METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER

A MANUAL FOR SMALL MUNICIPAL WASTEWATER TREATMENT PLANTS



Prepared by Skillings Connolly, Inc. 5016 Lacey Blvd SE, Lacey, WA 98503

Prepared for Washington Department of Ecology Water Quality Program

June 2007 Ecology Publication # 07-10-088



This page was intentionally left blank.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER

A MANUAL FOR SMALL MUNICIPAL WASTEWATER TREATMENT PLANTS



Pam Jenkins, P.E.

Skillings Connolly, Inc. 5016 Lacey Blvd SE Lacey, WA 98503

Prepared for:

Gary Bailey Water Quality Permit Specialist Washington Department of Ecology Water Quality Program Program Development Services Section

June 2007

This page was intentionally left blank.

TABLE OF CONTENTS

1.0	Introduction1					
	1.1	Purpose	1			
	1.2	Need	2			
	1.3	Organization of Report	2			
2.0	Why	Temperature Is Important	3			
	2.1	Water	3			
	2.2	Temperature and Aquatic Habitat	3			
	2.3	Regulatory Background	4			
	2.4	Washington's Temperature Water Quality Standards	5			
	2.5	Sources of Additional Information	7			
3.0	Ove	Overview of Approaches to Reduce Thermal Impacts to Receiving Waters8				
	3.1	Unique Solutions	8			
	3.2	Multiple Approaches	8			
	3.3	Method Categories	9			
	3.4	Cost Considerations	.10			
	3.5	Sources of Additional Information	.10			
4.0	Cool	Cooling Effluent While It Is Still Influent11				
	4.1	Public Awareness and Education	.11			
	4.2	Pretreatment of Heat Loads	.12			
5.0	In-Plant Modifications to Cool Effluent15					
	5.1	Clarifier Covers	.16			
	5.2	Disinfection Alternatives	.18			
6.0	Disc	harging from the Treatment Plant	.20			
	6.1	Seasonal Storage	.21			
	6.2	Move Discharge Location	.23			
	6.3	Multiple Port Diffusers	.25			
	6.4	Effluent Blending	.28			
	6.5	Land Application	.31			
	6.6	Unlined Ponds or Lagoons	.34			
	6.7	Infiltration Trenches	.36			
	6.8	Rapid Infiltration	.38			
	6.9	Exfiltration Gallery	.41			
	6.10	Hyporheic Injection and Floodplain Channel Restoration	.43			
	6.11	Constructed Wetlands	.46			
	6.12	Wastewater Reclamation and Reuse	.49			

7.0	Direct Cooling of Effluent		55
	7.1	Riparian Shading	
	7.2	Cooling Ponds	60
	7.3	Spray Cooling	63
	7.4	Cooling Towers	
	7.5	Chillers	
	7.6	Geothermal Heat Exchanger	
		C C	

Appendix: Fresh Water Designated Uses and Criteria, WAC 173-201A-200......77

1.0 INTRODUCTION

1.1 PURPOSE. The purpose of this manual is to provide the reader with an overview of methods to reduce or eliminate thermal impacts from municipal wastewater treatment plant discharges to surface water. If you are in some way involved with municipal wastewater treatment—as a plant operator, engineer, public works director, city council member, environmental advocate, or interested citizen, you may find this information of interest. The information provided is intended to assist decision makers in the first step of consideration and selection of effluent management options that may be most applicable to a particular situation.

This report does not address much in the way of engineering detail, and is not intended to substitute for the analysis and advice of a wastewater engineer. The selection of one method from several options will necessarily include a detailed review of equipment and cost analysis. This step of the selection process should be accomplished by an engineer who is familiar with treatment plant design, processes, and equipment. The analysis should include up-front capital costs as well as operation and maintenance costs over the plant's operating horizon or other logical planning period.

The ultimate goal of this document and the Water Quality Program that initiated it is to help our streams maintain appropriate temperature ranges to support their native and natural animals and plants, particularly fish that spawn, migrate, or live in cold water.

This report is provided to you through the Washington Department of Ecology (Ecology). Any opinions expressed herein or references to specific manufacturers, vendors, or equipment do not represent any sort of endorsement by the Department, nor any regulatory requirement or guidance. References to equipment or manufacturers are provided as examples only, and are not based on a review or analysis of similar equipment or manufacturers.



City of Yelm wastewater treatment plant Source: Skillings Connolly, Inc.

Water Quality staff at Ecology can provide additional assistance regarding temperature criteria and water quality standards, discharge permitting, total maximum daily load (TMDL) analysis, and financial assistance for municipal projects. An organization chart for the Water Quality Program and staff contacts by subject are available on Ecology's website at www.ecy.wa.gov/programs/wq/overview.html#contacts.

1.2 NEED. In November 2006, the Washington Department of Ecology adopted temperature criteria in the surface water quality standards, found at Chapter 173-201A, Washington Administrative Code (WAC). The temperature criteria limit the allowable temperature increase of the receiving water due to human caused impacts, including point source discharges. Ecology staff recognized that implementation of the new temperature criteria could impact municipal wastewater treatment plants if the effluent discharges were shown, through temperature modeling, to exceed the allowable temperature increment. In that event, municipalities would need to find ways either to reduce the temperature of the treatment plant effluent before discharge to the receiving water, or find another discharge mechanism that would reduce or eliminate the thermal impact of the plant's effluent. As municipal budgets are typically already overstretched, there was a clear need to identify approaches that could be implemented relatively inexpensively.

1.3 ORGANIZATION OF REPORT. This manual outlines a number of different approaches in an attempt to satisfy this need as well as to provide general comparative information for the methods. Section 2.0 discusses why receiving water temperature is important and how thermal loading impacts aquatic habitat. Section 3.0 provides an overview of the types of cooling methods described, the potential for using multiple approaches, and a brief discussion of the issue of cost. Approaches to limiting the heat content of wastewater before it reaches the treatment plant are addressed in Section 4.0. Modifications that could be made to the treatment plant itself to keep the wastewater from warming during the treatment process are addressed in Section 5.0. Alternative discharge methods are discussed in Section 6.0. Direct cooling methods are described in Section 7.0.

2.0 WHY TEMPERATURE IS IMPORTANT

2.1 WATER. Water is unquestionably the essential ingredient of life on this planet. Water is also a finite resource. As global population grows and the demand for food, fuel, electricity, industry, housing, and recreation increases, water becomes increasingly more valuable and precious. Management of this resource to ensure adequate water supplies for all of its uses is becoming year-by-year more difficult. Part of this difficulty is ensuring that water bodies are not contaminated by point and non-point discharges, and that the water quality remains sufficient to support the uses required of each stream, river, and lake.

Improvements in wastewater treatment in the U.S. over the past 100 years have helped reduce contamination of fresh water and marine water with biological and chemical constituents. We now have over 50 years of evidence that toxic chemicals from industrial practices can have devastating effects on wildlife, fish, and human health. Increasing understanding of aquatic habitats, particularly in studies related to endangered species, has shown that it is not just chemical or biological pollutants that can impair species health and survival rates. Physical properties such as temperature and dissolved oxygen are also very important to aquatic organisms.

2.2 TEMPERATURE AND AQUATIC HABITAT.

Pacific Northwest salmonids are cold-blooded. Their distribution, health, and survival depend on the temperature of

Great blue heron Source: Skillings Connolly, Inc.

the water in which they live. Certain activities in the life of a salmonid are triggered by water temperature, such as cooler river water temperatures in the fall which signal the time for upstream migration. To some degree, fish can tolerate the seasonal swings in temperature and the more dramatic variations in climatic conditions that push temperatures outside the optimal range. However, there is a clear connection between rising temperatures in many Northwest streams and reductions in salmonid populations in the same areas. Numerous studies since 1985 have documented declines in Oregon and Washington salmonid populations where temperature was identified as a contributing factor. (1)

Human activities have caused increases in stream water temperature in a number of ways. The following list summarizes activities that contribute to increasing the thermal input to the river, reducing the amount of groundwater that serves to moderate stream temperatures, or reducing the capacity of a river to absorb heat. (1)

• Urban development, timber harvest, land clearing for agricultural purposes, and livestock grazing have removed streamside vegetation that provides shade over rivers and streams. When the water receives direct sunlight, it is warmed.

- Stream bank erosion and sedimentation loading in the stream, also caused by removal of streamside vegetation, increases the solar heat transfer in the stream. Erosion causes the stream banks to widen and the streambed to become shallower.
- Water discharges from a variety of sources can add heat to the stream. These sources include stormwater runoff, industrial discharges, wastewater treatment plant effluent, and irrigation return flows.
- Withdrawal of excessive quantities of water from a river can significantly impact its capacity to absorb heat. The smaller volume of water remaining instream will heat more quickly and dissipate heat from a warm discharge less effectively.
- Reshaping a river for flood control, urban development, or agricultural purposes can also contribute to impairment of a river's natural ability to moderate temperatures. Straightening, channeling, diking, and dam construction can reduce the flow of groundwater through natural flood channels and through the hyporheic zone, where groundwater flows under and through the riverbed. Dams and reservoirs create different temperature patterns within the river system. (1)

2.3 REGULATORY BACKGROUND. Washington's adoption of temperature water quality standards in November 2006 was preceded by EPA Region 10's development of guidance on this same topic. The guidance document, *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards*, issued in April 2003, was the culmination of a three year process of scientific study and technical review, interagency policy discussions, peer review, and public input. The statutory basis for EPA's guidance is imbedded in the federal Clean Water Act, the goal of which is to restore and maintain the chemical, physical, and biological integrity of the nation's waters, and where possible, to achieve water quality that provides for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water. (1)

In addition to the Clean Water Act, development of temperature standards is considered critical to the protection and recovery of several species of Pacific Northwest salmonids listed as threatened or endangered under the Endangered Species Act. Water temperature is a significant characteristic of cold water fish habitat. EPA recognized that state and tribal water quality standards for temperature would have substantial influence on the restoration and maintenance of healthy salmonid populations in Pacific Northwest rivers and streams.

The states of Oregon, Washington, Idaho, and Alaska, among many other states that have cold water fish, have adopted temperature water quality standards. Implementation of the standards varies somewhat from state to state, often depending on the extent to which water body impairment is due to temperature as opposed to other contaminants. Each state is required to conduct a statewide water quality assessment every two years and submit the results to EPA. Those water bodies found to have pollution levels over water quality standards are placed on the "303(d)" list. A water cleanup plan, also known as a Total Maximum Daily Load (TMDL), must be developed for each of the listed water bodies to address the pollutant levels and restore the stream reach, river segment, or lake to a cleaner condition.

In 2004, 14 percent of the water body segments assessed by Ecology were listed as candidates on the 303(d) list. Of these 1,700 water body segments representing about 800 rivers and lakes, 33 percent

were listed because of temperature. Fecal coliform contamination affected another 29 percent. Low levels of dissolved oxygen were the reason 13 percent of the water bodies were listed. For another 6 percent of the listed waters, pH values were outside the acceptable range. High phosphorus levels affected 1 percent of the listings, and other pollutants including metals and toxics accounted for 17 percent of the waters listed. (2)

A TMDL is a pollutant-specific sum of the allowable quantities of that pollutant from both point and non-point sources that the water body can receive and still meet state water quality standards. The TMDL calculation includes a margin of safety, accounts for natural seasonal variations, and must be consistent with the use designation assigned to the water body. The TMDL establishes waste load allocations for each of the major pollutant sources feeding into the water body. For a point source, the waste load allocation is tied to the NPDES (National Pollutant Discharge Elimination System) discharge permit. States, Tribes, and EPA Region 10 have formed a partnership for TMDL development. The states have the primary responsibility for developing TMDLs. All TMDLs must be approved by EPA. (3)



Skagit River, Washington Source: Image by David Tarsi, Creative Commons Attribution-ShareAlike 2.5 www.shared-source-initiative.com

2.4 WASHINGTON'S TEMPERATURE WATER QUALITY STANDARDS. Washington's new water quality standards for temperature establish protection designations for fresh water bodies based on aquatic life uses, recreational uses, and water supply uses. Temperature criteria are listed for the eight identified aquatic life uses. Marine water protection designations are based on aquatic life uses and shellfish harvesting. Use designations are listed for specific Washington water bodies by water resource inventory area in WAC 173-201A-602. General use designations for water bodies not named in Table 602 are provided in WAC 173-201A-600, as are the descriptions of the various use categories.

The complete text of WAC 173-200A-200, "Fresh water designated uses and criteria," where the new temperature water quality standards are established for Washington, is provided in the Appendix .

A summary of the standards is provided in the table below. A temperature limitation in an NPDES permit may be the result of a TMDL for an impaired water body. This manual may help the permittee establish or maintain compliance with that requirement.

SUMMARY OF WASHINGTON'S WATER QUALITY TEMPERATURE STANDARD				
CATEGORY of AQUATIC LIFE USE	HIGHEST 7-DADMax			
Char spawning	9°C (48.2°F)			
Char spawning and rearing	12°C (53.6°F)			
Salmon and trout spawning	13°C (55.4°F)			
Core summer salmonid habitat	16°C (60.8°F)			
Salmonid spawning, rearing, and migration	17.5°C (63.5°F)			
Non-anadromous interior redband trout	18°C (64.4°F)			
Indigenous warm water species	20°C (68°F)			

7-DADMax is the 7-day average of the daily maximum temperatures.

If the receiving water is warmer than the criteria in the table above (or within 0.3°C) due to natural conditions, cumulative human impacts may not cause the 7-DADMax temperature to increase more than 0.3°C.

If the receiving water is cooler than the criteria in the table above, (1) incremental temperature increases from individual point sources may not exceed 28/ (T+7) at the mixing zone boundary; and (2) incremental temperature increases from the combined effect of all nonpoint sources must not exceed 2.8°C. T is the background temperature measured at a point unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.

Temperatures are not to exceed the criteria at a probability frequency of more than once every ten years on average.

Special criteria also apply to specific locations and timeframes identified by Ecology for the protection of native char, salmon, and trout reproduction.

Source: Washington Administrative Code 173-201A-200(1)(c).

2.5 SOURCES OF ADDITIONAL INFORMATION.

- U.S. Environmental Protection Agency, April 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards, EPA 910-B-03-002. Region 10, Office of Water, Seattle, WA.
- (2) Washington Department of Ecology, June 2005. "Water Quality Assessment for Washington, Summary Information."
- (3) U.S. Environmental Protection Agency, TMDL website updated April 2007. "Introduction to TMDLs" and "Overview of Current Total Maximum Daily Load TMDL Program and Regulations," at <u>www.epa.gov/owow/tmdl.html.</u>
- (4) Washington Department of Ecology, December 2002. "Evaluating Standards for Protection of Aquatic life in Washington's Surface Water Quality Standards, Temperature Criteria, Draft Discussion Paper and Literature Summary."

This page was intentionally left blank.

3.0 OVERVIEW OF APPROACHES TO REDUCE THERMAL IMPACTS TO RECEIVING WATERS

3.1 UNIQUE SOLUTIONS. Each situation is unique. By virtue of geographic location, climate, type and size of treatment plant, land availability, geology and soil types, proximity to other features, size of community, and a host of other variables, each wastewater treatment plant that is faced with having to reduce its temperature impacts will have a unique set of parameters and conditions to be considered. There is no one-size-fits-all solution to the temperature problem.

It is helpful to understand what the contributing factors are to elevated temperatures in the receiving water. Chances are, there are several. Temperature modeling may need to be done to determine the potential effectiveness of methods being considered. The assistance of a wastewater engineer to help with the process of determining a solution and designing it properly is very important.

3.2 MULTIPLE APPROACHES. Faced with the issue of having to reduce the thermal impact of the discharge from a particular wastewater treatment plant, decision makers may wish to formulate a combination of methods. There are a number of reasons why this might be advantageous. One is improving the probability of success. Another is to invite public interest in the issue, generate support for and ownership in the solution, and ultimately inspire community financial support. If industrial dischargers contribute to the problem, getting them to address their own discharges will shift some of the financial burden to the private sector. Another reason is consideration of collateral impacts. An array of methods may avoid or lessen an undesirable byproduct of one or more of the approaches, or may provide additional benefits beyond reducing thermal impact that enhance value to the environment and community.

Two municipal wastewater treatment plants in Oregon have embarked on a multi-level strategy to reduce their thermal impacts on their respective receiving waters. The Durham Advanced Wastewater Treatment Facility in Tigard and the Rock Creek Advanced Wastewater Treatment Facility in Hillsboro, both owned and operated by Clean Water Services, are located in the Tualatin River Basin in northwestern Oregon. The Tualatin River and most of its tributaries were listed on the 303(d) list as water quality impaired. In 2001, the Oregon Department of Environmental Quality issued TMDL requirements for the pollutants affecting Tualatin waters: bacteria, dissolved oxygen, phosphorus, and temperature. (1)

The NPDES permit issued to the Durham and Rock Creek treatment plants is a watershed-based waste discharge permit. The permit addresses four municipal treatment works, one municipal separate storm sewage system (MS4), and individual stormwater permits for the Durham and Rock Creek plants. Clean Water Services was required to prepare a Temperature Management Plan which described the proposed approach that will be implemented to meet the temperature requirements established in the temperature TMDL. This Plan described the temperature reduction methods considered and those that were selected for implementation.

Methods considered but not selected for reducing thermal impacts from the Durham and Rock Creek Treatment Facilities included:

- Evaporative cooling (cooling towers, spray ponds, cooling ponds)
- Mechanical cooling (refrigeration, heat pump)
- Wetlands treatment
- Exportation of the effluent outside the Tualatin Basin
- Removal of in-stream ponds
- Groundwater recharge with treated effluent. (1)

Clean Water Services selected the following temperature reduction methods for the two treatment facilities:

- Reclamation and reuse for irrigation
- Covering the primary clarifiers to limit solar radiation
- Source control for industrial customers subject to pretreatment requirements
- Flow augmentation using water from nearby reservoirs to increase flow in Tualatin River¹
- Streamside shading in degraded stream corridors. (1)

Reclamation and reuse is anticipated to be the most effective method among those selected to reduce thermal impacts to the Tualatin River. Shading projects on private properties will be done through an incentive program, which is bringing a lot of public attention to the issue of river temperature and the need for different land use and water resource strategies to preserve cold water fish habitat.

3.3 METHOD CATEGORIES.

A number of different approaches to reducing or eliminating the heat load impact of municipal wastewater treatment effluent to surface water are described in the following sections.

