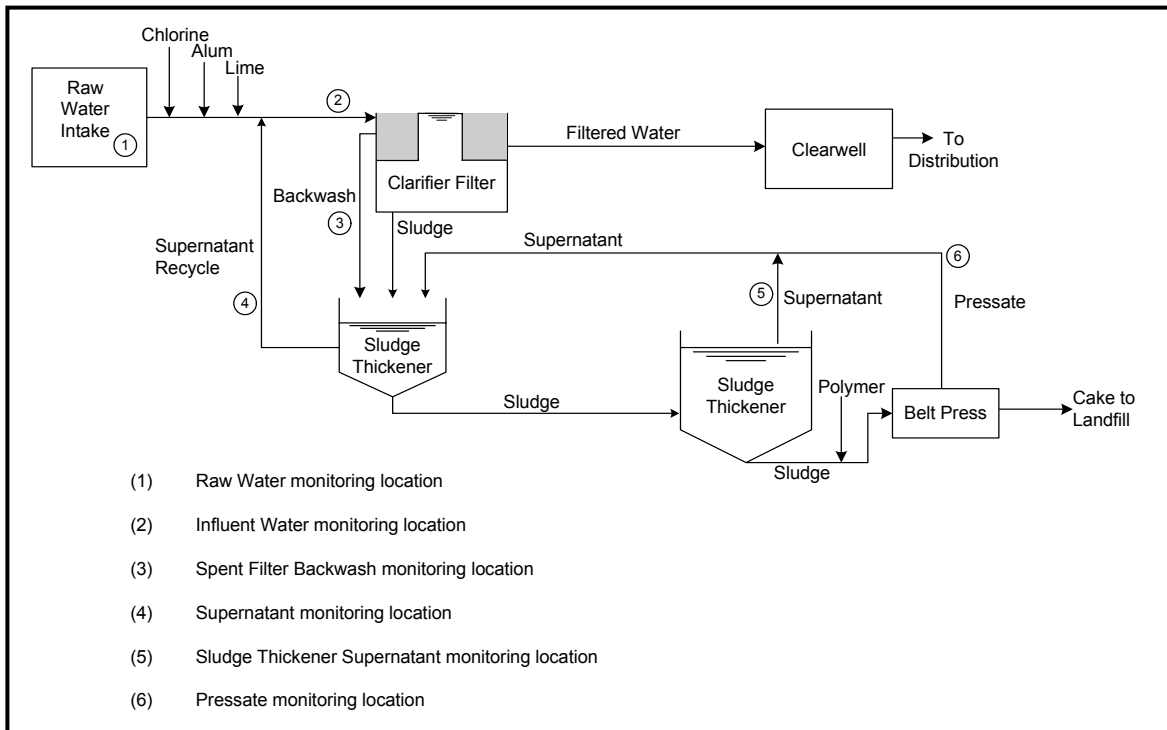


Table F-3 presents data for plant influent water quality as compared to treated (settled) spent filter backwash. The Kanawha Water Treatment Plant was the only system studied that recycled spent filter backwash exclusively. The comparison for finished water with and without recycle indicated that TTHM concentrations increased significantly (by 20 $\mu\text{g/L}$) during recycle. TTHM concentration increases of this magnitude could lead to TTHM compliance issues in the distribution system. Two of the three plants presented in Table F-3, Kanawha and New Castle Treatment Plants, showed higher TTHM formation potential and TOC in the recycled spent filter backwash exiting the backwash holding tank than in plant influent and raw water (raw water data not shown). The other plant (Swimming River Water Treatment Plant) did not exhibit this trend and the recycle spent filter backwash actually had lower TTHM formation potential and TOC than the plant influent and raw water (raw water data not shown). Figures F-2, F-3, and F-4 present schematics and monitoring locations for the Kanawha, Swimming River, and New Castle Water Treatment Plants, respectively.

Table F-3. Comparison of Plant Influent to Spent Filter Backwash Exiting the Backwash Holding Tank

Contaminant	Kanawha Treatment Plant		Swimming River Treatment Plant		New Castle Treatment Plant	
	Plant Influent ¹	SFBW Supernatant ²	Plant Influent ³	SFBW Supernatant ²	Plant Influent ⁴	SFBW Supernatant ²
TTHM, µg/L	4-14	28-98	4	40	14-25	60-118
TTHM Formation Potential, µg/L	82-145	160-265	153	126	214-400	259-658
Turbidity, NTU	6.2-27	78-400	12	1.2	10-23	50-75
TOC, mg/L	1.85-3.2	2.96-4.1	2.4	2.1	4.51-5.64	5.11-7.4
PH	6.6-7.0	8.5-9.6	6.4	6.8	6.5-6.8	7.2-7.5
Aluminum-Dissolved, mg/L	-----	-----	0.039	0.051	0.09-3.77	0.23-18.78
Aluminum-Total, mg/L	-----	-----	2.904	0.252	0.7-4.7	18.98-29.4
Manganese-Dissolved, mg/L	-----	-----	0.04	<0.02	<0.02-0.04	0.15-0.92
Manganese-Total, mg/L	-----	-----	0.16	<0.02	<0.02-2.51	0.89-21.7

¹ Plant influent represents the raw water plus chemicals (chlorine, lime, and polymer) that enters the mixing chamber when recycle is not occurring. This sampling point is just after the recycle return location.