Section 4.0 addresses approaches to reducing the temperature of wastewater before it reaches the wastewater treatment plant. Depending on the community and types of industrial wastewater customers, these methods may provide some reduction in effluent temperature. One or more of these methods may be effective in combination with other techniques.



Heritage Park Fountain, Olympia, WA Source: Skillings Connolly Inc.

Section 5.0 describes **modifications that can be made inside the wastewater treatment plant** that may prevent or reduce heating of the wastewater while it is being processed.

¹ Note: Flow augmentation and shading are both methods that involve thermal load trading credits in the Clean Water Services Temperature Management Plan. Trading is not addressed in this report. Further information on the subject can be found in the documents noted in Section 3.5.

Over a dozen methods are described in Section 6.0 that involve **changes in the way effluent is discharged from the treatment plant.** In general, these options have relatively low to moderate initial costs and low to moderate operational costs. Site specific characteristics may prohibit the use of one or more of these methods, or cause them to be too expensive to be attractive. Each one needs to be evaluated based on the circumstances of the specific treatment plant.

Finally, Section 7.0 addresses methods that involve **direct cooling of the effluent after treatment and prior to discharge.** Some of these methods involve equipment that is relatively expensive to procure and operate.

3.4 COST CONSIDERATIONS. No doubt most readers will have one big question on their minds as they muddle through all this information: How much will it cost? This is not a simple question to answer. There are so many variables to be considered for any one particular location, that it would be misleading to provide specific cost information on methods. Nearly all of the cooling methods presented here will require some level of engineering and/or temperature modeling. The characteristics unique to a specific treatment plant are important when it comes to determining actual implementation costs. In some cases, a cooling method may work famously in Moses Lake (eastern Washington) and miserably in La Conner (western Washington). Some methods may not be physically possible due to land use constraints, lack of real estate, or lack of stream flow. The method descriptions provide a general idea of initial capital costs and operation and maintenance costs. Site specific circumstances may cause a generally inexpensive method to be practically infeasible or down right outrageously expensive for a particular situation. The expertise of a wastewater engineer can assist in this part of the evaluation process.

3.5 SOURCES OF ADDITIONAL INFORMATION.

- (1) Clean Water Services, February 2005. Revised Temperature Management Plan for the Rock Creek and Durham Wastewater Treatment Facilities.
- (2) Oregon Department of Environmental Quality, July 2005. National Pollutant Discharge Elimination System Watershed-Based Waste Discharge Permit, Permit Nos. 101141, 101142, 101143, 101144, and MS4, issued to Clean Water Services for Durham Advanced Wastewater Treatment Facility (Tigard), Forest Grove Wastewater Treatment Facility (Forest Grove), Hillsboro Wastewater Treatment Facility (Hillsboro), Rock Creek Advanced Wastewater Treatment Facility (Hillsboro), and Municipal Separate Storm Sewer System.

This page was intentionally left blank.

4.0 COOLING EFFLUENT WHILE IT IS STILL INFLUENT

There are a few "source reduction" approaches to reducing the temperature of wastewater before it reaches the wastewater treatment plant. Depending on the community and types of industrial wastewater customers, these methods may provide some reduction in effluent temperature. One or more of these methods may be effective in combination with other techniques described in later sections of this manual.

4.1 PUBLIC AWARENESS AND EDUCATION. For someone who is employed by local government to provide public services such as sewage treatment, clean water, solid waste collection, or a host of other beneficial activities, there is great value in having a community that understands the challenges caused by competing land and water uses, increasing levels of environmental regulation, and the value of maintaining natural habitat and livable communities. There is also value in having a community that recognizes the cost of environmental protection and public service improvements. This understanding comes through educational efforts, bringing issues and ideas to community forums, local newspapers, and frequent friendly conversations.

If a municipal treatment plant is required to implement an effluent cooling method, ultimately the community will pay for the selected cooling system and for its operation and maintenance costs. The community might also be able to assist in implementing a cost-effective solution. Therefore, investing effort in educating the community about instream temperature issues and their impact on the treatment plant would be time well spent.

The impact that residential customers might have on reducing wastewater temperatures at their homes is realistically not very significant. Energy conservation measures to reduce hot water tank temperatures and using less hot water can have some impact on wastewater temperature reduction, but by itself, this approach is not likely to result in the temperature reductions required by a discharge permit. If there are industrial wastewater customers contributing heated wastewater to the sanitary system, there may be greater potential to achieve temperature reductions in working with them. This approach is discussed in more detail below.

Water conservation has long been discussed in communities where water is scarce. As a temperature reduction method, however, water conservation is not considered to provide much benefit. For example, low flush toilets will reduce the amount of <u>cool</u> water flowing to the treatment plant. On the other hand, community planting programs to increase streamside shading could be very effective in terms of reducing the temperature of the river or stream into which the treatment plant's effluent flows. This approach has been embraced by residents in the Tualatin River Basin where the Tualatin River is experiencing higher than normal temperatures.

4.2 PRETREATMENT OF HEAT LOADS. Pretreatment of identified heat loads is accomplished through a process of surveying industrial and commercial customers of the wastewater treatment plant. Power plants, laundries, food processors, chemical plants, refrigeration plants, and other processing or manufacturing entities may be generating heated wastewater that is sent to the municipal treatment plant. Pretreatment regulations can be adopted that establish a temperature limit for wastewater allowed into a municipal plant. It then becomes the responsibility of the heated wastewater generator to cool its wastewater before it enters the city sewer.

<u>Applicability</u>. This method would be most applicable where there are one or more significant wastewater customers that discharge heated water to the sewer system. This method would not be applicable to a municipal treatment plant that serves only residential customers.

<u>Potential Benefits and Disadvantages.</u> The potential benefits of this approach are (1) placing the responsibility for pretreatment on the wastewater generator as opposed to the entire community, (2) avoiding the financial burden of implementing a cooling method at the municipal treatment works, (3) addressing only the sources that contribute the greatest heat load, and (4) lots of precedence for this approach. A potential disadvantage of this approach is the additional staff time that may be required to establish a pretreatment ordinance, educate customers regarding their responsibilities, and conduct enforcement.

<u>Engineering Considerations.</u> There should be an engineering evaluation of the effectiveness of the methods selected and employed by industrial and commercial customers to reduce the temperature of their wastewater. This will also require additional staff time on the part of the city to review the temperature reduction proposals and approve plans.



Finex steel plant in Pohang, Korea Source: Daily News in English About Korea, May 31, 2007

Effectiveness of Method. The effectiveness of this method in a particular situation depends on the heat load contributed by industrial and commercial sources and other factors that may also contribute to the temperature of treated effluent from the municipal treatment plant. Temperature modeling, or at least a thermal balance calculation (considering heat input in and heat losses out) may be needed to determine the relative impacts of various heat contributions. Theoretically, removal or reduction of heat load before the wastewater enters the treatment plant is one of the best methods of reducing the temperature of the effluent.

<u>Cost.</u> This approach requires a commitment of community leaders to adopt and enforce a pretreatment ordinance. Additional city staff may be required to implement a pretreatment program. There is no capital cost or operating cost to the treatment plant.

<u>Locations Where Method Is Used.</u> There are many cities that have adopted pretreatment ordinances or regulations that limit pollutant concentrations and physical parameters of wastewater to be processed by the city. Under the federal rules, any Publicly Owned Treatment Works (POTW) with a total design flow greater than 5 million gallons per day (MGD) or a smaller POTW that has "significant industrial users", is required to establish a local pretreatment program. Smaller facilities may establish a pretreatment program, but are not required to do so under the federal rules.

Many cities have adopted the federal pretreatment guidelines found at 40 CFR 403. Specific prohibitions provided in the federal rules are listed below. Provision 5 limits wastewater at the treatment plant to 104°F.

Specific Discharge Prohibitions in the Federal Pretreatment Program
The following pollutants shall not be introduced into a POTW:
1) Pollutants which create a fire or explosion hazard in the POTW, including but not limited to, wastestreams with a closed cup flashpoint of less than 140 degrees Fahrenheit or 60 degrees Centigrade using the test methods specified in 40 CFR Part 261.21;
2) Pollutants which will cause corrosive structural damage to the POTW, but in no case discharges with pH lower than 5.0, unless the works is specifically designed to accommodate such discharges;
3) Solid or viscous pollutants in amounts which will cause obstruction to the flow in the POTW resulting in interference;
4) Any pollutant, including oxygen demanding pollutants (BOD, etc.) released in a discharge at a flow rate and/or concentration which will cause interference with the POTW;
5) Heat in amounts which will inhibit biological activity in the POTW resulting in interference, but in no case heat in such quantities that the temperature at the POTW treatment plant exceeds 40°C (104°F) unless the Approval Authority, upon request of the POTW, approves alternative temperature limits;
6) Petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through;
7) Pollutants which result in the presence of toxic gases, vapors, or fumes within the POTW in a quantity that may cause acute worker health and safety problems;
8) Any trucked or hauled pollutants, except at discharge points designated by the POTW.
Source: 40 CFR §403.5(b)

Sources of Additional Information.

- (1) U.S. Environmental Protection Agency, February 1999. *Introduction to the National Pretreatment Program*, EPA-833-B-98-002. Office of Wastewater Management.
- (2) U.S. Environmental Protection Agency, October 1983. *Guidance Manual for POTW Pretreatment Program Development*. NTIS PB93-186112.
- (3) U.S. Environmental Protection Agency, December 1987. *Guidance Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program.* EPA-833-B-87-202.
- (4) U.S. Environmental Protection Agency, September 1986. *Pretreatment Compliance Monitoring and Enforcement Guidance.*



Pig iron furnace Source: Farrell Grehan/Photo Reserachers, Inc.

5.0 IN-PLANT MODIFICATIONS TO COOL EFFLUENT

Methods in this section are modifications that can be made inside the wastewater treatment plant that may prevent or reduce heating of the wastewater while it is being processed.



This page was intentionally left blank.

5.1 CLARIFIER COVERS

DESCRIPTION. This method provides shade over the clarifiers to reduce the amount of solar radiation reaching the wastewater prior to discharge. Covers have been used in wastewater treatment plants for a long time, primarily as a means of odor control and to prevent freezing in very cold climates. For these applications, covers are most commonly used over the primary clarifiers and digesters, and employ fans and odor treatment to withdraw and process the emissions from the basins. Covers are also used to control algae growth.

There are three primary types of material used for covers: fabric, fiberglass and aluminum; and three common shapes: flat, truss supported, and dome. Access to the clarifiers is important, therefore most cover structures provide walkways, detachable sections, and/or adequate space between the cover and the basin water level to permit an operator to enter. Fabric covers are typically tensioned over an aluminum framework. Fiberglass covers may be installed on fiberglass or aluminum supports. Aluminum covers may be flat or dome-shaped. Domes provide a clear-span covering that enables easy access for operators and equipment.

WHERE METHOD WOULD BE MOST APPLICABLE. This method would be most applicable in a treatment plant where solar input increases the temperature of the wastewater in the plant significantly prior to discharge. The most effective application of covers would be on the primary and secondary clarifiers. In the primary clarifiers, aeration may provide some evaporative cooling, depending on the ambient temperature and humidity.

POTENTIAL BENEFITS. Benefits of this method include reduction of solar input to the wastewater, excluding pollutants or debris from entering the clarifiers, excluding rain and snow from entering the basins, and reduction of algae growth. In addition, covers have minimal operating costs and low maintenance costs.



Aluminum clarifier cover at East Millinocket, Maine, treatment plant Source: www.katahdingateway.com/eastmill/

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Clarifier Covers

<u>POTENTIAL DISADVANTAGES.</u> Potential disadvantages of this method include cost, and prevention of heat loss from the wastewater during cold months, exacerbating the difference in temperature between the treated effluent and receiving water in the winter.

ENGINEERING CONSIDERATIONS. Parameters to be considered include the amount of solar radiation, surface area of the basins, access points, collateral use for odor control (ventilation), snow load, capital costs, and maintenance costs.

EFFECTIVENESS OF

METHOD. Solar input is a significant source of effluent warming during the summer months. Removal of most of the solar heat gain will provide a substantial decrease in temperature rise as the effluent is in the treatment plant. There will be simultaneous reduction in convective heat loss.

Actual data comparing effluent exit temperatures before basins were covered with effluent temperatures after covers were installed were not located.



Reinforced membrane cover supported on a low profile aluminum arch frame. Source: Geomembrane Technologies Inc., www.gti.ca/info.html

<u>COST.</u> Cost of an aluminum

dome is roughly \$2,000 per diameter foot, installed. For a 50 foot diameter clarifier, an aluminum dome cover would cost approximately \$100,000. (1)

LOCATIONS WHERE METHOD IS USED. There were no wastewater treatment plants identified that use covers over the clarifiers for the purpose of reducing effluent temperature.

SOURCES OF ADDITIONAL INFORMATION.

- (1) Personal communication with John Simons, Goble Sampson Associates, Issaquah, WA, May 15, 2007.
- (2) Creative Pultrusions, Inc., Alum Bank, PA, <u>www.creativepultrusions.com</u>, 888-274-7855.
- (3) Geomembrane Technologies Inc., Fredericton, NB, <u>www.gti.ca/info.html</u>, 506-452-7304.
- (4) Ultraflote Corporation, Houston, TX, <u>www.ultraflote.com</u>, 713-461-2100.
- (5) Stanco Projects Ltd., Richmond, BC, <u>www.stancoprojects.com</u>, 604-273-6441.
- (6) TEMCOR, Gardena, CA, <u>www.temcor.com</u>, 310-523-2322

5.2 DISINFECTION ALTERNATIVES

DESCRIPTION. Three methods of disinfection are in common use in municipal treatment plants in Washington: hypochlorite solution, chlorine gas, and ultraviolet irradiation (UV). UV systems employ mercury lamps that transmit light in the range of 240 to 290 nanometers, which is the effective germicidal range. Some of this energy is transformed to heat as it contacts the effluent in the UV channel. Thermal energy may also be transmitted to wastewater in the chlorine contact basin if it is open to sunlight. Further study of temperature during the disinfection process is needed to provide an accurate comparison among the methods. However, some steps can be taken to minimize heat input during this part of the treatment process.



UV lamp inside a protective quartz sleeve Source: US Filter, Wallace & Tiernan Products, Journal AWWA

One option is to enclose the chlorine contact chamber or UV system to reduce the amount of solar heating of the wastewater during the disinfection process. More information about minimizing solar input can be found in the section on Clarifier Covers. Some UV disinfection systems are designed with the lamps inside an opaque tubular enclosure.

WHERE METHOD WOULD BE MOST

APPLICABLE. Should one disinfection method be shown to be advantageous over another in terms of temperature control, a change in disinfection system would be most applicable if the existing

system were already scheduled for replacement for another reason. The relative contribution of heat load from the disinfection system is considered to be quite small relative to other factors within the treatment system and relative to other approaches that involve changes in effluent discharge.

POTENTIAL BENEFITS. Benefits of replacing an existing disinfection system with one that would potentially assist in limiting heat gain during treatment might include (1) improved disinfection performance, (2) easier operation and maintenance, (3) reduction in effluent temperature, and possibly (4) lower cost.

POTENTIAL DISADVANTAGES. Potential disadvantages of disinfection system replacement may include up front cost and operating cost. However, the importance of disinfection in terms of public health cannot be over emphasized. In terms of cooling wastewater treatment plant effluent, this method may not deliver significant results.



Cutaway photo of a UV system that uses an automatic quartz sleeve cleaning system Source: US Filter, Wallace & Tiernan Products, Journal AWWA

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Disinfection Alternatives

ENGINEERING CONSIDERATIONS. Technical considerations regarding heat gain during disinfection require further study. The investigation itself could be accomplished readily using temperature probes and data loggers for recording temperatures of the wastewater at frequent and regular intervals both before and after disinfection. These data, normalized to flow rates, could be used to calculate thermal balance through this part of the treatment plant. Comparison of these results with treatment plants using different disinfection systems would provide a much better understanding of thermal behavior during disinfection.

Engineering considerations regarding the most common methods of disinfection include: contact time, concentration of disinfectant or intensity of light, temperature, safety concerns regarding the use and storage or toxic chemicals, specific wastewater chemistry, disinfection byproducts, dechlorination, and space requirements.

EFFECTIVENESS OF METHOD. The

differences between disinfection methods in terms of controlling heat load are not yet well enough understood to provide an indication of the effectiveness of this approach for reducing effluent temperatures. However, this approach by itself is not likely to provide a significant reduction in effluent temperature.



Covered chlorination tank Source: Falke Bruinsma, people.howstuffworks.com/sewer3.htm

COST. Replacement of an existing disinfection system is likely to be very expensive. Costs between hypochlorite, chlorine gas, and UV systems vary significantly. If dechlorination is required, this will increase system cost by approximately 30 to 50 percent. (4) Actual costs will depend on the choice of system, potential to reuse existing equipment, flow volumes, and wastewater characteristics.

SOURCES OF ADDITIONAL INFORMATION.

- (1) Metcalf & Eddy, Inc., 2003. <u>Wastewater Engineering, Treatment and Reuse</u>, Fourth Edition, McGraw-Hill, Chapter 12, "Disinfection Processes."
- (2) Washington Department of Ecology, October 2006. *Criteria for Sewage Works Design*, Chapter T5, "Disinfection."
- (3) Dussert, Bertrand W., July 2005. "Essential Criteria for Selecting an Ultraviolet Disinfection System," in Journal of the American Water Works Association.
- (4) U.S. Environmental Protection Agency, September 1999. "Wastewater Technology Fact Sheet Chlorine Disinfection," EPA 832-F-99-062, Office of Water.

6.0 DISCHARGING FROM THE TREATMENT PLANT

Over a dozen methods are described in this section that involve changes in the way effluent is discharged from the treatment plant. In general, these options have relatively low to moderate initial costs and low to moderate operational costs. Site specific characteristics may prohibit the use of one or more of these methods, or cause them to be too expensive to be attractive. Each one needs to be evaluated based on the circumstances of the specific treatment plant.



Forested wetland, Thurston County, Washington Source: Skillings Connolly, Inc.

This page was intentionally left blank.

6.1 SEASONAL STORAGE

DESCRIPTION. One approach to avoiding or reducing thermal impact to receiving water is to store the treated effluent during the critical temperature period, which is typically the summer and late summer months. In this way, when the stream temperatures are highest and/or when the stream's flow is least able to accommodate the thermal load from treatment plant effluent, the treatment plant does not discharge to the stream. Instead, the treated effluent is held in a reservoir until the stream temperature has decreased and flow increased to a point where discharge can be resumed without harm to aquatic habitat.

To avoid common problems that occur in open impoundments, the storage basin should be equipped with aeration. This could be accomplished using surface aerators, brush aerators, static tube aerators, diffused aeration, or a Speece cone. Aeration and mixing will combat low dissolved oxygen (contributing to odor and unhealthy for fish), excessive growth of algae and phytoplankton, and deterioration of water quality due to bird and rodent populations. Alternatively, an enclosed reservoir could be used. Aeration and recirculation would help maintain water quality within an enclosed reservoir.



Installation of Speece cone in Camanche Reservoir, East Bay Municipal Utility District, California Source: ECO2® Eco Oxygen Technologies, LLC

WHERE METHOD WOULD BE MOST APPLICABLE. This approach would be most applicable in a location where there is sufficient space to construct a reservoir. If the receiving water is effluent dominated, this method could be particularly helpful. Where low instream flows are problematic for fish survival, however, the ease of seasonal storage should be weighed against the benefits of using a direct effluent cooling method and returning the effluent to the stream for flow augmentation.

POTENTIAL BENEFITS. Potential benefits of this method include simplicity of design, and very low operation and maintenance costs.

POTENTIAL DISADVANTAGES. A disadvantage of this method is the removal of hydraulic volume from the receiving water during the storage season. While the treated effluent is being stored, the stream does not benefit from the additional volume contributed by the treatment plant's discharge. For a receiving water that is already flow impaired, this loss of volume could be less

desirable than the discharge of warm effluent. Aeration adds power consumption to the operating cost of this method, but is necessary to avoid a serious deterioration of water quality.

ENGINEERING CONSIDERATIONS. Parameters to be considered in design of a storage reservoir include space available, surface area, depth, average monthly effluent flow rates, precipitation, and monthly average evaporation rates. (1) Because evaporation is typically highest during the months when seasonal storage would be implemented, and precipitation is lowest, the size of an open storage reservoir would be significantly less than the size required for an enclosed reservoir. Both evaporation rates and precipitation vary significantly with geographic location. Historic or average climatic data are available from the National Oceania and Atmospheric Administration (NOAA).

The power input for aeration and destratification of an open basin is roughly 1.14 to 1.89 kilowatts per million gallons (0.30 to 0.50 kilowatts per thousand cubic meters) of water. Actual power consumption may be affected by characteristics of the reservoir, including surface area, aspect ratio, depth, and ambient temperature. (1)

EFFECTIVENESS OF METHOD. This method would be highly effective in any situation where treatment plant effluent has a significant impact on receiving water temperature. This approach completely removes the contribution from the wastewater treatment plant to thermal loading of the receiving water

COST. The cost of implementing this method using an open basin lies primarily in the following features: land area for impoundment basin, puncture and ultraviolet resistant impermeable liner for the basin, aerators, and power consumption for aerator operation. Costs for an enclosed reservoir include: land area for the reservoir, steel tank or flexible bladder tank, aeration/circulation equipment, and power costs. For preliminary estimating purposes, reservoir construction cost is anticipated to range from about \$0.10 to \$0.20 per cubic foot of storage volume (2) for a membrane-lined basin to \$1.00 to \$1.40 per gallon for an enclosed steel tank.

LOCATIONS WHERE METHOD IS USED. There were no municipal wastewater treatment plants identified that are currently using seasonal storage as a method of avoiding thermal impacts to receiving water. However, seasonal storage is employed by the wastewater treatment system in Connell, Washington, which uses a seasonal land application system for disposal of treated effluent. During the growing season, treated effluent is used to irrigate hay on a tract of land set aside for this purpose. During the winter months, treated effluent is stored in a lined basin, to be pumped through sprinklers on the adjoining hay field the following spring and summer.

SOURCES OF ADDITIONAL INFORMATION.

- (1) Metcalf & Eddy, Inc., 2003. <u>Wastewater Engineering, Treatment and Reuse</u>, Fourth Edition, McGraw-Hill, Chapter 13.
- (2) Andrews, J.E., PE, Natural Resource Conservation Service, undated. "Wastewater Storage Pond Design," presentation at Colorado CNMP Workshop. www.colostate.edu/Dept/SoilCrop/extension/Soils/cnmp/Docs/sec8.ppt

6.2 MOVE DISCHARGE LOCATION

DESCRIPTION. This method involves the identification of an alternate location for discharging treated effluent in order to avoid thermal impact to a stream that is already temperature impaired. Many other methods described in this report address moving the discharge from surface water to some form of ground discharge. The approach described in this section focuses on moving the discharge from the affected water body to a different portion of the stream or to a different surface water body altogether.

WHERE METHOD WOULD BE MOST APPLICABLE. This method would be most applicable where another, perhaps larger, body of surface water is located within reasonable proximity to the wastewater treatment plant. This option might be attractive in a location where steep slopes, other geographic or land development constraints, or inadequate soils would prohibit implementation of one of the ground discharge alternatives.

POTENTIAL BENEFITS. Potential benefits of this method include avoiding undesirable thermal impact to the original receiving water, not having to acquire or maintain cooling equipment, the ability to use the method seasonally, and improvement of instream flows in the alternate discharge location.

POTENTIAL DISADVANTAGES. One potential downside to this approach is removal of the volumetric flow from the original receiving water which could compromise water and habitat quality. Another disadvantage could be cost, as an alternate discharge line and possibly one or more pump stations would be needed to export the effluent to another location. Additionally, the thermal load of the effluent could have an adverse impact on the alternate receiving water.

ENGINEERING CONSIDERATIONS. Constructing a new pipeline and pump station to implement this method would require identification of potential receiving water bodies, and analysis of pipeline routes, topography, other buried utilities within the pipeline corridor, rights-of-way, and outfall considerations. Gravity flow is typically preferable to the use of force mains. Preliminary engineering of the pipeline would be needed to provide a meaningful estimate of potential costs.

EFFECTIVENESS OF METHOD. This method would be quite effective in terms of eliminating thermal impact to the original receiving water.

<u>COST.</u> In general, the cost of this approach will depend on the distance from the wastewater treatment plant (WWTP) to the alternate discharge location, topography between the two points, and the volume of wastewater to be conveyed. Numerous corridor specific details will influence cost, including potential mitigation for unavoidable impacts along the route. Installed pipeline costs may range from \$100 per lineal foot for 8-inch pipe up to \$1,000 per lineal foot for 48-inch pipe, in year 2000 dollars. (1)

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Move Discharge Location

This approach was considered for the Rock Creek and Durham Advanced Wastewater Treatment Facilities which discharge into the Tualatin River in Oregon. For the Rock Creek plant, located in Hillsboro, a rough order-of-magnitude cost estimate came to \$77.6 million for two pump stations, 16 miles of new force main, and a new outfall in the Columbia River to handle the projected 2020 design flow of 92 MGD. (2)

Corresponding estimates for the Durham WWTP in Tigard, OR, were \$25 to \$30 million for conveying the discharge about 6 miles to the Willamette River; or \$80 to \$90 million for piping the effluent 22 miles to the Columbia River. The 2020 design flow for these estimates was 52 MGD. (2) This approach was not selected for either treatment facility in the final Temperature Management Plan.

LOCATIONS WHERE METHOD IS USED. There were no municipal wastewater treatment plants identified that are currently using this approach.

SOURCES OF ADDITIONAL INFORMATION.

- (1) Oregon Department of Environmental Quality, July 2000. *Oregon Temperature Management Plan Guidance Manual*, Chapter 5.0 "POTW BMPs".
- (2) Clean Water Services, October 2003. Draft Temperature Management Plan for the Rock Creek and Durham Wastewater Treatment Facilities.
- (3) Paquet, Albert and P. Nelson, CH2M HILL, December 27, 2006. Technical Memorandum: "Summary of Potential Wastewater Effluent Temperature Reduction Technologies in Respect to Proposed Temperature Standards." Prepared for City of Loveland, CO, Water & Power Department.

6.3 MULTIPLE PORT DIFFUSERS

DESCRIPTION. How the effluent is released into the receiving water can significantly impact the localized short-term concentration of pollutants as well as the overall impact of the effluent on the water body. Particularly in situations where the effluent is released through a single port, improvements to receiving water quality can be gained through the use of multiple ports and improved diffuser valve design.

Multi-port diffuser systems release the effluent in several locations simultaneously into the receiving water. This provides for much more rapid and complete mixing. For the purpose of heat dissipation, this is clearly advantageous, as the warm effluent comes into contact more readily with the receiving water, providing faster cooling, thereby presenting far less threat of a critical heat zone for aquatic organisms.

Typical diffuser ports are circular steel orifices. Elastomeric diffusers are now available that offer several advantages over the steel diffuser. They are made of a material that is flexible and durable, rust-proof, corrosion-proof, low maintenance, and essentially unbreakable. Use of multiple "duckbill" diffusers would provide several advantages over a typical single circular discharge opening. Elastomeric duckbill diffusers provide a variable orifice size that changes with flow rate, resulting in improved dispersion velocity at lower flows and reduced head loss through the orifice at higher flows. The "duckbill" shape creates a narrow, rectangular shaped plume, as opposed to the cylindrical plume from a circular orifice. This narrow rectangular orifice can be rotated to the most optimal orientation relative to the flow of receiving water in order to achieve rapid and complete mixing. (1)



Multiple port diffusers on outfall line Source: Red Valve Company, Inc., Carnegie, PA, <u>www.redvalve.com</u> (Data #1031-8/98)

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Multiple Port Diffusers

WHERE METHOD WOULD BE MOST APPLICABLE. This method would be most applicable for retrofitting a facility that currently uses a single point discharge into the receiving water, or an outfall pipe with a very small number of ports. This approach, using flexible diffuser valves, would also be applicable to any plant that discharges to marine water. How effective this approach would be in an effluent-dominated stream (i.e., one where the dilution factor is very low) would need to be determined through modeling.

POTENTIAL BENEFITS. This approach requires no modification to the plant process, no additional cooling equipment, requires little maintenance, and is relatively easy to engineer. Elastomeric diffuser check valves prevent discharged water from flowing back up into the pipe, so they are useful in areas that are tidally influenced or that have variable water levels. This backflow prevention is extremely important for marine dischargers where the outfall is subject to wave or tidal action, and also prohibits intrusion of marine growth inside the outfall pipe. Obstructions in diffuser lines can be very costly to clean out. Outfall lines without backflow prevention require periodic purging or flushing in order to remain clear. (2) In addition, the elastomeric material is abrasion resistant, very durable (service life of 50 years), and requires little or no maintenance. (1)

<u>POTENTIAL DISADVANTAGES.</u> This approach requires retrofitting or possibly replacement of the outfall pipe. Dilution modeling is likely to be required in order to demonstrate its effectiveness for permitting purposes.

ENGINEERING CONSIDERATIONS. Key parameters for specifying the appropriate multiple port diffuser valves include: maximum flow rate, maximum flow velocity, back pressure, line pressure, and discharge location. Temperature modeling would also require specification of the receiving water flow rate, temperature, effluent temperature, effective open area for each orifice, and other ambient parameters.

EFFECTIVENESS OF METHOD. Multiple port effluent diffuser valve systems have been successfully applied in a variety of locations to solve problems related to adverse effluent concentration impacts on receiving water. (3) Power plants have used effluent diffusers for many years to reduce the thermal impact of discharging hot water from cooling towers. (4) Modeling of a specific effluent discharge using the multiple port diffusion approach would demonstrate whether temperature impacts would be successfully mitigated in a particular application.

COST. Costs of implementing this option will vary dramatically depending on flow rate, existing outfall design, and selected diffuser equipment. A meaningful cost estimate for a particular situation can be obtained through a wastewater equipment distributor or representative. As a very rough estimate using year 2000 dollars, installed diffuser costs range from \$200 per foot for 18-inch diameter diffusers up to \$1,500 per foot for 48-inch diffusers. (5)

LOCATIONS WHERE METHOD IS USED. At the municipal wastewater treatment plant in Cedar Rapids, Iowa, the existing outfall line was redesigned into a multi-port diffuser. This approach enlarged the effective dilution zone substantially and cause the effluent to mix with the receiving water more quickly. The new diffuser uses 73 ports evenly spaced across the length of the outfall pipe. Each port has a flexible diffuser valve on a rubber riser and a 45-degree rubber elbow. The particular design of the duckbill diffuser valve maximizes the velocity of the discharging effluent and increases the speed of mixing. (6)
According to the Operations Specialist in charge of the Cedar Rapids treatment plant, before modification of the diffuser system, the heat at the single discharge point did not dissipate in the river for over a mile. With the modified diffuser approach, heated wastewater generally dissipated within 100 yards of each operating discharge port. (6)

The City of Centralia, Washington, recently purchased eight 16-inch effluent diffuser check valves for its outfall into the Chehalis River in order to reduce the impact of the treated effluent on receiving water quality. (7) Results of Centralia's new diffuser system on water quality in the Chehalis River were not available at the time of this writing.

- (1) Red Valve Company, Inc. Application Data Wastewater Treatment, Diffuser System, Tideflex[®], <u>www.redvalve.com</u>.
- (2) Tideflex[®] Technologies, Inc., <u>www.tideflex.com</u>, "Pitfalls of Not Providing Tideflex[®] Diffuser Check Valves on Diffuser Outfall Lines."
- (3) Tideflex[®] Technologies, Inc., <u>www.tideflex.com</u>, case study: "Tideflex[®] diffuser system helps city maintain compliance with EPA chlorine regulations."
- (4) Tideflex[®] Technologies, Inc., <u>www.tideflex.com</u>, case study: "Effluent diffuser eliminates foaming and discoloration problems or Oostanaula River, Georgia."
- (5) Oregon Department of Environmental Quality, July 2000. *Temperature Management Plan Guidance Manual*, Chapter 5.0 "POTW BMPs."
- (6) Tideflex[®] Technologies, Inc., <u>www.tideflex.com</u>, case study: "Tideflex[®] Effluent Diffusers improve water quality, allow for city growth."
- (7) Tideflex[®] Technologies, Inc., <u>www.tideflex.com</u>, case study: "Effluent outfall uses Tideflex[®] diffuser valves."

6.4 EFFLUENT BLENDING

DESCRIPTION. Effluent blending involves mixing the treated effluent with cooler groundwater or surface water prior to discharge. The method typically requires pumping the cooling water into a mixing basin or into the discharge pipe, providing for sufficient mixing time and agitation to ensure relatively uniform temperature in the water at the outfall. The blending water could also be added directly to the receiving water, using the stream itself as the blending chamber.

WHERE METHOD WOULD BE MOST APPLICABLE. This approach would be most applicable where there is an adequate source of groundwater or surface water that could be used for this purpose. Obviously, the temperature of the blending water must be significantly cooler than that of the treated effluent. The greater the temperature differential between the blending water and the treated effluent, the less dilution water would be needed to reach the required discharge temperature. This method would be advantageous in a location where space for implementing other types of cooling methods was severely constrained.

POTENTIAL BENEFITS. The effluent blending approach is the simplest method of all that are described in this report. This method is easy to apply on a seasonal or as needed basis. It has the additional benefit of providing instream flow augmentation—which would be desirable if the receiving water experiences critical periods of low flow.

POTENTIAL DISADVANTAGES. Potential disadvantages of this method are the availability and cost of blending water, or securing water rights for this use. If blending water must be conveyed to the site, the expense of constructing a new pipeline could be a deterrent. The discharge line and outfall may require modification to handle the larger flow volume. Blending water quality must meet the wastewater treatment plant discharge requirements.

ENGINEERING CONSIDERATIONS. The primary engineering considerations are:

- Heat load of the effluent
- Required discharge temperature
- Temperature of the blending water
- Calculated volume of blending water required to meet discharge temperature
- Provision for mixing (basin, pipeline)
- Well, pump, and/or pipeline to convey the blending water to the site
- Discharge line and outfall capacities.

The quantity of blending water can be estimated through a simple thermal balance calculation. The thermal load before blending equals the thermal load after blending, where thermal load is the product of water flow (gpd) and temperature (°C or °F). This calculation should be used for gross estimating purposes only, and does not substitute for the mixing zone equations used by Ecology in preparing discharge permit limits.

 $T_1Q_1 + T_2Q_2 = T_3Q_3$ $Q_3 = Q_1 + Q_2$

where: $T_1 = effluent$ temperature

 T_2 = blending water temperature

T3 = permit required discharge temperature

Q1 = effluent flow rate (mgd)

Q2 = blending water flow rate (mgd)

Q3 = total discharge flow rate (mgd)

Solving for Q₂: $Q_2 = [Q_1(T_1/T_3 - 1)] / (1 - T_2 / T_3)$

Example

A treatment plant processes 1.0 MGD and produces an effluent at 21°C. The plant is required to attain a discharge temperature of 18°C. Groundwater is available at a temperature of 11°C. The quantity of groundwater needed for blending to achieve the desired discharge temperature is 0.43 MGD.

EFFECTIVENESS OF METHOD. This method can be extremely effective. It reduces thermal impact without removing the volumetric flow from the receiving water.

<u>COST.</u> The cost of implementing this method depends on the availability and access to a cool water source. If the source is groundwater, a new well may need to be installed. Well construction typically costs from \$75 to \$150 per foot, depending on site characteristics. New pipeline installation costs roughly \$100 to \$150 per lineal foot, and could be more depending on right-of-way procurement. If blending water is purchased from a utility district or municipality, the cost of water might be negotiated under a special contract.

LOCATIONS WHERE METHOD IS USED. A variation of this method is proposed for use in the Tualatin River Basin in northwest Oregon by Clean Water Services. Water released from Scoggins and Barney Reservoirs during mid-summer will augment the flow in the Tualatin River. During the summer months, low river flows are correlated with higher temperatures and reduced water quality. The additional water will both cool the effluent from two wastewater treatment plants in Hillsboro and Tigard, OR, as well as restore instream flow to improve aquatic habitat. (1)

Another variation of this method is being considered by the City of Loveland, Colorado, where the municipal treatment plant discharges into the Big Thompson River. Reclaimed gravel pit ponds are located adjacent to the WWTP. Groundwater in the ponds could potentially be used to blend with the treated effluent. Key factors in this approach include obtaining information regarding the temperature and flow capacity of the ponds, agreements with the owners of the reclamation ponds, obtaining a discharge permit to direct the effluent into the ponds, and installation of a pump station. (2)

- (1) Clean Water Services, February 2005. Revised Temperature Management Plan for the Rock Creek and Durham Wastewater Treatment Facilities.
- (2) Paquet, Albert and P. Nelson, CH2M HILL, December 27, 2006. Technical Memorandum: "Summary of Potential Wastewater Effluent Temperature Reduction Technologies in Respect to Proposed Temperature Standards." Prepared for City of Loveland, CO, Water & Power Department.