² Spent filter backwash supernatant is the recycle stream exiting the backwash holding tank that has been partially equalized and settled. This flow consists solely of spent filter backwash.

³ Plant influent represents the raw water plus powdered activated carbon prior to additional chemical feed points that enters the clarifier/filters (Aldrich Units) when recycle is not occurring. This sampling point is just after the recycle return location.

⁴ Plant influent represents the raw water plus chemicals (potassium permanganate, alum, polymer, carbon, and chlorine or chlorine dioxide) that enters the rapid mix basin when recycle is not occurring. This sampling point is just after the recycle return location.

Source: Cornwell and Lee, 1993.

Figure F-2. Kanawha Valley Water Treatment Plant

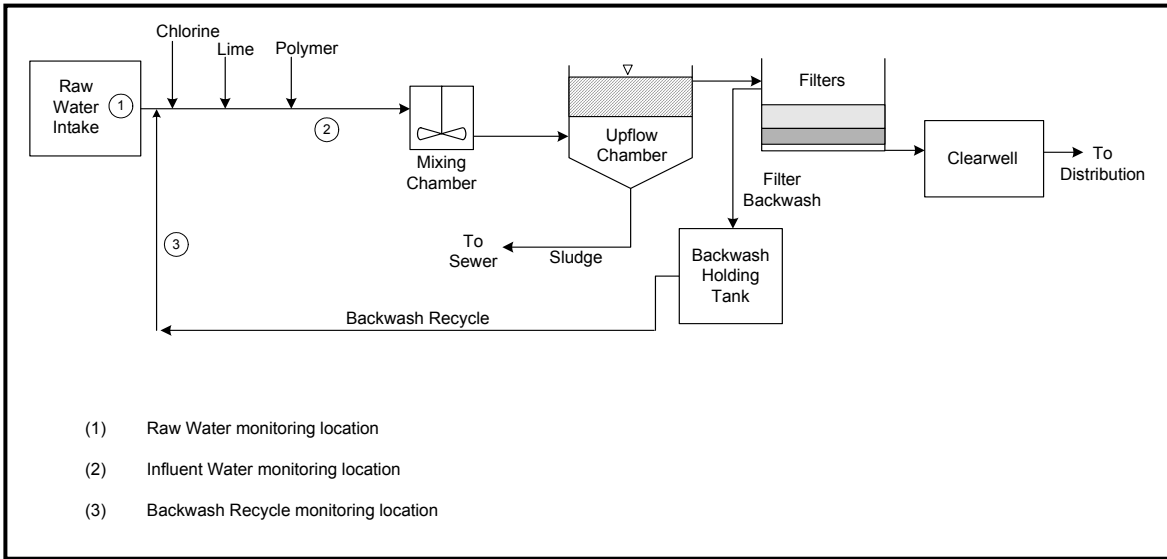


Figure F-3. Swimming River Water Treatment Plant

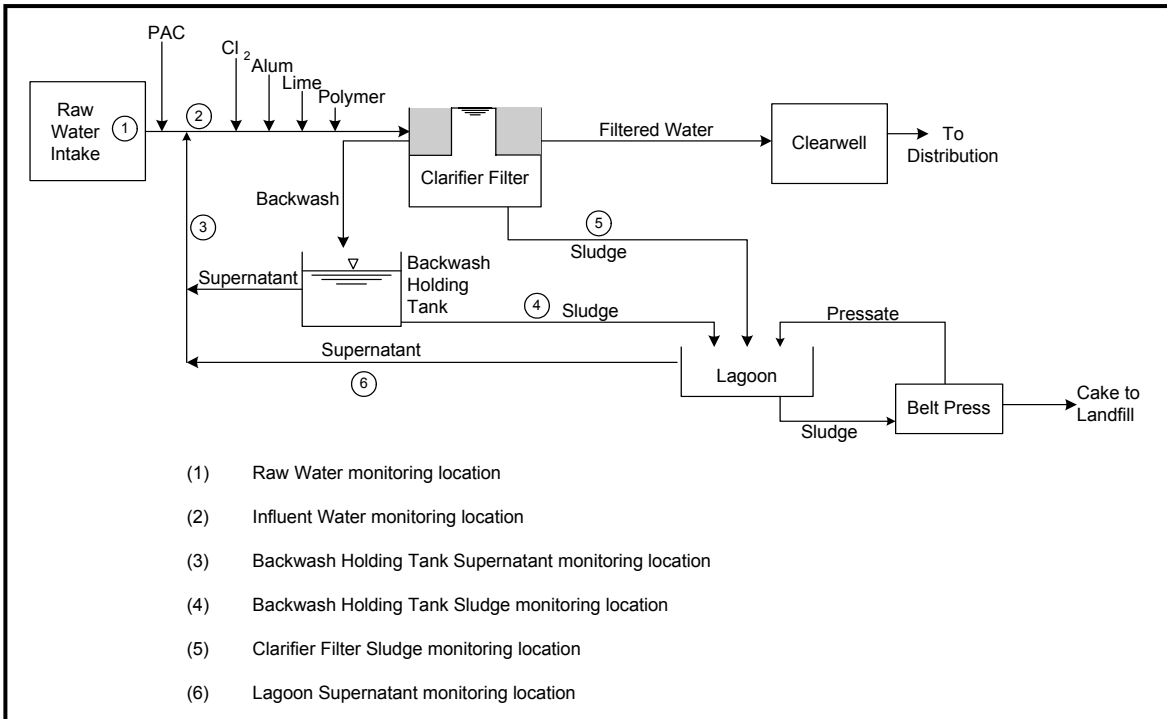
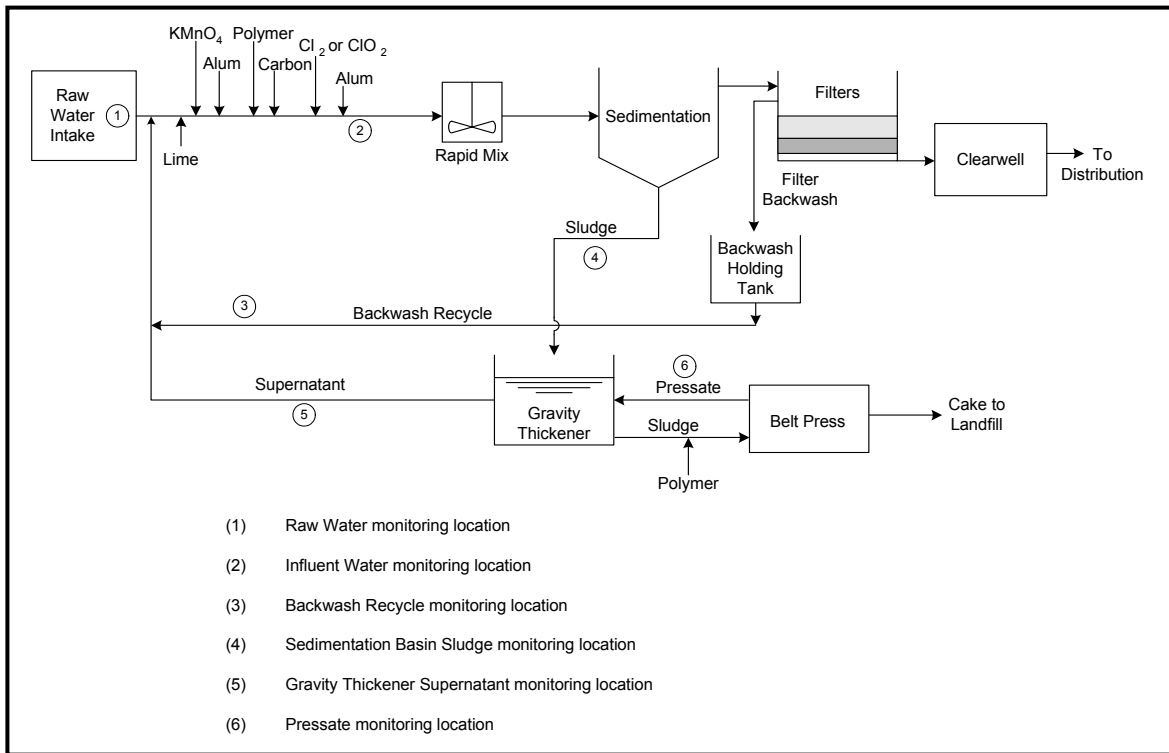


Figure F-4. New Castle Water Treatment Plant



References

Cornwell, D., M. MacPhee, N. McTigue, H. Arora, G. DiGiovanni, M. LeChevallier, and J. Taylor. 2001. Treatment Options for *Giardia*, *Cryptosporidium*, and Other Contaminants in Recycled Backwash Water. AWWARF. Denver, CO.

Cornwell, D., and R. Lee. 1993. Recycle Stream Effects on Water Treatment. AWWARF. Denver, CO.

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Appendix G.