6.5 LAND APPLICATION

DESCRIPTION. This approach employs sprinklers or another irrigation system to deliver treated effluent to an area where trees or other vegetation is being cultivated. This method can be used seasonally, diverting treated effluent from direct discharge to surface water to land application when stream temperatures are most critical.

WHERE METHOD WOULD BE MOST

APPLICABLE. Land application of treated effluent would be most applicable in a location where trees or other crops not grown for human consumption are within a reasonable proximity to the treatment plant. The soil must have sufficient porosity to allow the treated effluent to infiltrate the surface and reach the root zone. This method would also be advantageous in a location where the treatment plant is a long way from surface water. Piping to a distant discharge point can be quite expensive.

POTENTIAL BENEFITS. The most obvious potential benefit of this approach is the reuse of treated wastewater. This reuse may replace the



Source: Rain Bird Corporation, www.rainbird.com

use of potable water for irrigation. In an area where potable resources are scarce or expensive, wastewater reuse can be a very valuable alternative. The nitrogen and phosphorus in effluent are nutrients in irrigation water, not contaminants. This nutrient-rich water can be used on a variety of areas such as golf courses, parks, plant nurseries, timber, and turf farms, depending on effluent classification for reuse. The method is also relatively inexpensive to install, operate, and maintain.

POTENTIAL DISADVANTAGES. One potential drawback to this method is the requirement under Washington regulations to meet reclamation and reuse standards (see Wastewater Reclamation and Reuse section). This may require an upgrade to the treatment systems within the treatment plant. For some communities, locating enough suitable land to receive the reclaimed wastewater may be difficult. Adverse soil conditions, topography (such as steep slopes), and existing land use may constrain the use of land application for treated wastewater.

ENGINEERING CONSIDERATIONS. Soil permeability is a key parameter for determining the extent of land needed for a land application system. Very low soil permeability would increase the land requirement substantially. The amount of moisture in soil may also be a constraining factor. A water balance should be calculated to determine the effects of water loss through evapotranspiration, infiltration, vegetative consumption, and rainfall runoff, and the inputs of rainfall and wastewater irrigation. Total land area needed to accommodate the hydraulic load can then be determined. If too much water is applied, too much water may remain in the root zone and plant health will be affected. A nitrogen balance should also be developed for the irrigation site to ensure that excess nitrogen will

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Land Application

not result in groundwater contamination. (1) Regulations require that land application be at normal agronomic rates.

If land application is employed during the winter as well as in the summer months, consideration must be given to an alternate discharge method or to storing the effluent until irrigation season. Provisions must also be made to protect the irrigation system during the winter, including freeze protection and draindown. (1)

Other parameters common to all ground discharge methods must also be considered in site selection and engineering of the irrigation system. These include: topographic features, site lithology, depth to groundwater, groundwater gradient and direction, etc.

EFFECTIVENESS OF METHOD. Provided that irrigation is applied at rates commensurate with the permeability of the soils, vegetative uptake, precipitation, and local evapotranspiration rates, and there is no surface runoff that impacts surface water, this method can be an effective approach to avoiding thermal impacts to surface water. The effectiveness of the irrigation system itself will depend on its conveyance design and on the delivery method. Delivery methods fall into three categories: sprinkler, surface, and drip. Sprinkler systems are the most common and can be used on all types of crops. Drip systems are the most efficient. Surface systems present the most challenge to providing uniform distribution. (1)



Vineyard with drip irrigation system Source: Rain Bird Corporation, www.rainbird.com

COST. The most significant cost in this approach is likely to be the cost of land, if land has to be purchased, or the cost of treatment plant upgrades to produce a higher quality effluent to meet reuse standards. There may also be a cost to convey the treated effluent to the discharge site. Gravity flow to a location downgradient from the treatment plant may be less expensive than pumping the effluent up to a higher elevation. If a higher water quality is required than what is currently produced by the treatment plant, an upgrade may be required in order to use land application for effluent disposal. Pumps, valves, backflow preventers, irrigation piping, and sprinklers or emitters comprise the primary components of the land application system. In some instances, a storage reservoir may be used from which to draw the effluent for irrigation. Operating costs are typically low. Maintenance expenses may depend on geographic location, winter-summer temperature extremes, and other site specific conditions.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Land Application

LOCATIONS WHERE METHOD IS USED. Land application is the treated effluent discharge method currently employed by the Washington Corrections Center wastewater treatment plant, located near Shelton, Washington. This facility processes approximately 300,000 gpd. Effluent is sprinkled on 17 acres of trees. Tree growth has been two to four times more rapid during the years of land application than it was prior to the implementation of this method.

A second correctional facility in Washington uses land application seasonally. The Olympic Corrections Center NPDES permit requires daily temperature monitoring of the stream into which the treatment plant's effluent is normally discharged. When the receiving water warms in late summer, the treatment plant pumps the treated effluent to a land application system, sprinkling several acres of trees on neighboring Washington Department of Natural Resources forest property.

The City of Walla Walla operates a 12 MGD sewage treatment plant. During the irrigation season, the plant's effluent is directed to the Gose and Blalock Irrigation Districts. (4)

- (1) Ohio State University Extension, "Reuse of Reclaimed Wastewater Through Irrigation," Bulletin 860, <u>ohioline.osu.edu/b860.html.</u>
- (2) L.G. James, et al, December 2001. *Irrigation Requirements for Washington, Estimates and Methodology*, Washington State University Cooperative Extension, EB1513.
- (3) Rain Bird Corporation, <u>www.rainbird.com</u>.
- (4) Washington Department of Ecology, June 2005. National Pollutant Discharge Elimination System Waste Discharge Permit No. WA-002462-7, City of Walla Walla.

6.6 UNLINED PONDS OR LAGOONS

DESCRIPTION. This approach uses an unlined wastewater storage impoundment or lagoon made by constructing an embankment or excavating a pit to temporarily contain treated effluent and allow it to percolate into the subsurface. In Washington, this disposal method is permitted through a State Waste Discharge Permit (WAC 173-216) and must comply with the Groundwater Quality Standards in WAC 173-200. (1) A hydrogeologic study and monitoring plan must be prepared to satisfy permit application requirements.

WHERE METHOD WOULD BE MOST APPLICABLE. This method would be most applicable where there is a suitable location and soils for construction of a pond or lagoon in close proximity to the wastewater treatment plant.

POTENTIAL BENEFITS. Potential benefits of this approach are relatively low construction cost (depending on the cost of real estate) and very low operating and maintenance costs.

POTENTIAL DISADVANTAGES.

Potential disadvantages of the unlined pond/lagoon approach are the need to meet Washington's groundwater quality standards at the point of discharge into the pond or lagoon. No credit is given for potential treatment of the wastewater during percolation through the subsurface. For some contaminants, groundwater quality standards are more stringent than surface water standards. Thus, additional treatment of the wastewater may be required before discharge to an unlined pond, which would entail additional expense.



Unlined pond under construction Source: www.aquaticbiologists.com/images/pond_liners3.jpg

ENGINEERING CONSIDERATIONS. Key parameters to be considered in the implementation of this method include: soil characteristics and lithology; geological features such as faults, fractures, fissures, or other subsurface attributes that may affect wastewater movement and contaminant migration; hydrogeological characteristics such as transmissivity, hydraulic conductivity, porosity, and dispersivity; and groundwater flow parameters such as flow rate and gradient. Precipitation, evaporation, and evapotransporation rates may also be factors in sizing the pond or lagoon. (1)

EFFECTIVENESS OF METHOD. This method could be very effective in avoiding thermal impacts to surface water. The amount of cooling of the effluent percolating through the subsurface before mixing with groundwater will depend on soil characteristics and depth to the saturated zone. If there is no connection between the groundwater receiving the treated effluent and surface water, thermal impact to surface water will be entirely avoided. In a situation where there is a groundwater-surface water connection, effluent mixing with cooler groundwater will provide for some measure of cooling before effluent contacts surface water.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Unlined Ponds or Lagoons

<u>COST.</u> The primary cost element in implementation of this method is the land area needed for construction of the pond or lagoon. One or more groundwater monitoring wells may be required for monitoring impacts on groundwater quality. Less significant costs may include pumping and piping. Producing a higher quality effluent in order to meet groundwater quality standards could involve an expensive upgrade to the treatment plant. Construction cost of the unlined pond or lagoon is roughly estimated in the range of \$0.25 to \$0.50 per gallon of storage.

LOCATIONS WHERE METHOD IS USED. There were no municipal wastewater treatment plants identified that are using this approach for the purpose of avoiding thermal impacts to surface water.

An unlined pond for groundwater percolation is used as the discharge mechanism for a 45,000 gpd wastewater treatment facility serving the Panaca Farmstead Association in Panaca, Nevada. Monitoring of the receiving water is conducted at a groundwater monitoring well located 250 feet west and downgradient from the percolation pond.

- (1) Washington Department of Ecology, *Implementation Guidance for the Groundwater Quality Standards*, October 2005, Publication No. 96-02.
- (2) Nevada Division of Environmental Protection, 2007, Permit No. NEW87045, for the Panaca Farmstead Association, Panaca, NV.

6.7 INFILTRATION TRENCHES

DESCRIPTION. An infiltration trench or infiltration gallery is an excavated trench, typically 3 to 12 feet deep, filled with a stone aggregate and lined with filter fabric. (1) Wastewater directed into the trench fills the voids between the rocks and slowly percolates into the soil. This method is commonly used for stormwater treatment and provides some pollutant removal as the water is filtered through the soil.

WHERE METHOD WOULD BE MOST APPLICABLE. This method would be applicable for limited quantities of effluent (i.e., a very small treatment plant) in a location with plenty of relatively flat land available, away from buildings, slopes, highway pavement, wells, and bridge supports. Soils must be sufficiently permeable to provide an appropriate infiltration rate, ranging between 0.5 and 3 inches per hour. (2) The soils should contain less than 20 percent clay, and less than 40 percent silt/clay. (3) Sufficient separation between the seasonally high groundwater table and the bottom of the infiltration trench is also required, typically 2 to 5 feet. Infiltration trenches should not be used in regions of karst formation due to the potential for developing sinkholes or contaminating groundwater. (2) In addition, if infiltration trenches are to be used during winter months in a cold climate, protection from freezing must be provided. This is usually achieved by locating the top of the infiltration trench about 2 feet below ground surface.

POTENTIAL BENEFITS. The potential benefits of this approach are its relatively simple design, its applicability in a variety of locations, potential use on a seasonal basis, "polishing" of the effluent as it percolates through the soil-- further improving its quality, and relatively low cost of implementation.



Source: Southeastern Wisconsin Regional Planning Commission, 1991.

Typical stormwater infiltration trench design Source: U.S. Environmental Protection Agency, September 1999

POTENTIAL DISADVANTAGES. Site soils must have appropriate permeability for this approach. Generally impermeable soils containing clay and silt (Hydrologic Soil Types C and D) or areas of fill are not suitable for infiltration trenches. (4) The amount of land required may be a limiting factor. Should a trench become clogged, it is difficult to restore its function.

ENGINEERING CONSIDERATIONS. Design of infiltration trenches involves an understanding of permeability of the soil, subsurface characteristics, presence of any geological conditions that could inhibit the flow of water. Drain rock should be 1.5 to 2.5 inches in diameter. Required trench volume is calculated assuming a void space of 35 percent. Bottom surface area of the trench and trench depth are calculated to provide for draining the trench in 72 hours or less, using the infiltration rate of site soils. One or more observation wells should be provided to enable monitoring of the drain time and performance of the infiltration trenches. (4)

EFFECTIVENESS OF METHOD. This method provides a way to divert wastewater treatment plant effluent discharge from surface water to ground. As such, it would be a very effective method to avoid thermal impact to surface water, provided that effluent percolating through the infiltration trenches does not reconnect with surface water through subsurface lateral flow. As a ground discharge method, it is subject to Washington State Waste Discharge Permit requirements.

COST. Caltrans installed two infiltration trenches for stormwater treatment in southern California at a cost of about \$50 per cubic foot of stormwater treated, or \$6,685 per thousand gallons. (4) Actual construction costs at a specific location may vary based on local wage rates, fuel costs, site access characteristics, and geological conditions. Maintenance costs are estimated at 5 to 20 percent of the capital cost. (4) Maintenance of infiltration trenches for stormwater treatment is anticipated to be more expensive than for treated wastewater, due to the sediment, oils, and other contaminants in groundwater that could lead to clogging.

LOCATIONS WHERE METHOD IS USED. Locations where this method is in use for the cooling of treated wastewater effluent were not identified. This method is used in a number of locations for stormwater treatment, including California and mid-Atlantic states.

- (1) U.S. Environmental Protection Agency, September 1999. "Storm Water Technology Fact Sheet Infiltration Trench," EPA 832-F-99-019. Office of Water, Washington, D.C.
- (2) "Stormwater Management Fact Sheet," <u>www.stormwatercenter.net</u>.
- (3) Center for Watershed Protection, Environmental Quality Resources and Loiederman Associates, 1998. Maryland Stormwater Design Manual, Draft. Prepared for Maryland Department of the Environment, Baltimore, MD. www.mde.state.md.us/environment/wma/stormwatermanual/mdswmanual.html.
- (4) California Stormwater Quality Association, January 2003. California Stormwater BMP Handbook, New Development and Redevelopment, "Infiltration Trench," TC-10.

6.8 RAPID INFILTRATION

DESCRIPTION. A rapid infiltration basin is an engineered permeable soil basin designed to treat and disperse municipal wastewater. The basin is flooded or sprinkled with wastewater, which then infiltrates into the soil, percolating through relatively course material and dispersing vertically and/or horizontally. The basin is then allowed to rest and dry before being saturated again. Multiple basins are required to facilitate this resting and drying phase. Most rapid infiltration systems are preceded with some type of conventional wastewater treatment, and are designed specifically to provide additional treatment, as rapid infiltration can be used to remove or reduce particulates, biochemical oxygen demand, trace metals, suspended solids, and pathogens. Nitrogen removal of about 50 percent can be readily achieved. (1) In Washington, use of this method may require production of Class A effluent by the wastewater treatment plant.

For the purpose of this report, rapid infiltration is discussed as a means to dispose of treated municipal wastewater and avoid thermal impacts to a surface receiving water.



Rapid infiltration basins Source: Minnesota Pollution Control Agency, 2005

WHERE METHOD WOULD BE MOST APPLICABLE. This approach requires ample land area for construction of several adjoining infiltration basins. Site soils should be uniform, unsaturated, and moderately permeable, and the groundwater table located fairly deep beneath the site. Unsuitable locations include areas with steep slopes, shallow water table or shallow bedrock, adjacent to wetlands, within a wellhead protection area, above a sole source aquifer, on backfilled materials, or located within a flood plain. (1) In addition, the infiltration basins should be located far enough from surface water to avoid direct impact. A complete hydrogeologic study and mounding analysis should be conducted as part of site evaluation.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Rapid Infiltration

POTENTIAL BENEFITS. One of the benefits of this approach is that the infiltration basins will provide additional treatment or polishing of the treatment plant effluent, resulting in a very high quality effluent when it eventually mixes with surface water or groundwater. In addition, loading and resting cycles can be designed to maximize nitrogen removal. This requires flooding of the entire basin, using an application period long enough for the soil bacteria to deplete soil oxygen, which results in anaerobic/denitrifying conditions. The drying phase must be long enough to reaerate the soil and dry and oxidize the filtered solids. (1)

Another advantage is low operating cost, as the only equipment required is pumps or sprinklers and possible piezometers to measure groundwater levels. This system lends itself readily to seasonal operation. Other potential benefits include groundwater recharge, recharge of surface streams by interception of groundwater, or temporary storage of groundwater in the aquifer. (2)

<u>POTENTIAL DISADVANTAGES.</u> Possible disadvantages are the fairly stringent siting considerations, land area requirements, high quality of effluent required, and potential for undesirable mounding.

ENGINEERING CONSIDERATIONS. The hydraulic loading rate depends on the type of soil, depth of groundwater, quality of the wastewater as applied, and the level of treatment required. (2) The number of rapid infiltration basins for a specific installation ranges from a minimum of three to about 17, depending on the anticipated number and duration of loading and resting cycles. Basins typically range in size from ½ to 5 acres for small and medium size systems, to 5 to 20 acres for large systems. The orientation of basins relative to the direction of groundwater flow may affect mounding. Basins are typically square or rectangular and adjoining. (1)

A full analysis of the site, soils, and hydrogeology is needed before design. Hydraulic loading rates can then be determined based on soil characteristics and effluent discharge rates.

Key parameters that should be considered include:

- Elevation of bedrock
- Presence of limiting geologic layers
- Elevation of groundwater table
- Hydraulic gradient
- Surface disturbance or compaction
- Presence of backfilled soil
- Flooding or run-on potential
- Uniformity of soil over the site
- Soil texture, consistency, and structure
- Saturated soil hydraulic conductivity and horizontal transmissivity
- Analysis of mounding potential.

EFFECTIVENESS OF METHOD. This method is in use in other areas of the country (such as Minnesota) as a means of wastewater treatment. (1) Temperature models for this type of system were not found in the literature. The effectiveness of this approach as an effluent cooling method may yet need to be demonstrated.

<u>COST.</u> The most expensive component of a rapid infiltration system is the real estate. Other costs include annual maintenance to the basin surface soils by discing, as well as pump and valve maintenance. Overall operation and maintenance costs of this approach are very low relative to other cooling methods.

LOCATIONS WHERE METHOD IS USED. This method is used as a means of wastewater treatment in many locations across the U.S. including Minnesota, Florida, Idaho, Delaware, Wisconsin, Nevada, among others. There were no municipal treatment plants identified that currently use this method as a means to reduce the thermal impact of their effluent on receiving water.

- (1) Minnesota Pollution Control Agency, March 2005. *Guidance and Submittal Requirements for Rapid Infiltration Basin Wastewater Treatment Systems.*
- (2) U.S. Army Corps of Engineers, Engineering Manual, Chapter 4, "Rapid Infiltration Systems" at www.usace.army.mil/publications/eng-manuals/em1110-2-504/c-4.pdf.
- (3) Delaware Riverkeeper[®], Fact Sheet: "Rapid Infiltration & Overland Flow", at <u>www.delawareriverkeeper.org/newsresources/factsheet.asp?ID=17</u>.
- (4) Sumner, D.M., and L.A. Bradner, 1996, Hydraulic Characteristics and Nutrient Transport and Transformation Beneath a Rapid Infiltration Basin, Reedy Creek Improvement District, Orange County, Florida. U.S. Geological Survey, Water Resources Investigations Report 95-4281.