Characteristics of Thickener Supernatant

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Table G-1 summarizes data from three different plants in the AWWARF study (Cornwell and Lee, 1993) for influent water, sludge, and supernatant. Figures G-1, G-2, and G-3 present plant schematics and monitoring locations for the plants presented in Table G-1. The sludge had significantly higher TTHM, TTHM formation potential, and TOC than raw water and plant influent (raw water data not presented in Table G-1). The supernatant also exhibited higher concentrations for these same three contaminants than the plant influent and raw water (raw water data not presented). Recycle of the supernatant, however, did not impact filtered water quality at any of these three systems.

With regard to inorganics, the results were more varied. Aluminum and manganese levels in the sludge were very high in comparison to plant influent. The aluminum concentrations in the supernatant were less than aluminum concentrations in the plant influent. Conversely, manganese levels in the supernatant were greater than levels in the influent water. Again, recycle of the supernatant did not affect filtered water quality.

Table G-2 presents data on decant from lagoons.

Table G-1. Comparison of Plant Influent to Sludge and Thickener Supernatant

Contaminant	Mianus Water Treatment Plant		Swimming River Water Treatment Plant				New Castle Water Treatment Plant		
	Plant Influent ¹	Super-Natant ²	Plant Influent ³	Backwash Holding Tank Sludge	Clarifier Filter Sludge	Super-natant ⁴	Plant Influent ⁵	Sludge from Sedimentation Basin	Super-natant ⁶
TTHM, µg/L	8-19	156-525	4	36	25	19	14-25	321-674	113-197
TTHM Formation Potential, µg/L	169-200	349-444	153	190	209	192	214-400	468-2,032	270-686
Turbidity, NTU	4.5-10.0	0.7-5.0	12	-----	-----	4.5	10-23	-----	1-10
TOC, mg/L	2.37-4.4	3.75-5.0	2.4	75	245	3.6	4.51-5.64	14-59.4	5.06-15.1
pH	5.5-6.5	6.0-6.7	6.4	6.3	6.3	6.8	6.5-6.8	-----	7.0-7.5
Aluminum-Dissolved, mg/L	0.026-3.3	<0.001-0.27	0.039	0.013	0.024	0.003	0.09-3.77	0.45-300	0.04-0.66
Aluminum-Total, mg/L	2.2-3.6	0.18-0.62	2.904	110.2	808.3	0.976	0.7-4.7	300-1,021	0.215-0.92
Manganese-Dissolved, mg/L	0.04-0.16	1.14-4.1	0.04	0.47	1.66	0.62	<0.02-0.04	2.4-5.22	0.26-3.08
Manganese-Total, mg/L	0.04-0.24	1.25-4.5	0.16	6.22	48.61	0.70	<0.02-2.51	5.24-73.9	0.26-3.69
Iron-Dissolved, mg/L	0.18	<0.05	-----	-----	-----	-----	-----	-----	-----
Iron- Total, mg/L	0.23	0.08	-----	-----	-----	-----	-----	-----	-----

¹ Plant influent represents the raw water plus chemicals (chlorine, alum, and lime for this plant) that enters the clarifier filter when recycle was not occurring. This sampling point is just after the recycle return location.

² Thickener treats sludge from supernatant tanks that receive sludge and spent filter backwash from clarifier filter, supernatant from the thickener, and pressate.

³ Plant influent represents the raw water plus powdered activated carbon prior to additional chemical feed points that enter the clarifier/filters (Aldrich Units) when recycle is not occurring. This sampling point is just after the recycle return location.

⁴ Includes sludge from clarifier filter and backwash holding tank, plus pressate.

⁵ Plant influent represents the raw water plus chemicals (potassium permanganate, alum, polymer, carbon, and chlorine or chlorine dioxide) that enters the rapid mix basin when recycle is not occurring. This sampling point is just after the recycle return location.

⁶ Gravity thickener receives sludge from sedimentation basin and pressate from belt press. Source: Cornwell and Lee, 1993.

Figure G-1. Mianus Water Treatment Plant

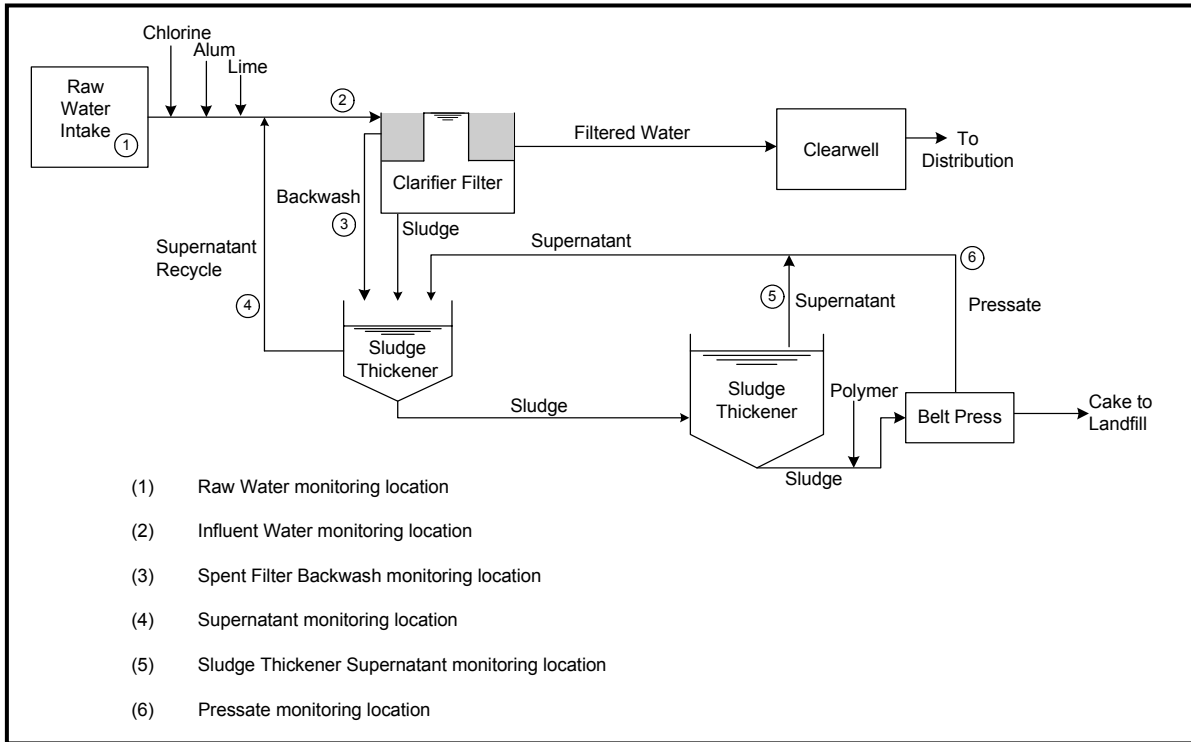


Figure G-2. Swimming River Water Treatment Plant

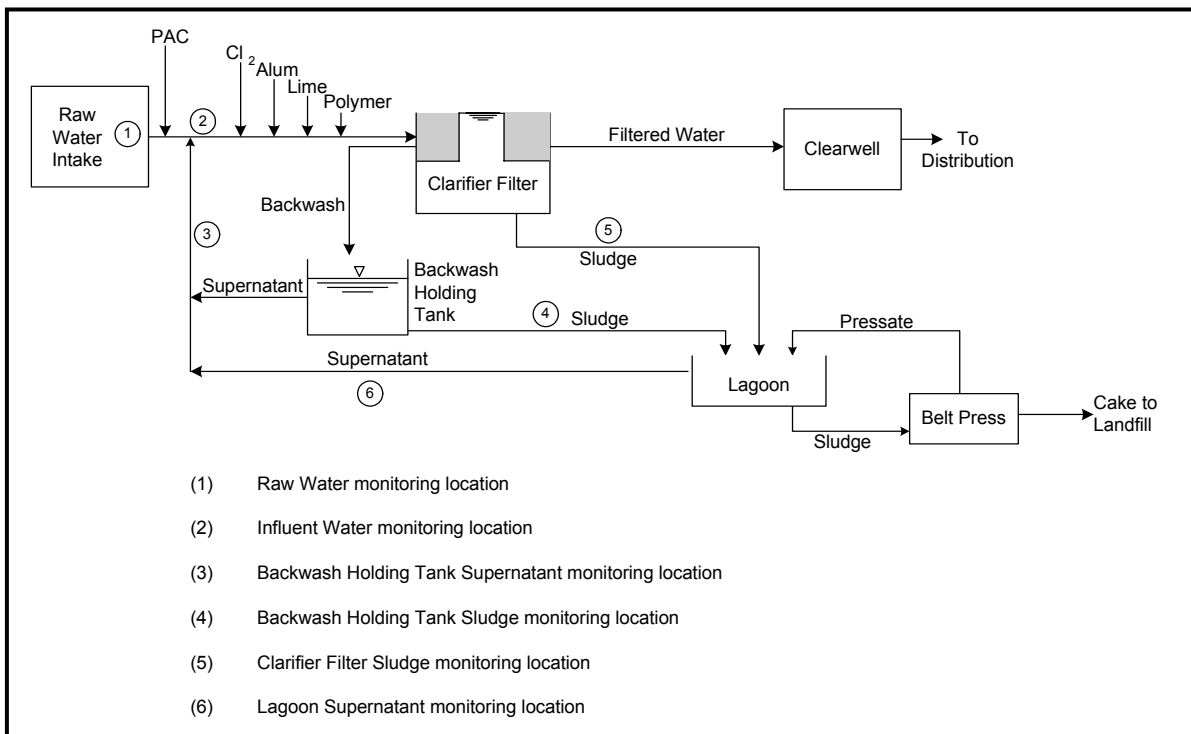


Figure G-3. New Castle Water Treatment Plant

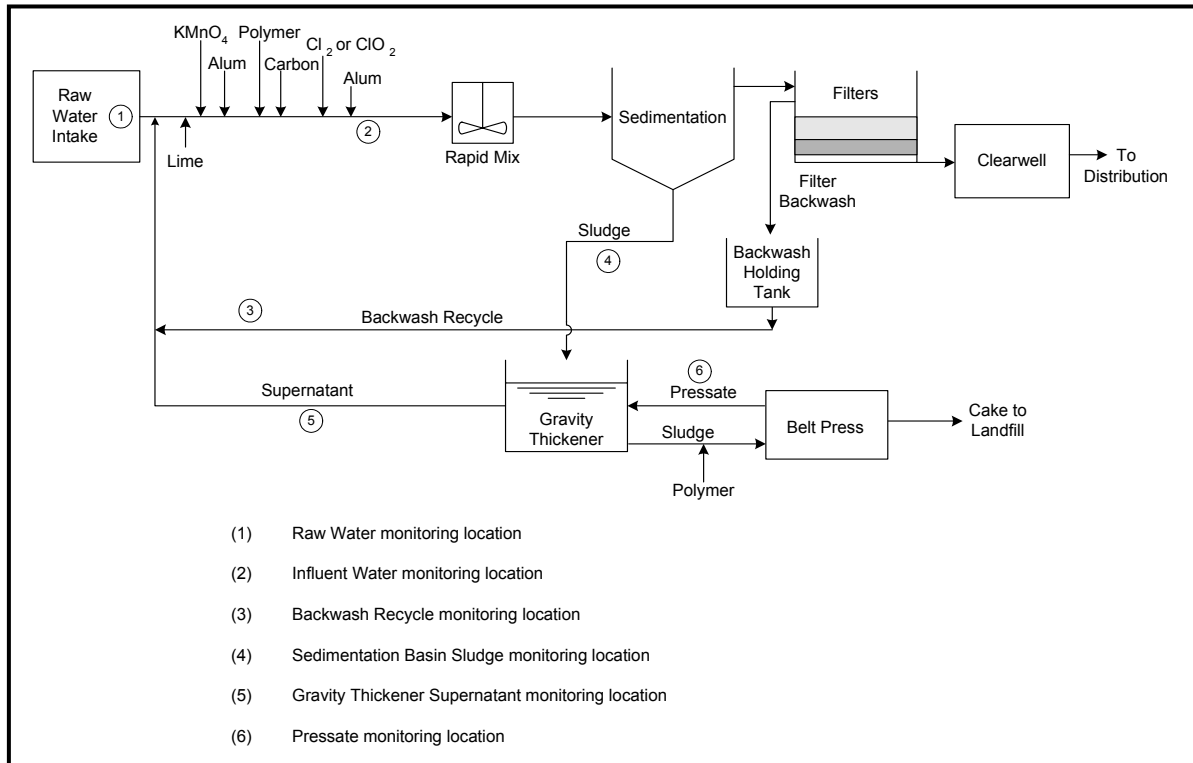


Table G-2. Lagoon Decant Data

Contaminant	Lagoon Decant
TTHM, µg/L	15.8-85.2
TTHM Formation Potential, µg/L	192
Turbidity, NTU	1.94-4.5
TOC, mg/L	3.6
PH	6.8-8.1
Aluminum- Dissolved, mg/L	0.003
Aluminum- Total, mg/L	<0.01-1.24
Manganese- Dissolved, mg/L	0.62
Manganese- Total, mg/L	<0.01-0.7
Iron- Dissolved, mg/L	-----
Iron- Total, mg/L	-----
<i>Giardia</i> , cysts/ L	-----
<i>Cryptosporidium</i> cysts/L	-----

Source: Environmental Engineering and Technology, 1999.

References

Cornwell, D. and R. Lee. 1993. *Recycle Stream Effects on Water Treatment*. AWWARF. Denver, CO.

Environmental Engineering and Technology. 1999. *Background Papers on Potential Recycle Streams in Drinking Water Treatment Plants*. AWWA.

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Appendix H.

Characteristics of Liquids from Dewatering Processes

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Dewatering can be accomplished through non-mechanical and mechanical means. Table H-1 presents information on dewatered residuals.