6.9 EXFILTRATION GALLERY

DESCRIPTION. An exfiltration gallery is a series of horizontal wells or trenches, typically installed well below grade. Slotted high density polyethylene pipe may be used, installed with a specific sand/gravel pack mixture around the slotted pipe. The exfiltration gallery disperses treated effluent into the subsurface, sometimes below a confining layer. The wide dispersal of effluent may avoid mounding of groundwater. Like other subsurface discharge methods, exfiltration galleries are subject to compliance with Washington's State Waste Discharge Permit requirements (WAC 173-216) and Groundwater Quality Standards (WAC 173-200).

WHERE METHOD WOULD BE MOST APPLICABLE. This method would be most applicable in a situation where shallow soils have low hydraulic conductivity that would prohibit percolation. An exfiltration gallery can be installed below a confining layer into a layer of greater hydraulic conductivity to ensure dispersal of the effluent.

POTENTIAL BENEFITS. Potential benefits of this method include the ability to develop the land above the exfiltration system, providing broad dispersion of the effluent into the subsurface, thereby maximizing cooling effects from percolation through deeper subsurface strata to groundwater, and avoidance of mounding. Other potential benefits are the ability to site exfiltration galleries in difficult locations that might not allow for implementation of other subsurface discharge methods.

POTENTIAL

DISADVANTAGES. Potential disadvantages of this approach include cost of implementation, and costs of maintaining underground facilities. Another potential downside is the requirement to meet Washington groundwater quality standards.

ENGINEERING CONSIDERATIONS. Key

considerations are a thorough understanding of site lithology and hydrogeologic characteristics,



Installation of horizontal well for exfiltration gallery Source: Horizontal Subsurface Systems, Inc., <u>www.horizontal.com</u>

including parameters such as hydraulic conductivity, transmissivity, porosity, groundwater flow and gradient, depth to groundwater, etc. The exfiltration system must be sized appropriately for the effluent flow and receiving soil characteristics.

EFFECTIVENESS OF METHOD. As a method for avoiding the direct discharge of warm treated effluent to surface water, this approach could be very effective. However, there were no data found in the literature regarding the use of this method for effluent cooling purposes.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Exfiltration Gallery

<u>COST.</u> The cost of implementing an exfiltration gallery is considered low to moderate, relative to other effluent cooling methods described in this manual. Major capital cost items include the land area needed for the trenches, drain rock, and conveyance equipment. Operating costs are very low. Maintenance costs are considered low to moderate.

LOCATIONS WHERE METHOD IS USED. There were no applications of this method identified that were implemented for the purpose of avoiding thermal discharge impacts. This method is in use for other reasons, primarily to reduce chemical and biological contaminant impacts on surface water. One example is an exfiltration gallery system that was installed to dispose of treated wastewater from a citrus processing plant in Fort Pierce, Florida. This system consisted of three trenched horizontal wells from 750 to 1,000 linear feet, installed 18 feet below grade. Six-inch diameter slotted HPDE pipe was installed and backfilled with a special sand/gravel pack in a single pass process developed by the installation firm. After installation of the slotted pipe below the confining layer, an 80-mil HPDE liner was installed over the trenches and backfilled with a fine grained sand/bentonite mixture. (1)

Several projects that involved exfiltration galleries were funded by the St. Johns River Water Management District in northern and east-central Florida in 2005. They included a bioretention/exfiltration project for reconstruction of Ocean Beach Boulevard in the City of Cocoa Beach, stormwater treatment for the City of Ponce Inlet, and modification of the Connecticut Avenue outfall treatment system for the City of Lake Helen. (2)

A 35,000 gpd wastewater treatment facility in the Village of Shoreham, Vermont, discharges to a nearby wetland area called Cedar Swamp, through an underground exfiltration gallery. (3)



Puzzle Lake, part of St. Johns River Water Management District, Florida Source: St. Johns River Fast Facts, www.nbbd.com/godo/StJohns.htm.

- (1) Horizontal Subsurface Systems, Inc., Cape Coral, Florida, www.horizontal.com/Projects/Water_Supply/FL_FtPierce_Citrus/proj-hirr_citrus_FtPierce.html
- (2) St. Johns River Water Management District, Agenda Request for Governing Board Meeting, November 8, 2005.
- (3) Rural Utilities Service, "Success Stories: Shoreham, Vermont," at www.usda.gov/rus/water/ees/environsuccess/Shoreham_VT.doc.

6.10 HYPORHEIC INJECTION & FLOODPLAIN CHANNEL RESTORATION

DESCRIPTION. The hyporheic zone is the intermediate zone between the river bed surface in which a river flows and the subsurface alluvial aquifer. The concept of hyporheic injection to cool a wastewater discharge is to use the thermal capacity of the hyporheic zone as a heat sink for the thermal loading of the heated discharge. This can be accomplished in two ways. One is to reconnect or restore floodplains and side channels to a river's mainstem. During periods of high flows (fall, winter, spring), these reconnected areas would increase the hyporheic zone available for recharge. The recharged historic hyporheic areas upstream of a heated discharge would serve to allow seepage of naturally cold water from the hyporheic zone into the river, thereby diluting the heated discharge and reducing the thermal impact on aquatic organisms.



Schematic representation of the hyporheic zone for a typical stream Source: Lancaster et al, 2005 (1)

The second approach is to inject the heated discharge directly into the hyporheic zone. The porous sands, gravels, and silt in the hyporheic zone, cooled by groundwater, would absorb the heat from the heated effluent, thereby reducing the direct thermal impact to the river. Hyporheic injection may also delay an infusion of warm wastewater into the river until the cooler months, providing "storage" of the heated effluent until the critical discharge period has passed.

WHERE METHOD WOULD BE MOST APPLICABLE. This method would be most applicable for a treatment plant that discharges to a receiving water whose hyporheic zone provides adequate volume and/or storage capacity to dissipate the heat from a warm discharge or delay its mixing into the main portion of the stream. The hyporheic zone is complex and its boundaries may be difficult to define. Therefore, a streambed that is thoroughly studied will offer a potentially more reliable cooling method than one that is poorly understood.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Hyporheic Injection & Floodplain Channel Restoration

POTENTIAL BENEFITS. One of the benefits of this approach is that it does not require additional equipment, except perhaps for piping and pumps to convey the effluent into the targeted discharge area(s). Therefore, its maintenance and operation expense is also minimal. The system relies on natural "infrastructure" already in place. In addition to cooling, the wastewater may also be "polished" as it travels through the gravels below and along the margins of the river, providing additional treatment to the effluent before it is fully mixed with mainstem river water. Restoration of floodplains and side channels can have multiple benefits in terms of riverine system habitat improvements. Returning treated effluent to the river may help mitigate low stream flows.

POTENTIAL DISADVANTAGES. A potential disadvantage to this method is that neither direct hyporheic injection nor floodplain restoration has yet been demonstrated for temperature mitigation. The approach requires substantial study of streambed morphology and hydrology to determine feasibility within a particular receiving water. A modeling study conducted by a team of researchers at Oregon State University showed the amount of cooling produced through side channel restoration was small (1), which would imply that such a restoration project would need to be large in order to produce meaningful temperature reduction. This could make the floodplain restoration option prohibitively expensive.

ENGINEERING CONSIDERATIONS. The key questions to be answered in considering this approach are:

- (1) What is the cooling capacity of the receiving water's underlying porous media?
- (2) To what extent will enhancement of hyporheic flow reduce thermal impact from the effluent discharge?

The Oregon State University study modeled the temperature impacts of both subsurface effluent discharge into the hyporheic zone and flood plain restoration. (1) This study showed that the two most significant parameters in determining timing and magnitude of thermal impact are injection rate and hydraulic conductivity. Other factors that influence heat transfer are specific heat and density of the subsurface material. Denser materials are more desirable for hyporheic injection, and less dense materials were favorable for floodplain restoration.

EFFECTIVENESS OF METHOD. According to the Oregon State University study, direct hyporheic injection may produce a thermal impact two orders of magnitude less than the temperature effect estimated for direct mixing. (1) In addition, the peak temperature increase in the river occurred at the end of the 60-day injection period, implying that this approach could provide a significant delay in thermal impact in order to avoid the most critical period for river temperature.

Modeling results showed that the floodplain/channel restoration approach was not highly effective in reducing thermal impact. (1) One reason for this is that this approach relies on once or twice per year flood events, which appear to be insufficient for providing the cooling input for a continuous discharge.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Hyporheic Injection & Floodplain Channel Restoration

<u>COST.</u> There are no cost data available based on actual implementation of this cooling method. Equipment required to accomplish direct hyporheic injection includes piping, pumps, and diffusers, all of which are standard materials in wastewater applications. Capital costs to construct a hyporheic zone discharge system may be only slightly higher than costs for a direct river outfall. Operating and maintenance costs are anticipated to be relatively close. Therefore, this method is considered a low cost approach to effluent cooling.

LOCATIONS WHERE METHOD IS USED. There were no municipal treatment plants identified that are currently using this approach. This strategy has been considered for discharges to the Willamette River in Oregon.

SOURCES OF ADDITIONAL INFORMATION.

(1) Lancaster, Stephen, Roy Haggerty, et al, December 2005. *Investigation of the Temperature Impact of Hyporheic Flow: Using Groundwater and Heat Flow Modeling and GIS Analysis to Evaluate Temperature Mitigation Strategies on the Willamette River, Oregon.* Oregon State University, Corvallis, OR.

6.11 CONSTRUCTED WETLANDS

DESCRIPTION. This approach employs constructed wetlands as the initial receiving water for treated effluent from a wastewater treatment plant. Wetlands have been shown to provide significant reductions of chemical oxygen demand and dissolved organic carbon in wastewater. Wetland performance depends on the plant species selected, ambient temperature, and wastewater characteristics. The utility of wetlands as a method for avoiding thermal impact to surface water would rely on several factors: heat loss through evapotranspiration, adequate shading of the wetlands to reduce solar input, long detention time, and depth of the wetland channels.

Wetlands may be constructed either as surface flow or as subsurface flow systems. A surface flow system typically requires more space, but in general is simpler to design and easier to construct and maintain than a subsurface system. Wastewater flows into a surface wetland, flows slowly through the shallow basins where specific wetland plants are growing, and is then discharged. The plantings are emergent and aquatic wetland species that tolerate saturated soil and aerobic conditions. (1)



Constructed wetlands at Cochrane Park, Yelm, Washington Source: Skillings Connolly Inc.

In a subsurface wetland, the wastewater

flows underground through a coarse substrate such as gravel. A subsurface system may provide a higher rate of contaminant removal than a surface flow facility, but does not provide waterfowl habitat or recreation and aesthetic features. Subsurface systems are useful in cold climates where the ground provides insulation for subsurface flow and treatment, and in locations where bird activity is discouraged such as near airports. (1)

The use of wetlands for effluent temperature reduction is a relatively new approach. Theoretical models and estimates suggest that 2 to 5 degrees (F) of cooling can be achieved. However, little actual data are available on wetlands' cooling performance. Anecdotal information suggests that long detention times (low flow rates) through shaded, deep wetlands with little turbulence will provide the best reduction in temperature. Wetland design that incorporates deep, narrow channels is much easier to shade than a wide open pond area. The deeper water tends to be significantly cooler than at the surface. Effluent withdrawal from the wetland should be from the cool, deep layer. (2)

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Constructed Wetlands

WHERE METHOD WOULD BE MOST APPLICABLE. This method would be most applicable in a location where there is sufficient land area available for wetland construction, or where there are natural wetlands that could be augmented. Site characteristics must be evaluated for wetland construction. Steep slopes, for example, are not suitable for this type of facility. Soil type, existing vegetation, existing soil contamination levels, stormwater flows, and proximity to surface water and groundwater are important considerations in site evaluation. (1)

POTENTIAL BENEFITS. Potential benefits of this approach include additional polishing or treatment of the wastewater before entering surface water or groundwater, creation of an attractive public amenity that can serve as a park, wildlife area, recreation area, or informational facility, and very low cost for operation and maintenance. In addition, operation and maintenance costs are relatively low.

POTENTIAL DISADVANTAGES.

Potential disadvantages to this approach are the large space requirement and uncertainty regarding the level of temperature reduction that will be achieved.

ENGINEERING

CONSIDERATIONS. The cooling aspect of a wetland system will depend primarily on convective transfer to air, evapotransipiration, solar radiation, water channel depth, and shading. Conductive heat transfer to ground is small compared to atmospheric thermal transfer. A long detention time will provide for temperature equilibrium;



Water feature in Cochrane Memorial Park wetlands, Yelm, WA Source: Skillings Connolly Inc.

however, a low flow regime implies a larger wetland. The effluent flow rate into the wetland must also be considered with the wetland's total volume, residence time, and flow rate.

EFFECTIVENESS OF METHOD. The effectiveness of constructed wetlands as an effluent cooling method depends on the specific design employed. Not every wetland design will result in an effective cooling system. In effect, a constructed wetland is not much different than a cooling pond, responding to the same basic principles of evaporative heat loss and solar input. Channel depth and open water surface area must be balanced to optimize evaporative cooling, reduce solar input, and take advantage of thermal stratification of the water. Predictive models suggest that wetlands could be a very effective cooling method, however, there are little empirical data available at this time to substantiate the model results.

<u>COST.</u> Relative cost of implementation of this method is moderate—less expensive than mechanical cooling or exporting effluent to another body of surface water, and more expensive than a cooling pond, spray aeration, or effluent blending, generally speaking. Actual costs depend on site specific criteria, other beneficial uses for which the wetlands will be designed, and the volume of water to be treated.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Constructed Wetlands

LOCATIONS WHERE METHOD IS USED. There were no municipal treatment plants identified at this time that are using constructed wetlands as an effluent cooling method. However, there are a number of treatment plants that have incorporated wetlands into their design for other reasons. For example, in 1999, the City of Yelm, Washington, upgraded its wastewater treatment plant to provide treatment to Class A effluent and biosolids. Class A effluent can be reused in any application except as drinking water and human contact applications. The final treatment in the City's wastewater treatment process occurs in a beautiful wetland system as the water flows from one wetland cell to the next. The wetlands provide the centerpiece of a city park, including a fish pond, fountain, and informational kiosks that explain the source of the park's water features.

- (1) Lorion, Renee, August 2001, "Constructed Wetlands: Passive Systems for Wastewater Treatment," Technology Status Report prepared for the U.S. EPA Technology Innovation Office.
- (2) Paquet, Albert and P. Nelson, CH2M HILL, December 27, 2006. Technical Memorandum: "Summary of Potential Wastewater Effluent Temperature Reduction Technologies in Respect to Proposed Temperature Standards." Prepared for City of Loveland, CO, Water & Power Department.
- (3) NFESC, "Constructed Wetland Technology Application Guide, Inception through Implementation."
- (4) USDA-NRCS, EPA Region 3, "A Handbook of Constructed Wetlands: Volume 1 General Considerations."
- (5) US EPA, Constructed Wetlands Treatment of Municipal Wastewater, EPA/625/R-99-010.
- (6) Kadlec, Robert H., and R.L. Knight, 1996. <u>Treatment Wetlands</u>, Chapter 10: "Temperature, Oxygen, and pH." CRC Press, Inc.

6.12 WASTEWATER RECLAMATION AND REUSE

DESCRIPTION. Most of the cooling methods described in this report involve thermal treatment or redirection of treated effluent to cool it prior to disposal. Another approach is to prepare the effluent for reuse and avoid discharging it (or some portion of it) altogether. Reuse applications include agricultural and landscape irrigation, industrial use such as boiler feed or process water, groundwater recharge, recreational use, environmental enhancement, nonpotable uses such as fire fighting and toilet flushing, and potable reuse. A list of applications for reclaimed wastewater and considerations for each category of use are provided in the following table, in order of current demand. The type of use to which the reclaimed water will be put will determine both the level of treatment and the level of system reliability or redundancy required. (1)

Reclaimed Wastewater Uses	Considerations
Agricultural irrigation Crop irrigation Commercial nurseries	 Surface and groundwater contamination if not managed properly Marketability of crops and public acceptance
Landscape irrigation Parks; school yards Freeway medians Golf courses Cemeteries Greenbelts; residential areas	 Effect of water quality, particularly salts, on soils and crops Public health concerns related to pathogens (e.g., bacteria, viruses, and parasites) Use area control including buffer zone may result in high user costs
Industrial recycling and reuse Cooling water Boiler feed Process water Heavy construction	 Constituents in reclaimed water related to scaling, corrosion, biological growth, and fouling Public health concerns, particularly aerosol transmission of pathogens in cooling water Cross connection of potable and reclaimed water lines
Groundwater recharge Groundwater replenishment Saltwater intrusion control Subsidence control	 Possible contamination of groundwater aquifer used as a source of potable water Organic chemicals in reclaimed water and their toxicological effects Total dissolved solids, nitrates, and pathogens in reclaimed water
Recreational / environmental uses Lakes and ponds Marsh enhancement Stream flow augmentation Fisheries Snow making	 Health concerns related to presence of bacteria and viruses (e.g., enteric infections and ear, eye, and nose infections) Eutrophication due to nitrogen and phosphorus in receiving water Toxicity to aquatic life
Nonpotable urban uses Fire protection Air conditioning Toilet flushing	 Public health concerns about pathogens transmitted by aerosols Effects of water quality on scaling, corrosion, biological growth, and fouling Cross connection of potable and reclaimed water lines
Potable reuse Blending in water supply reservoirs Pipe-to-pipe water supply	 Constituents in reclaimed water, especially trace organic chemicals and their toxicological effects Esthetics and public acceptance Health concerns about pathogen transmission, particularly enteric viruses

Source: Metcalf & Eddy, Inc., 2003. Wastewater Engineering, Treatment and Reuse, Fourth Edition, McGraw-Hill, p. 1352.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Wastewater Reclamation and Reuse

Bearing in mind that avoidance of thermal impact to the receiving water is the objective, consideration of the final destination of the reclaimed water after reuse is essential. If the reclaimed water is discharged after reuse, it must still meet the temperature discharge requirements of the receiving water. Therefore, the reclamation usage must not result in further heating of the water unless another cooling method is also applied before discharge.

In Washington, water reclamation and reuse are governed by State Department of Health and Department of Ecology regulations and guidance. A rule revision process began in 2006 with legislative revisions to RCW 90.46. The most recent regulatory information can be found on the agency website at <u>http://www.ecy.wa.gov/laws-</u> <u>rules/activity/wac173219.html</u>. A table has been included in this section showing the four types of reclaimed water allowed for various use categories in Washington. (2)



Water reuse piping, Yelm, Washington Source: Skillings Connolly Inc.

Often, storage facilities are included with a

wastewater reclamation upgrade. The ability to store reclaimed water facilitates its use for off-peak flow irrigation use (golf courses, parks), seasonal storage for opposite season discharge or use, and reduction of pumping costs related to meeting peak water use demands. Wastewater storage can eliminate or significantly reduce discharges when temperature in the receiving water is most critical. See the section on Season Storage for more information.

WHERE METHOD WOULD BE MOST APPLICABLE. Treated wastewater reclamation would be most applicable in a location where there is a strong or developing market for reclaimed water. Such areas may be where water resources are scarce or where potable supplies are distant or expensive. Significant volumes of reclaimed water can be used for agricultural irrigation, and this is currently the largest use. If the municipal treatment plant is located near one or more industries that could use reclaimed water, this is likewise advantageous. Current Washington rules require a redundant or backup disposal method or discharge/reuse destination.

POTENTIAL BENEFITS. There are potentially multiple benefits of this approach. First, thermal impact to the receiving water can be avoided. Second, the effort and cost of wastewater treatment can be put into the provision of a resource rather than into a waste product, which is a more sustainable and potentially more efficient pathway, particularly in areas where water is scarce or expensive. Third, reclaimed water can be directed into a variety of uses.

POTENTIAL DISADVANTAGES. A potential disadvantage of wastewater reclamation is cost and lack of public acceptance. Additional treatment of the municipal wastewater may be required to meet the requirements of the particular reuse desired. This is not always the case, however, and should be thoroughly investigated if this approach is seriously considered. The cost of implementing additional treatment may compare favorably with other approaches outlined in this report, particularly in areas where real estate costs are high. Agreements regarding cost of the reclaimed water and provisions to prevent cross connection with potable supplies are typically required.

Declaimed Water Use	Type of Allowed Reclaimed Water			
Reclaimed water Use	Class A	Class B	Class C	Class D
Irrigation of Nonfood Crops				
 Trees and fodder, fiber, and seed crops 	YES	YES	YES	YES
 Sod, ornamental plants for commercial use, and pasture to which milking cows or goats have access 	YES	YES	YES	NO
Irrigation of Food Crops				
 Spray irrigation 				
All food crops	YES	NO	NO	NO
Food crops which undergo physical or chemical processing sufficient to destroy all pathogenic agents	YES	YES	YES	YES
 Surface irrigation Food crops where there is no reclaimed water contact with 				
edible portion of crop	YES	YES	NO	NO
Root crops	YES	NO	NO	NO
Orchards and vineyards	YES	YES	YES	YES
Food crops which undergo physical or chemical processing sufficient to destroy all pathogenic agents	YES	YES	YES	YES
Landscape Irrigation				
 Restricted access areas (e.g. cemeteries and freeway landscapes) 	YES	YES	YES	NO
 Open access areas (e.g., golf courses, parks, playgrounds, school yards and residential landscapes) 	YES	NO	NO	NO
Impoundments				
Landscape impoundments	YES	YES	YES	NO
 Restricted recreational impoundments Neprestricted recreational impoundments 	YES	YES	NO	NO
Fish Heteberry Besine	VES	VES	NO	NO
Pish Hatchery Basins	VES	NO	NO	NO
Decorative Fountains	VES	VES	VES	VES
Flushing of Sanitary Sewers	TES	TES	160	TES
Street Cleaning	VES	VES	VES	NO
 Street sweeping, brush dampening Street washing, spray 	YES	NO	NO	NO
Washing of Corporation Yards Lots and Sidewalks	YES	YES	NO	NO
Dust Control (Dampening Unpaved Roads and Other Surfaces	YES	YES	YES	NO
Dampening of Soil for Compaction (at Construction Sites, Landfills, etc.)	YES	YES	YES	NO
Water jetting for Consolidation of Backfill Around Pipelines				
 Pipelines for reclaimed water, sewage, storm drainage, and gas, and conduits for electricity 	YES	YES	YES	NO
Fire Fighting and Protection				
Dumping from aircraft	YES	YES	YES	NO
 Hydrants or sprinkler systems in buildings 	YES	NO	NO	NO
Toilet and Urinal Flushing	YES	NO	NO	NO
Ship Ballast	YES	YES	YES	MO
Washing Aggregate and Making Concrete	YES	YES	YES	NO
Industrial Boiler Feed	YES	YES	YES	NO

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Wastewater Reclamation and Reuse

Paclaimad Water Usa	Type of Allowed Reclaimed Water			
	Class A	Class B	Class C	Class D
 Industrial Cooling Aerosols or other mist not created Aerosols or other mist created (e.g., use in cooling towers, forced air evaporation, or spraving) 	YES YES	YES NO	YES NO	NO NO
 Industrial Process Without exposure of workers With exposure of workers 	YES YES	YES NO	YES NO	NO NO
 Wetlands All wetlands Noncontact recreational or educational use with restricted access Fisheries use, or noncontact recreational or educational use with 	YES YES YES	YES YES YES	YES YES NO	YES NO NO
 open (unrestricted) access Potential human contact recreational or educational use 	YES	NO	NO	NO
Groundwater Recharge	YES	NO	NO	NO
Streamflow Augmentation	YES	NO	NO	NO

Source: Washington Department of Ecology, Criteria for Sewage Works Design, Table E1-1.

ENGINEERING CONSIDERATIONS. The wastewater treatment plant must be designed and operated to achieve the reclaimed water quality required by its use, as noted in the table above. For some plants, this may require a significant upgrade. For others, depending on the class of reclaimed water desired, a relatively minor revision to plant design or operation may be sufficient. The classes of reclaimed water are defined by treatment levels as well as by indicator turbidity and bacteriological analyses. The table below provides these treatment and water quality characteristics, which will provide a general idea of the potential level of plant modification required to implement water reclamation and reuse. In addition, Ecology requires specific system reliability and redundancy features, including standby power, alternative disposal or storage, and treatment system reliability features. (2) Providing these reliability features and redundant systems would be part of the engineering considerations for implementing wastewater reclamation and reuse.



Purple reclaimed water pipes in varying sizes used to transport reclaimed water Source: Skillings Connolly, Inc.

Characteristics	of the F	our Classes	of Reclaimed	Water
-----------------	----------	-------------	--------------	-------

Class	Characteristics
	Class A reclaimed water will at all times be oxidized, coagulated, filtered, and disinfected wastewater. State water reclamation and reuse standards call for Class A reclamation water to be filtered to a turbidity level which does not exceed an average operating turbidity of 2 nephelometric units (NTUS), determined monthly, and which does not exceed 5 NTU at any time. Filtration can be achieved by passing oxidized wastewater through natural undisturbed soils or through filter media such as sand or anthracite. Class A reclaimed water must be disinfected such that the median number of total coliform
A	organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last seven days for which analyses have been completed, and such that the number of total coliform organisms does not exceed 23 per 100 milliliters in any sample.
	Class A reclaimed water is currently the only reclaimed water class for which Ecology requires coagulation and filtration. Further, the disinfection requirements for Class A reclaimed water are more stringent than for Class C or D reclaimed water. (The disinfection requirements for Class B reclaimed water are identical to those for Class A). Class A reclaimed water must be used where the potential for public exposure to reclaimed water is high.
В	Class B reclaimed water will at all times be oxidized and disinfected wastewater. The wastewater will be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last seven days for which analyses have been completed, and such that the number of total coliform organisms does not exceed 23 per 100 milliliters in any sample.
C	Class C reclaimed water will at all times be oxidized and disinfected wastewater. The wastewater will be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 23 per 100 milliliters, as determined from the bacteriological results of the last seven days for which analyses have been completed, and such that the number of total coliform organisms does not exceed 240 per 100 milliliters in any sample.
D	Class D reclaimed water will at all times be oxidized and disinfected wastewater. The wastewater will be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 240 per 100 milliliters, as determined from the bacteriological results of the last seven days for which analyses have been completed.

Source: Washington Department of Ecology, Criteria for Sewage Works Design, Table E1-8.

EFFECTIVENESS OF METHOD. This method can be highly effective as a means of avoiding thermal impact to the receiving water. Water reclamation and reuse are being used as a strategy in some locations for zero discharge to surface water. This method, as mentioned previously, may need to be coupled with one or more other effluent cooling strategies, depending on the use of the reclaimed water, whether further heating or cooling of it has occurred, and its final disposition (discharge to surface water, ground, or reclamation).

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Wastewater Reclamation and Reuse

COST. The cost of implementing wastewater reclamation depends on the level of treatment required by its reuse application. In some cases, little or no additional treatment may be needed over the existing level in order to achieve the water quality required for agricultural irrigation, for example. In other cases, additional treatment equipment may need to be installed at the municipal treatment plant. Operating and maintenance costs for additional wastewater treatment equipment are typically higher for this approach than for some of the non-equipment intensive methods described elsewhere in this report. However, water reclamation can provide a new utility revenue stream for the municipality. Washington water law indicates that a municipality that reclaims wastewater for reuse owns the water rights to that water, provided that there is no impairment to downstream users. In most cases, reclaimed water will replace the use of potable water or some other water supply. The dollar value of the reclaimed water will depend on local demand for these other water sources, proximity of alternate water supplies, and water quality demands.

LOCATIONS WHERE METHOD IS USED. The Rock Creek and Durham Advanced Wastewater Treatment Facilities, two large municipal treatment plants in Oregon, are pursuing water reclamation, among other approaches, to reduce thermal impacts to receiving waters in the Tualatin River Basin. Reclaimed water will be used for irrigation, substituting for withdrawals of water from Hagg Lake or streams in the area. This approach avoids discharge of warm treated effluent to the temperature impaired Tualatin River and helps maintain instream flows in other streams used for irrigation. (4)

- (1) Metcalf & Eddy, Inc., 2003. <u>Wastewater Engineering, Treatment and Reuse</u>, Fourth Edition, McGraw-Hill, Chapter 13, "Water Reuse."
- (2) Washington Department of Ecology, October 2006. *Criteria for Sewage Works Design,* Chapter E1, "Water Reclamation and Reuse."
- (3) Washington Department of Health and Washington Department of Ecology, September 1997. *Water Reclamation and Reuse Standards.*
- (4) Clean Water Services, February 2005. Revised Temperature Management Plan for the Rock Creek and Durham Wastewater Treatment Facilities.

7.0 DIRECT COOLING OF EFFLUENT

Methods described in this section involve direct cooling of the effluent after treatment and prior to discharge. Some of these methods involve equipment that is relatively expensive to procure and operate. One method is quite inexpensive and provides multiple community benefits.



Schematic of the refrigeration cycle Source: Honeywell Control Systems Ltd.
7.1 RIPARIAN SHADING

DESCRIPTION. This method employs the establishment of streamside forests to provide shade over the receiving water. Modeling is used to determine the amount of cooling provided by trees planted along a river or creek bed, taking into account the width of the treed area, the height of the trees at maturity, the width of the water body, and the length of reach to be planted.

<u>WHERE METHOD WOULD BE MOST APPLICABLE.</u> This method is most applicable in areas where forests have been cut to make room for agriculture or development, but theoretically could be applied to any river or stream.

POTENTIAL BENEFITS. One of the most appealing benefits of this method as a means of reducing thermal impact is cost. This approach is substantially less expensive over time compared to mechanical cooling methods. In addition, there are a number of attractive ancillary benefits, including the provision of a significant scenic resource for the community, similar to the benefits provided by a city park. In at least one community, a bike trail through the streamside forest is planned as well as picnic areas. Trees also help remove pollutants from the air and water and provide enhanced habitat for fish and wildlife. The following figure illustrates the multiple beneficial functions of riparian forests.



Source: David Evans and Associates, Inc. and ECONorthwest, 2004

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Riparian Shading

The economic value of streamside forests has been estimated for a variety of stream restoration projects, showing that the multiple benefits of riparian shading can outweigh much of the cost of implementation. This is a unique attribute among the cooling methods reviewed in this report. The table below itemizes the ecosystem services provided through a streamside forest proposed for Johnson Creek in Portland, Oregon, and their associated estimated economic values.

Ecosystem Goods & Services	Economic Value*	
Services from Vegetation and Soils		
Reduced water temperatures		
 Increased fish populations Avoided costs of complying with the Clean Water Act and Endangered Species Act 	\$4.54 per month per household Insufficient data to support a reliable estimate	
Air purification		
 Reduced respiratory illness because streamside vegetation removes pollutants 	 CO - \$0.47 per lb removed per year PM10 - \$2.20 per lb removed per year SO2 - \$0.61 per lb removed per year O - \$3.30 per lb removed per year Insufficient data to support a reliable estimate 	
 Avoided costs of complying with the Clean Air Act Carbon sequestration 	\$10.21 per ton carbon removed per year	
Water purification		
 Improved quality of stream water because streamside vegetation removes pollutants 	\$590 per acre of wetland	
Precipitation interception and storage		
Flood mitigation Reduced road closures	 Residential - \$71,706 per 10-yr flood event for all residences in the area Business - \$491,368 per 10-yr flood event for all businesses in the area Utilities - \$11,288 per 10-yr flood event Emergency Services - \$5,375 per 10-yr flood event 	
	\$34.65 per vehicle-hour of delay	
Biodiversity Maintenance		
Improvement of avian habitat		
 Habitat for wintering/migratory species Refuge for at-risk species, e.g., migratory songbirds 	\$433 per acre Insufficient data to support a reliable estimate	
Improvement of salmonid habitat	Insufficient data to support a reliable estimate	
Cultural Services		
Natural area and open space	T	
 Recreational opportunities Increased value for nearby properties 	\$4.30 per day per user \$1,796 increase per property within 1,500 ft of park	

Economic Benefits of Streamside Forests

*Values are in 2005 dollars.

Source: Niemi, Ernie et al; from David Evans and Associates, Inc. and ECONorthwest, 2004.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Riparian Shading

POTENTIAL DISADVANTAGES. One disadvantage to this method is the time required for trees to mature and provide maximum shading of the stream. In addition, a streamside forest requires maintenance to ensure its long term health. Another potential disadvantage is that the stream banks are not necessarily under the control of the wastewater treatment plant, so arrangements such as rights-of-way or land purchases have to be negotiated in order to implement riparian shading along a stream reach.

ENGINEERING CONSIDERATIONS. Temperature/shade modeling will determine the amount of shade required to reduce stream temperatures to acceptable levels. Variables considered in this determination include: amount of insulation (location specific), climatic regime, height of trees when mature, planting density, stream width, stream flow, and stream buffer width. A planting plan must consider these parameters as well as site specific issues such as road access, property ownership, bank stability, stream width, native and non-native species, plant mortality, and other considerations. The Clean Water Services' streamside forest program for portions of the Tualatin Basin used the following variables:

Parameter	Value*
Canopy height after 20 years from planting	60 feet
Canopy density after 20 years from planting	60%
Stream aspect	450
Stream width target	10 feet; individual projects vary
Location of plantings	Urban, rural, public, private
Buffer width target on each side of stream	45 feet on both sides of stream; individual
	projects vary
Solar energy blocked by trees	18.8 million kcal/day /mile
Solar energy blocked by 1 acre of trees	1.46 – 1.73 million kcal/day
Potential cost of establishing streamside forest along 35	¢10 200 211
miles of stream (present value)	\$12,392,311
Potential savings over 20 years, relative to chiller	\$50,503,388
alternative (present value)	ψJU,J33,300

Summary of Clean Water Services' Streamside Forest Program

*Values are in 2005 dollars.

Source: Niemi, Ernie at al; from ECONorthwest, with data from Clean Water Services (a) and (b); Smith and Ory, 2005.

EFFECTIVENESS OF METHOD. Modeling studies indicate that riparian shade can be a very effective method of reducing stream temperature. Indeed, where streams used to be covered with a deep forest canopy prior to clearing of trees, solar heating has had significant adverse impacts. Streamside forests would assist in restoring streams to a more natural state.

<u>COST.</u> This method can be significantly less expensive than the use of a mechanical chiller on a treatment plant discharge. "Operation" of the streamside forest is free. Once the trees and shrubs have been planted, there is relatively little energy consumption involved in maintenance and some labor expense. Use of community volunteers to assist in planting the trees on public lands and small tributaries can further reduce implementation costs.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Riparian Shading

Cost estimates used in developing Clean Water Services' "Healthy Streams Plan" for streamside forests are as follows (2005 dollars):

Property purchase Plant starts Planting density \$20,000 per acre\$2.50 per plant2,614 plants per acre

LOCATIONS WHERE METHOD IS USED. Riparian shade is being restored on many streams in the northwest. As a method for reducing the thermal impact from a municipal wastewater treatment plant, streamside forests are proposed for two treatment plants in Oregon – Durham Advanced WWTP in Tigard and Rock Creek Advanced WWTP in Hillsboro – and one in Centralia, WA.

SOURCES OF ADDITIONAL INFORMATION.

- (1) Clean Water Services (a), February 2005. Revised Temperature Management Plan.
- (2) Clean Water Services (b), 2005. *Temperature Management Plan and Water Quality Credit Trading Combined Annual Report.*
- (3) David Evans and Associates, Inc. and ECONorthwest, June 2004. *Comparative Valution of Ecosystem Services: Lents Project Case Study*, prepared for City of Portland Watershed Management Program.
- (4) Niemi, Ernie, Kristin Lee, and Tatiana Raterman, undated. "Net Economic Benefits of Using Ecosystem Restoration to meet Stream Temperature Requirements." ECONorthwest. Retrieved from http://www.econw.com/reports/Economic-Benefits-Ecosystem-Restoration_ECONorthwest.pdf
- (5) Smith, Kendra, and Jill Ory, June 2005. Healthy Streams Plan. Clean Water Services.

7.2 COOLING PONDS

DESCRIPTION. A cooling pond is a shallow reservoir designed to receive warm water and discharge cool water, relying on evaporative and radiative heat loss. Cooling ponds are typically lined with an impermeable material that is resistant to ultraviolet radiation and punctures, and that can withstand the temperatures to which it is exposed. (1) Evaporation can be enhanced through the use of spray nozzles which increase the surface area of water exposed to air. Further information on this approach can be found in the section on spray cooling.