Table H-1. Characteristics of Dewatered Plant Residuals

Contaminant	Sludge Drying Bed Underflow ¹	Monofill Leachate ²	Mechanical Dewatered ³
TTHM, µg/L	-----	-----	128-276
TTHM Formation Potential, µg/L	-----	-----	397-499
Turbidity, NTU	1.6-32	-----	30-200
TOC, mg/L	-----	-----	5.8-14.3
pH	6.9-7.8	5.5-7.5	6.6-9.1
Aluminum-Dissolved, mg/L	-----	<0.6	0.12-0.81
Aluminum-Total, mg/L	<0.05-177	-----	0.15-129.0
Manganese-Dissolved, mg/L	-----	0.03-22.8	5.21-12.2
Manganese-Total, mg/L	0.05-12.34	-----	3.47-31.45
Iron- Dissolved, mg/L	-----	<0.01-1.42	<0.05
Iron- Total, mg/L	0.06-8.45	-----	0.4-165
<i>Giardia</i> , cysts/ L	0.210	-----	-----
<i>Cryptosporidium</i> cysts/L	<0.210	-----	-----

¹ Source: Environmental Engineering and Technology, 1999. Data is based on one to 17 samples.

² Source: Cornwell et al., 1992. Data is from three pilot-scale monofills.

³ Source: Environmental Engineering and Technology, 1999. Data represents samples from two water treatment plants with belt filter presses, one plant with a plate and frame press, and one plant with a centrifuge.

Another AWWARF study (Cornwell and Lee, 1993) examined pressate from two different plants. The data is presented in Table H-2. Figures H-1 and H-2 present plant schematics and pressate monitoring locations. The pressate exceeded influent water concentrations for most contaminants listed in Table H-2. The pressate in both plants was mixed with other waste streams prior to being recycled. The water quality of the recycled supernatant is shown in Table H-3. The impacts of the recycled pressate are unknown since the pressate is mixed with other waste streams prior to being recycled.

Table H-2. Pressate Quality in Comparison to Influent Water

Contaminant	Mianus Water Treatment Plant		New Castle Water Treatment Plant	
	Influent Water ¹	Pressate ²	Influent Water ³	Pressate ²
TTHM, µg/L	8-19	128-276	14-25	114-151
TTHM Formation Potential, µg/L	169-200	397-448	214-400	366-616
Turbidity, NTU	4.5-10.0	30-40	10-23	50-75
TOC, mg/L	2.37-4.4	5.82-9.2	4.51-5.64	14.34-18.2
PH	5.5-6.5	6.8-7.2	6.5-6.8	7.3
Aluminum-Dissolved, mg/L	0.026-3.3	0.021-0.81	0.09-3.77	0.12-3.94
Aluminum-Total, mg/L	2.2-3.6	6.4-31.8	0.7-4.7	7.6-186
Manganese-Dissolved, mg/L	0.04-0.16	7.43-12.2	<0.02-0.04	1.5-5.21
Manganese-Total, mg/L	0.04-0.24	8-16	<0.02-2.51	1.49-20.3
Iron- Dissolved, mg/L	0.18	<0.05	-----	-----
Iron- Total, mg/L	0.23	0.66	-----	-----

¹ Plant influent represents the raw water plus chemicals (chlorine, alum, and lime for this plant) that enters the clarifier filter when recycle was not occurring. This sampling point is just after the recycle return location.

² Pressate is from a belt press that dewateres sludge from a thickener. Polymer is added prior to the belt press.

³ Plant influent represents the raw water plus chemicals (potassium permanganate, alum, polymer, carbon, and chlorine or chlorine dioxide) that enters the rapid mix basin when recycle is not occurring. This sampling point is just after the recycle return location.

Source: Cornwell and Lee, 1993.