One of the most common applications of cooling ponds is in thermoelectric power generation. A thermoelectric plant may use natural gas, oil, coal, biomass, solid waste, or nuclear fuel, or geothermal energy to heat water in a



Brazos Electrical Power Cooperative's cooling pond Source: MPC Containment Systems LLC, www.mpccontainment.com

boiler to produce steam. The steam turns a turbine generator which produces electricity. Once the steam has passed through the turbine it is cooled in a condenser, and the resulting warm water is looped back to the boiler. The cooling water from the condenser which has absorbed much of the heat from the steam, is either discharged or cooled and recycled back to the condenser. The cooling is often accomplished through the use of cooling ponds. (2)

<u>WHERE METHOD WOULD BE MOST APPLICABLE.</u> This method is most applicable where the temperature differential between the heated water and wet bulb temperature is large, and where real estate costs are relatively low.

POTENTIAL BENEFITS. Potential benefits of this approach might include relatively low initial cost (depending on the cost of land) and very low operating and maintenance costs. This cooling method is potentially easier to design and operate than some other methods. Because the method relies on evaporative heat loss, no power consumption is required in the cooling process. Other benefits include the potential use of the pond(s) for habitat enhancement (fish and waterfowl) and/or recreation.

POTENTIAL DISADVANTAGES. Potential disadvantages of the cooling pond approach are the need for lots of space and suitable geographic conditions for pond construction, and the counteractive effects of solar influx and evaporative cooling, particularly in the summer. Solar input is highest during the months when receiving water temperature is most critical and the ambient versus water temperature differential is lowest.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Cooling Ponds

ENGINEERING CONSIDERATIONS. Air temperature, humidity, solar heating, and wind strongly affect the cooling performance of a pond. In addition to these site specific characteristics, pond design parameters include capacity, surface area and depth, hydraulic velocity, and residence time. Use of internal baffles and attention to design of entrance mixing and residence time in the pond may enhance the effectiveness of the pond. (3) Pond design needs to consider the following heating and cooling processes (2):

Heating Processes	Cooling Processes
Absorption of shortwave radiation from the sun and the sky	Emission of shortwave solar radiation by the water
Absorption of longwave radiation from the atmosphere	Emissions of longwave radiation by the water
Heat rejected to the pond from the wastewater source	Convection between the water and the ambient air
	Evaporation of pond water into the atmosphere

EFFECTIVENESS OF METHOD. The overall effectiveness of a cooling pond is limited by the difference in temperature of the wastewater routed to the pond and the ambient wet bulb temperature (a function of ambient temperature and humidity). The greater the difference in these two parameters, the more effective the pond will be. In addition, solar input in the summer generally causes thermal stratification in ponds and lakes. A warm layer of water sits at the top (epilimnion), a cool layer rests at the bottom (hypolimnion), and the area in between is a zone of temperature decline known as a thermocline (metalimnion). The thickness of the upper warm layer depends on the degree of mixing caused by wind on the pond's surface. This stratified condition typically lasts all summer. (4) The summer months, particular late summer, are the months when receiving waters are most temperature-critical due to lower flows and higher upstream and ambient temperatures. During this period, ambient temperatures and solar influx may decrease the effectiveness of the cooling pond.

<u>COST.</u> The major cost elements of a cooling pond are the real estate and the liner. Real estate costs vary significantly depending on location. If real estate is expensive or simply unavailable, a cooling tower might be a better option for cooling effluent. As a preliminary estimate, construction of a lined pond will cost in the range of \$0.10 to \$0.20 per cubic foot of storage volume. (5) Operating cost of a cooling pond is very low. Maintenance costs are also low.

LOCATIONS WHERE METHOD IS USED. Cooling ponds are commonly used for cooling water from thermoelectric power generating plants. In these applications, cooling water is the medium used to condense the steam that has been used to turn the turbine generator. The condensed steam is returned to the steam generator, while the cooling water is discharged to the cooling pond, allowed to cool, then pumped back into the condenser unit and used again to remove heat from the steam. There were no municipal wastewater treatment plants identified that currently use this cooling method.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Cooling Ponds

SOURCES OF ADDITIONAL INFORMATION.

- MPC Containment Systems LLC, Chicago, IL, "Protecting our air and water with flexible membrane liners, covers, and fabrications – cooling ponds," at <u>www.mpccontainment.com/cooling-pond.shtml.</u>
- (2) Brill, David J., "Circulating Water Systems," in <u>Power Plant Engineering</u>, Black & Veatch et al. Kluwer Academic Publishers, 1996.
- (3) Jirka, Gerhard H., D. Harleman, and C. Cerco, November 1981. "Efficient Cooling Ponds: Design," in *Journal of the Hydraulics Division*, Vol, 107, No. 11, pp.1547-1563.
- (4) Davenport, Thomas E., "Lakes: Physical Processes," at <u>www.waterencyclopedia.com/Hy-La/Lakes-Physical-Processes.html.</u>
- (5) Andrews, J.E., PE, Natural Resource Conservation Service, undated. "Wastewater Storage Pond Design," presentation at Colorado CNMP Workshop. www.colostate.edu/Dept/SoilCrop/extension/Soils/cnmp/Docs/sec8.ppt

This page was intentionally left blank.

7.3 SPRAY COOLING

DESCRIPTION. Spray cooling employs evaporative cooling to remove heat from treated wastewater. The heated water is repeatedly sprayed into the atmosphere from a lined pond, exposing millions of droplets to the air which absorbs some of the moisture, transferring heat out of the remaining water. The operative physical cooling principle is the same as in a cooling tower or cooling pond. Spray cooling uses a pump and motor, manifold, nozzles, and a floating platform. This approach requires more space than a cooling tower, but less land than a cooling pond.

WHERE METHOD WOULD BE MOST APPLICABLE. The approach would be applicable in a location where there is insufficient space for a static cooling pond, or where additional dissolved oxygen in the effluent would be advantageous. Because of limitations in evaporative cooling effectiveness, there should be at least a 10°C difference between the effluent temperature and ambient wet bulb temperature.

POTENTIAL BENEFITS. In addition to cooling the effluent, spraying has the benefit of aerating the wastewater. Dissolved oxygen is a very important parameter for stream health, and this approach would provide both a well oxygenated effluent as well as reduced discharge temperature. The space required for spray cooling is substantially less than that needed for a static cooling pond. According to one spray system vendor, the land required is only 5 percent of that needed for cooling ponds. (1)



Spray cooling Source: Aqua-Aerobic Systems, Inc.

POTENTIAL DISADVANTAGES. Spray cooling consumes power for pumping and spraying the effluent, and therefore is a more expensive approach than a cooling pond. Continuous exposure of the motor to very humid conditions requires that the motor be specially designed for this application, and that it be well maintained. In some weather conditions, fog may form and drift from the spray pond. Such fog can impair visibility or create condensation on nearby buildings, vehicles, or equipment. Strong winds will cause drift away from the pond. (1)

Water lost to evaporation is also lost to instream flow in the receiving surface water. During low periods, this loss of water may exacerbate fish habitat issues. In addition, the water lost to evaporation is no longer available to the municipality under its water rights.

ENGINEERING CONSIDERATIONS. The theoretical level of cooling that can be achieved through an evaporative system depends on the difference between the effluent temperature and the ambient wet bulb temperature, surface area of water in contact with the air, the relative velocities of the air and water droplets during contact, and the amount of time the effluent is in contact with the air. (1) If there is an insufficient difference between the temperature of the effluent and the air's wet bulb temperature, little or no cooling will occur.

Other engineering considerations include the use of corrosion resistant materials or coatings on the motor assembly, pumps, and manifold system. Pumps should be efficient at low head (20 to 23 feet of water) and high flow operating conditions. The manifold should provide even distribution of the water to the nozzles with low head loss. Nozzle design should avoid clogging and provide for a fine spray of small droplets. (1)

EFFECTIVENESS OF METHOD. As mentioned above, the effectiveness of this method depends on the difference between the ambient wet bulb temperature and the temperature of the effluent being sprayed. This method would probably not be effective in an application where ambient wet bulb temperature and effluent temperature were less than 10°C different. From a sustainability perspective, the power required and the associated generation of carbon emissions to spray the effluent in order to achieve a few degrees of cooling may not be justified.

Vendors can model the cooling impact for a particular application. This temperature modeling exercise is highly recommended during method evaluation.

<u>COST.</u> The cost of this approach includes the same costs as a cooling pond, plus spray equipment, including several spray nozzles, a pump, motor, manifold, floating platform, and associated piping. Operating costs include power for the motor and pump, and equipment maintenance. Generally speaking, this approach would be more expensive than a cooling pond and less expensive than a cooling tower.

LOCATIONS WHERE METHOD IS USED. The wastewater treatment plant in Granite Falls, Washington, uses three floating surface aerators on its effluent just ahead of the UV disinfection system. The effluent is routed through the former 7,000 gallon contact chamber where the aerators were installed to help increase dissolved oxygen prior to discharge. This system is expected to also cool the effluent by approximately 1°C, however, the level of cooling has not been verified. The influent flows through the bioselector to the clarifier, then into the aeration basin. Two large rotors located at either end of the aeration basin agitate the water, which also cools it. The rotors operate 21 hours a day, and submersible mixers operate during the 3 hours when the rotors are still (part of the denitrification process). The rotors are turned by two 20-hp motors. The three floating surface aerators are operated occasionally during the summer months to enhance dissolved oxygen in the effluent prior to discharge. If there are sulfates in the water, the aerators create excess bubbles, which is problematic for the UV disinfection system. (2)

Celgar Pulp Company in Castlegar, British Columbia, operates a large bleached kraft pulp mill adjacent to the Columbia River. The plant processes 15 to 20 million gallons of wastewater per day, and uses five 75-hp spray cooling units after the primary clarifier and before the aeration basin. The wastewater enters the spray cooling pond at 55°C (131°F) and is cooled to 35°C (95°F). Several cooling methods were considered by plant management. Constraints on land available made evaporation ponds infeasible. A cooling tower was rejected because of high initial cost and concerns regarding dissipation of the steam plume in the valley. The 22-feet deep, 428 by 454 feet spray cooling basin operates year round. Ambient temperatures range from 0°F in winter to 100°F in summer. Spray cooling was selected as the preferred method for this particular application. (3)

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Spray Cooling

SOURCES OF ADDITIONAL INFORMATION.

- (1) Shell, Gerry L. and R.C. Wendt, "Spray Cooling: An alternative to cooling towers." Aerators Inc., Roscoe, IL
- (2) Bjornson, Lyle, Granite Creek Lead Wastewater Treatment Plant Operator, Granite Falls, WA. Personal communication, May 2007.
- (3) Aerators Inc., Roscoe, IL. "Aqua-Lator® Spray Cooler Pulp Mill," Case History #695.
- (4) Aqua-Aerobic Systems, Inc., Rockford, IL, <u>www.aqua-aerobic.com</u>.

This page was intentionally left blank.

7.4 COOLING TOWERS

DESCRIPTION. A cooling tower is an evaporative cooling method used to dissipate heat from process water, such as the cooling water used in power plants, oil refineries, or commercial building air conditioners. This technology is applicable to small heat loads and small volumes, as well as to very large applications such as nuclear power plants. Cooling tower units can be small, factory-built units that are installed on the roof of a building or large structures built on site.

There are two primary mechanisms of heat transfer used in cooling towers: evaporation, used in wet cooling towers (direct, open circuit, or simply cooling towers), and convection, used in dry cooling towers (indirect or closed circuit), where heat is transmitted through a surface that separates the hot fluid from ambient air. Some cooling towers use a hybrid of the two approaches. The evaporative approach is most applicable to sewage treatment plants, so the information that follows refers only to "wet," "direct," or "open circuit" cooling towers.

In a wet cooling tower, a flow of air is drawn past a flow of hot water. During the contact between the heated water and cooler air, some of the water evaporates into the flow of air (if the air is not saturated), extracting heat from the remaining water flow. Thus the heat from the hot water is dissipated into the air. Water as a heat transfer medium is far more effective than air.

Most open circuit cooling towers use a packing or fill to increase the surface area between the air and hot water. The fill may consist of several levels of horizontal or randomly distributed splash elements which create a cascade of many small droplets, resulting in a large combined surface area (splash fill). Another form of fill is a series of multiple vertical wetted surfaces upon which thin films of water flow, providing expanded air-to-water contact. The water is cooled as it descends by gravity through the packing as the air flows upward, absorbing water vapor and extracting heat. The warm moist air is discharged to the atmosphere, and the cool water is collected in a basin below the fill.

Cooling towers can be designed as counterflow devices, with the air traveling upward through the fill, and the water moving downward. In a cross-flow cooling tower, the air moves horizontally through the fill and the water flows downward.



Crossflow style cooling tower Source: SPX Cooling Technologies, www.spxcooling.com

The air can be moved through a cooling tower using the natural buoyancy of the heated exhaust air rising in a tall chimney to provide draft. Alternatively, the air can be moved by power-driven fans that either draw or force the air through the tower.

WHERE METHOD WOULD BE MOST APPLICABLE. Cooling towers are most effective where there is a difference of 10°C or more between the temperature of the heated effluent and the ambient wet bulb temperature. Cooling towers do not require much space, and can be specified as off-the-shelf units.



MC Fluid Cooler manufactured by Marley Source: SPX Cooling Technologies, www.spxcooling.com

POTENTIAL BENEFITS.

Cooling towers can be relatively uncomplicated and easy to operate. They can be turned on during the critical season and turned off when stream temperatures have decreased. They are not as expensive to operate as chillers. Like chillers, cooling towers provide predictable cooling performance.

<u>POTENTIAL</u> DISADVANTAGES.

Cooling towers may become clogged with biological growth such as algae. This requires cleaning the tower, which can be difficult depending on the unit's design. Cooling towers are not very effective in humid locations. They do consume power to run the fan and the pump. Drift from a cooling tower can impact other buildings or impair visibility.

ENGINEERING CONSIDERATIONS. The ability of a cooling tower to reduce the water temperature is based on how much water is lost to evaporation, which depends on the temperature and humidity of the ambient air (or "wet bulb" temperature). In a region with high humidity, there will be less evaporation than in an arid climate. Typically, a cooling tower is effective if the target temperature is $75^{\circ}F(23.9^{\circ}C)$ or higher, depending on the wet bulb temperature for the tower.

Freeze protection methods must be used to prevent freezing during very cold weather. Methods used include basin heaters, a drain system or remote basin design, or tower draindown.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Cooling Towers

At the Cedar Creek Corrections Center in Littlerock, Washington, a small cooling tower was engineered and installed in 2001 for the extended aeration activated sludge wastewater treatment plant. The plant handles approximately 50,000 gallons of wastewater per day, and discharges into a very small creek. Following are the key design parameters that were used to specify the cooling tower for this plant.

Key Design Parameters for Cedar Creek Corrections Center Treatment Plant Cooling Tower

Parameter	Value
Effluent temperature prior to cooling	75°F (24°C)
Target effluent discharge temperature	64.5°F (18°C)
Wet bulb air temperature	61°F (16°C)
WWTP flow range	40,000 – 67,000 gallons per day
Effluent recirculation flow rate	150 gallons per minute

Source: Gray & Osborne, April 2001, Addendum No. 1, Engineering Report, Wastewater Treatment Facility, Cedar Creek Corrections Center, for Washington Department of Corrections.

EFFECTIVENESS OF METHOD. Cooling towers are very effective cooling devices, and have been used successfully in a variety of applications, such as cooling heated water for power generation plants and large office building chiller systems.

<u>COST.</u> The cooling tower installed at the 0.05 MGD plant at Cedar Creek Corrections Center cost \$129,000 (installed) in 2001 dollars. Capital cost for a cooling tower is high, as are both operating and maintenance costs. This is one of the most expensive options discussed in this report.

LOCATIONS WHERE METHOD IS USED. Two small wastewater treatment plants in Washington use cooling towers during the summer months. These plants are owned and operated by the Washington Department of Corrections at Larch Corrections Center in Yacolt, Washington, and Cedar Creek Corrections Center in Littlerock, Washington.

SOURCES OF ADDITIONAL INFORMATION.

- (1) Baltimore Aircoil Product and Application Handbook, Vol. II, Baltimore Aircoil Company, Baltimore, MD, <u>www.baltimoreaircoil.com</u>, 410-799-6200
- (2) Cooling Technology Institute, <u>www.cti.org</u>
- (3) Cooling Technology, Inc., Charlotte, NC, <u>www.coolingtechnology.com/About_Process_Cooling/cooling-towers/default.html</u>, 414-607-7016
- (4) Delta Cooling Towers, Inc., Rockaway, NJ, www.deltacooling.com, 973-586-2201
- (5) SPX Cooling Technologies, Overland Park, KS, <u>www.spxcooling.com</u>, 913-664-7400

This page was intentionally left blank.

7.5 CHILLERS

DESCRIPTION. Chillers are mechanical devices that employ an evaporator, compressor, condenser, expansion valve, and refrigerant to remove heat from a liquid or gaseous material. A chiller could be used to provide direct cooling of effluent before it is discharged to the receiving water. There are basically five different types of chillers, based on the type of compressor: absorption, reciprocating, scroll, screw, and centrifugal. Chillers are either water-cooled or air-cooled. For this discussion, an air-cooled chiller is assumed to be the more practical choice.

The liquid refrigerant in the evaporator absorbs heat from the material being cooled. As it leaves the evaporator, the refrigerant is a low pressure, low temperature vapor being drawn into the compressor. The compressor "squeezes" the refrigerant, increasing its pressure and temperature. The refrigerant, now a vapor at a higher temperature and pressure, is pumped to the condenser where it is (typically) air-cooled. In the condenser, the refrigerant returns to liquid phase as heat is released. The liquid refrigerant, still under pressure, then passes through the expansion valve into the evaporator. The expansion valve allows the pressure of the liquid refrigerant to release, further reducing the temperature of the refrigerant.



Trane water chiller Source: High Performance HVAC Systems, <u>www.high-</u> performance-hvac.com/air-conditioning/chillers/chiller-types.html

WHERE METHOD WOULD BE MOST APPLICABLE. A chiller can be used essentially anywhere that power is available. Chillers are reliable in any climate. Chillers do not require much space and are available in a variety of configurations to accommodate different installation needs. This approach might be attractive in a location where there is no land available for a ground discharge option, and where power costs are not prohibitive.

POTENTIAL BENEFITS. Potential benefits of using a chiller to cool effluent include certainty of effectiveness, precision in temperature control, low space requirements, and the ability to obtain an off-the-shelf-unit.