Figure H-1. Mianus Water Treatment Plant

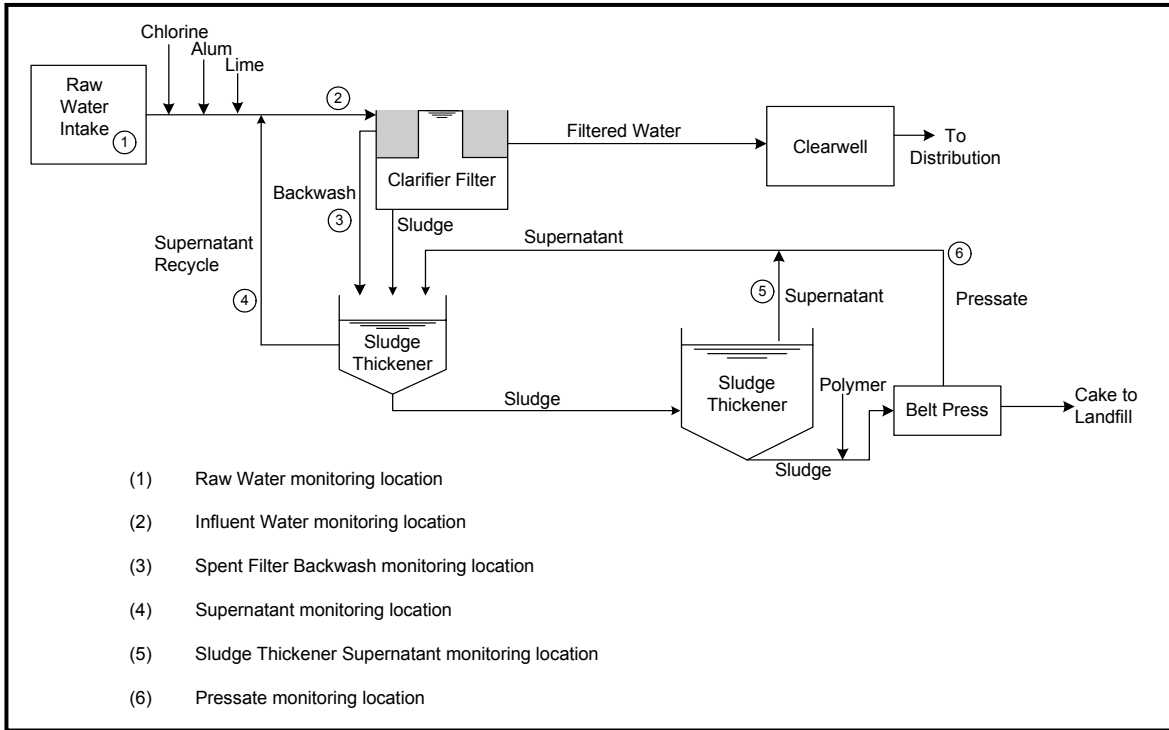
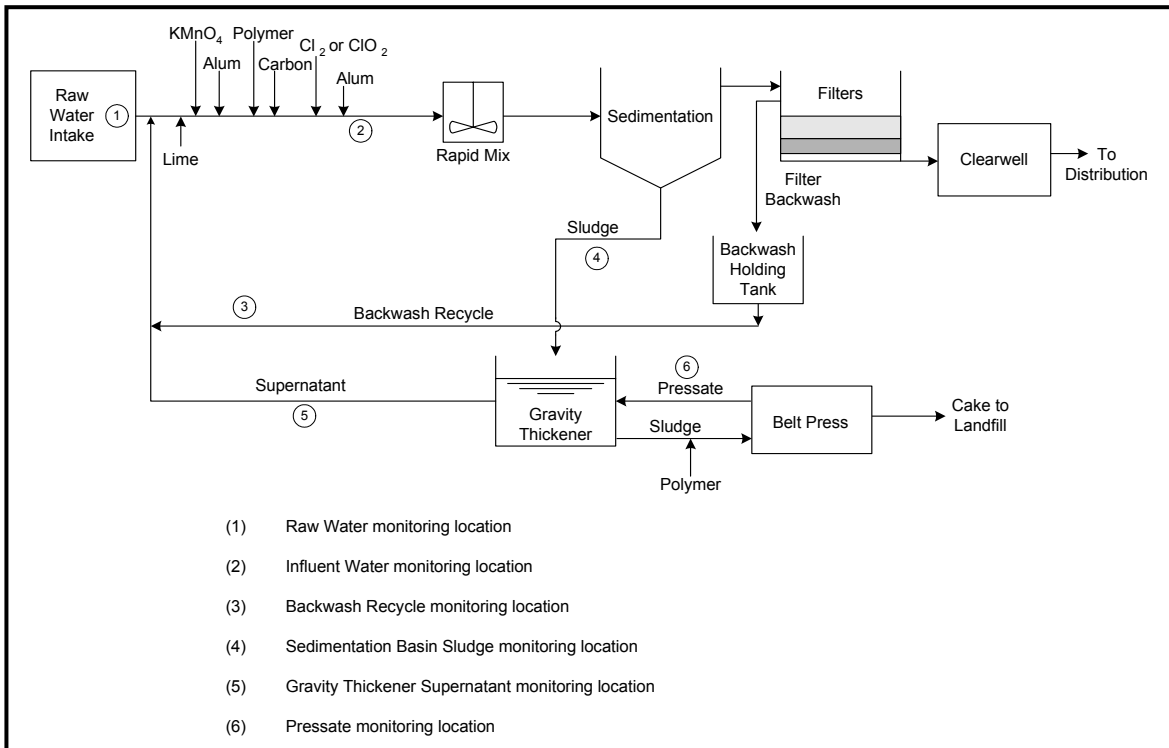


Figure H-2. New Castle Water Treatment Plant



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Cornwell, D. and R. Lee. 1993. *Recycle Stream Effects on Water Treatment*. AWWARF. Denver, CO.

Cornwell D.A., C. Vandermeiden, G. Dillow. 1992. *Landfilling of Water Treatment Plant Coagulant Sludges*. AWWARF. Denver, CO.

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