POTENTIAL DISADVANTAGES. Potential downsides to using a chiller are capital cost, operating cost, and maintenance effort and cost.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Chillers

ENGINEERING CONSIDERATIONS. There are several important considerations in the specification of a chiller for effluent cooling. Selection of an efficient unit will save on operating costs. A mechanical engineer and chiller vendor can assist with the selection of an efficient cooling system. Parameters that should be considered include:

- Heat load, calculated from effluent temperatures and flow rate
- Input temperature
- Required discharge temperature
- Flow rate through the unit
- Type of compressor
- Type of refrigerant (aim for low global warming potential and avoid ozone depleting products)
- Installation location
- Physical restrictions
- Electrical service available
- Chiller efficiency [Integrated Part-Load Value (IPLV) and Full-Load (FL) ratings]



Industrial chiller Source: Motivair[™] Cooling Solutions, <u>www.motivaircorp.com</u>

• Life cycle cost. (2, 3)

EFFECTIVENESS OF METHOD. The effectiveness of chiller use to reduce effluent temperature would be very high. A chiller, if well specified for the particular application, can cool effluent to a precisely controlled temperature.

COST. Chillers are expensive units to purchase and operate. Careful attention should be paid to appropriate sizing of the unit and its efficiency ratings. An order of magnitude capital cost for a chiller system is \$25,000 to \$60,000 (in 2003 dollars) per MGD per °F. Operating costs are roughly estimated at \$5,000 to \$10,000 (in 2003 dollars) per MGD per °F per year. (4) Actual operating costs will depend on the number of months the chiller must operate and local power costs.

Cost Example

A treatment plant processes 1.0 million gallons per day (mgd) and produces an effluent at 75°F. The plant is required to attain a discharge temperature of 64°F. A chiller would cost in the range of \$275,000 to \$660,000. Operating costs are estimated in the range of \$55,000 to \$110,000 per year.

METHODS TO REDUCE OR AVOID THERMAL IMPACTS TO SURFACE WATER Chillers

LOCATIONS WHERE METHOD IS USED. There were no municipal wastewater treatment plants identified that use a chiller for effluent cooling. Process chillers are in common use in many industries such as food and beverage processing, plastics, printing, laser cutting, rubber manufacturing, power generation, chemical processing, die casting and machine-tooling, and medical equipment. (5)

SOURCES OF ADDITIONAL INFORMATION.

- (1) Honeywell Control Systems Ltd., 2004. "The Refrigeration System, an Introduction to Refrigeration."
- (2) ArctiChill, Newberry, SC. Process Chiller Selection Requirement Questionnaire, <u>www.artichill.com.</u>
- (3) Wikipedia, June 2007. Chiller, <u>http://en.wikipedia.org/wiki/Chiller</u>.
- (4) Clean Water Services, October 2003. Draft Temperature Management Plan for the Rock Creek and Durham Wastewater Treatment Facilities.
- (5) Zycon Global Services, Industrial Process Chillers, <u>www.zycon.com/Design-Info/Chillers/Chillers.asp.</u>
- (6) U.S. Department of Energy, Federal Energy Management Program, November 2003. "How to Buy an Energy-Efficient Air-Cooled Electric Chiller," <u>http://www1.eere.energy.gov/femp/pdfs/air_chillers.pdf</u>.
- (7) U.S. Department of Energy, Federal Energy Management Program, November 2003. "How to Buy an Energy-Efficient Water-Cooled Electric Chiller," <u>http://www1.eere.energy.gov/femp/pdfs/wc_chillers.pdf.</u>
- (8) Motivair[™] Corp., Amherst, NY. MPC Water Chillers, <u>www.motivaircorp.com</u>.

This page was intentionally left blank.

7.6 GEOTHERMAL LOOP

DESCRIPTION. Geothermal or ground loop heat exchangers use the temperature of subsurface strata or groundwater to heat or cool a flow of water or other heat transfer medium. Such systems are becoming more common for the heating and cooling of schools, office buildings, and other commercial structures. (1) For the purposes of cooling sewage treatment plant effluent, a geothermal cooling system would route the effluent through underground piping where groundwater would absorb heat from the effluent-filled pipes before discharge of the effluent into surface receiving water. Another configuration that uses the same cooling concept would employ one or more groundwater wells to extract cold water and pass it through an isolated heat exchanger located above ground, where the treatment plant effluent would be cooled prior to discharge (indirect openloop system). In either approach, there is no direct contact between the effluent and groundwater. Discharge of effluent directly into groundwater is considered "groundwater injection," and is discussed in another section of this report. Use of groundwater in direct contact (i.e., mixing) with effluent is addressed in the section titled "Dilution".

There are several different piping configurations possible with ground loop systems—horizontal, spiral ("slinky"), vertical, and submerged, as well as hybrid systems that combine the use of a cooling pond or cooling tower. The hybrid systems are not addressed here, however other sections of this report describe cooling ponds and cooling towers. The combination of these systems with geothermal loops is relatively straightforward and could be explored further for a particular application with a design engineer.

In a horizontal loop system, pipes are installed in multiple trenches, typically 4 to 10 feet deep. Multiple loops can be installed in each trench. This configuration requires the greatest amount of land area per unit of cooling, relative to other ground loop arrangements. (1)



Horizontal ground loop schematic with parallel loops and one loop per trench. Note: this schematic is of a typical building geothermal system where water is rerouted back into the building.

The slinky system, or spiral loop, is a variation of the horizontal loop system, where 3 to 6-foot diameter coils of HDPE pipe are either laid flat in a trench of the same width, or the coils are inserted upright into a very narrow trench.



Left: Slinky ground loop schematic. Drawing shows a typical building loop system, not an effluent cooling and discharge system. Right: Installation of a slinky loop system.

A vertical loop system may be advantageous where land area is constrained. This system uses a series of borings, typically 200 to 300 feet deep, into which U-tube HDPE loop pipes are installed.

A submerged loop system uses a coiled piping loop anchored near the bottom of a pond or lake at least 6 to 8 feet below the water surface, and preferably deeper to ensure favorable temperature

differential and thermal mass. A facility that has an artificial pond for aesthetic enhancement could potentially use the pond for a submerged system, provided the pond has adequate surface area and depth. (1)





Above: Vertical loop system schematic. Note: This drawing shows a typical building heating/cooling system, not an effluent cooling & discharge system. Left: Submerged loop system schematic.

WHERE METHOD WOULD BE MOST APPLICABLE. A horizontal loop system is most applicable in an area with plenty of land area for installing the piping loops, and where groundwater is high enough to provide adequate heat transfer. This configuration lends itself to installation under other features such as parking lots, recreation fields, or playgrounds. Advantages of the horizontal loop system include lower cost for trenching than drilling in a vertical system; broader selection of contractors who can install such a system; variety of installation methods; ability to "hide" the system under another land development feature. (1)

Disadvantages of the horizontal configuration include requirement for greatest land area; cooling performance can be affected by season, rainfall, and drought events that lower groundwater levels; care must be taken in installation not to damage the HDPE pipe during backfilling of the trenches; and typically longer pipe lengths are needed than in a vertical system for equivalent cooling performance. (1)

POTENTIAL BENEFITS. Slinky systems require less real estate and less trenching than the horizontal loop system, and installation costs may be significantly less. (1)

A vertical loop system has a couple of advantages over slinky and horizontal configurations. One is that it requires significantly less land area and less total pipe length. Seasonal soil temperature variations have minimal impact on system performance. A vertical system can be employed in an area where the groundwater table is deeper than that required for a horizontal or slinky system.

POTENTIAL DISADVANTAGES. Slinky coils are more prone to damage during backfill, and/or to incomplete backfill which would leave voids around the tubing, which decreases system performance. Another disadvantage is higher pumping costs due to higher head loss than in a horizontal system. (1)

Vertical systems are more expensive to install than horizontal and slinky loop systems because they rely on drilling as opposed to trenching or bulldozing. The U-tube piping is also more costly than coiled or straight HDPE tubing.

ENGINEERING CONSIDERATIONS. Key parameters that must be considered in the design of a geothermal system include the following:

- Subsurface geologic formations
- Depth to bedrock
- Groundwater level, temperature, and seasonal fluctuation
- Soil characteristics, including porosity, thermal conductivity, and heat capacity. (2)

In a horizontal loop system, pipes are installed in trenches typically 4 to 10 feet deep. Multiple loops can be installed in each trench, usually from one to six loops of $\frac{3}{4}$ -inch to $\frac{1}{2}$ -inch high density polyethylene (HDPE) tubing. (1) Trench lengths, spacing, and number of loops per trench depend on soil characteristics and cooling demand. According to information from Virginia Tech, trench lengths can range from 100 to 400 feet per ton of cooling (one ton = 12,000 BTU/hr). Land space requirements range typically from 1,500 to 3,000 square feet per system ton. (1)

Slinky systems require roughly 700 to 900 feet of piping per system ton. Typically, 80 to 120 feet of piping are installed per 10 feet of trench, and trenches are usually about 12 feet apart. This configuration reduces the land space requirement three to five times from the horizontal loop layout, at approximately 500 to 800 square feet per system ton. (1)

Vertical systems employ loop piping inserted into a series of deep borings. Depending on soil characteristics, particularly thermal conductivity, typical piping required is 400 to 600 linear feet per system ton, or one to two boreholes. Borings are spaced 15 to 20 feet apart. Land needed for a vertical loop system is approximately 150 to 300 square feet per system ton. (1)

The performance of a submerged loop system depends on pond size and depth and the characteristics of the pond's thermocline. Typically, a pond at least 10 feet deep can support a loop system ranging from 15 to 85 system tons per acre of pond surface area. A submerged system requires roughly 300 linear feet of piping per system ton. The coils should be secured 9 to 18 inches above the bottom of the pond to allow for adequate convective circulation around the tubing.

EFFECTIVENESS OF METHOD. A geothermal system that employs sufficient tubing adequately spaced in the ground with generous groundwater flow could be a very effective effluent cooling technique. A highly effective system would rely on groundwater as the primary heat sink, not soil, as soil would likely reach an equilibrium temperature and not provide adequate cooling particularly in hotter months when effluent cooling is most critical. The heat capacity of dry soil is about 0.20 BTU per pound per °F of temperature change, which is one-fifth the heat capacity of water. Therefore, installation of the system below the summer groundwater table is essential. Soil texture also affects system performance. More porous soils, where the pore spaces between particles are filled with water, will provide greater thermal conductivity than tighter soils, and much greater thermal conductivity than dry coarse soils.

COST. A high school in Fond du Lac, Wisconsin, has a 700-ton geothermal heat pump system connected to a submerged pond loop. In 2001, this was the largest geothermal pond system in the U.S. This system uses 179 water-to-air heat pumps in the classrooms, 14 water-to-water heat pumps in the common areas and for general ventilation, and four boilers for vestibules and backup heat. The submerged pond loop consists of 720 300-foot tubing coils in independent circuits. Total system cost was \$5.66 million, or \$12 per square foot of building space. The pond loop itself cost \$465,000. (3) Annual savings over a traditional heating and cooling system are \$290,000 from reduced power and maintenance costs. (4)

LOCATIONS WHERE METHOD IS USED. A new 38,000 square foot warehouse and engineering office space building constructed in 2005 at the Washington State Penitentiary in Walla Walla, Washington, uses a geothermal loop system for building heating and cooling and for operation of large food coolers. The horizontal loop system uses flat coils buried 5 to 8 feet below ground surface. The system was designed by DLR Group out of Seattle, Washington.

Fond du Lac High School, mentioned above, is a 400,000 square foot building with 2,400 students. The geothermal pond system uses 41 miles of ³/₄-inch HDPE tubing, submerged in two 20-feet deep ponds that have a combined surface area of 12 acres. This system saves about 20 percent on energy consumption over a traditional chiller/boiler cooling and heating system, produces 13 percent less carbon dioxide, saved about 50 percent of the space within the building that would have been occupied by mechanical heating and cooling systems, and reduced maintenance requirements. (4)

Luther College Center for the Arts, located in Decorah, Iowa, has a vertical loop geothermal system serving a two-level, 60,000 square foot building. This 248-ton system employs 86 wells at 300 feet deep and was designed by Thelen Engineering of Oconomowoc, Wisconsin. (5)

There were no municipal wastewater treatment plants identified that use a geothermal system for cooling their treated effluent.

SOURCES OF ADDITIONAL INFORMATION.

- (1) Virginia Tech, Geo4va program, "Ground Loop Configuration and Installation," at <u>www.geo4va.vt.edu/A2/A2.htm</u>.
- (2) Virginia Tech, Geo4va program, "Earth Temperature and Site Geology," at <u>www.geo4va.vt.edu/A1/A1.htm</u>.
- (3) Alliant Energy, CDH Energy Corporation, and Focus on Energy, "Fond du Lac High School -What Lies Beneath?" at www.alliantenergygeothermal.com/stellent2/groups/public/documents/pub/geo_001414.pdf.
- (4) Alliant Energy, "Geothermal in Action: Schools & Churches Fond du Lac High School," at <u>www.alliantenergygeothermal.com/stellent2/groups/public/documents/pub/geo_act_sch_001349.</u> <u>hcsp.</u>
- (5) Alliant Energy, "Geothermal in Action: Schools & Churches Luther College Center for the Arts," at

www.alliantenergygeothermal.com/stellent2/groups/public/documents/pub/geo_act_sch_001351. hcsp. This page was intentionally left blank.

APPENDIX A

WAC 173-201A-200 Fresh water designated uses and criteria

This page was intentionally left blank.

WAC 173-201A-200 Fresh water designated uses and criteria

The following uses are designated for protection in fresh surface waters of the state. Use designations for water bodies are listed in WAC <u>173-201A-600</u> and <u>173-201A-602</u>.

(1) **Aquatic life uses.** Aquatic life uses are designated based on the presence of, or the intent to provide protection for, the key uses identified in (a) of this subsection. It is required that all indigenous fish and nonfish aquatic species be protected in waters of the state in addition to the key species described below.

(a) The categories for aquatic life uses are:

(i) **Char spawning and rearing.** The key identifying characteristics of this use are spawning or early juvenile rearing by native char (bull trout and Dolly Varden), or use by other aquatic species similarly dependent on such cold water. Other common characteristic aquatic life uses for waters in this category include summer foraging and migration of native char; and spawning, rearing, and migration by other salmonid species.

(ii) **Core summer salmonid habitat.** The key identifying characteristics of this use are summer (June 15 - September 15) salmonid spawning or emergence, or adult holding; use as important summer rearing habitat by one or more salmonids; or foraging by adult and subadult native char. Other common characteristic aquatic life uses for waters in this category include spawning outside of the summer season, rearing, and migration by salmonids.

(iii) **Salmonid spawning, rearing, and migration.** The key identifying characteristic of this use is salmon or trout spawning and emergence that only occurs outside of the summer season (September 16 - June 14). Other common characteristic aquatic life uses for waters in this category include rearing and migration by salmonids.

(iv) **Salmonid rearing and migration only.** The key identifying characteristic of this use is use only for rearing or migration by salmonids (not used for spawning).

(v) **Non-anadromous interior redband trout.** For the protection of waters where the only trout species is a non-anadromous form of self-reproducing interior redband trout (*O. mykis*), and other associated aquatic life.

(vi) **Indigenous warm water species.** For the protection of waters where the dominant species under natural conditions would be temperature tolerant indigenous nonsalmonid species. Examples include dace, redside shiner, chiselmouth, sucker, and northern pikeminnow.

(b) **General criteria.** General criteria that apply to all aquatic life fresh water uses are described in WAC $\underline{173-201A-260}(2)(a)$ and (b), and are for:

(i) Toxic, radioactive, and deleterious materials; and

(ii) Aesthetic values.

(c) **Aquatic life temperature criteria.** Except where noted, water temperature is measured by the 7-day average of the daily maximum temperatures (7-DADMax). Table 200 (1)(c) lists the temperature criteria for each of the aquatic life use categories.

Table 200 (1)(c)

Category	Highest 7-DADMax
Char Spawning	9°C (48.2°F)
Char Spawning and Rearing	12°C (53.6°F)
Salmon and Trout Spawning	13°C (55.4°F)
Core Summer Salmonid Habitat	16°C (60.8°F)
Salmonid Spawning, Rearing, and Migration	17.5°C (63.5°F)
Salmonid Rearing and Migration Only	17.5°C (63.5°F)
Non-anadromous Interior Redband Trout	18°C (64.4°F)
Indigenous Warm Water Species	20°C (68°F)

Aquatic Life Temperature Criteria in Fresh Water

(i) When a water body's temperature is warmer than the criteria in Table 200 (1)(c) (or within 0.3° C (0.54°F) of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the 7-DADMax temperature of that water body to increase more than 0.3° C (0.54°F).

(ii) When the background condition of the water is cooler than the criteria in Table 200 (1)(c), the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted as follows:

(A) Incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/(T) as measured at the edge of a mixing zone boundary (where "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge); and

(B) Incremental temperature increases resulting from the combined effect of all nonpoint source activities in the water body must not, at any time, exceed 2.8° C (5.04° F).

(iii) Temperatures are not to exceed the criteria at a probability frequency of more than once every ten years on average.

(iv) Spawning and incubation protection. The department has identified waterbodies, or portions thereof, which require special protection for spawning and incubation in ecology publication 06-10-038 (also available on ecology's web site at www.ecy.wa.gov). This publication indicates where and when the following criteria are to be applied to protect the reproduction of native char, salmon, and trout:

• Maximum 7-DADMax temperatures of $9^{\circ}C$ (48.2°F) at the initiation of spawning and at fry emergence for char; and

• Maximum 7-DADMax temperatures of 13°C (55.4°F) at the initiation of spawning for salmon and at fry emergence for salmon and trout.

The two criteria above are protective of incubation as long as human actions do not significantly disrupt the normal patterns of fall cooling and spring warming that provide significantly colder temperatures over the majority of the incubation period.

(v) For lakes, human actions considered cumulatively may not increase the 7-DADMax temperature more than 0.3° C (0.54°F) above natural conditions.

(vi) Temperature measurements should be taken to represent the dominant aquatic habitat of the monitoring site. This typically means samples should:

(A) Be taken from well mixed portions of rivers and streams; and

(B) Not be taken from shallow stagnant backwater areas, within isolated thermal refuges, at the surface, or at the water's edge.

(vii) The department will incorporate the following guidelines on preventing acute lethality and barriers to migration of salmonids into determinations of compliance with the narrative requirements for use protection established in this chapter (e.g., WAC <u>173-201A-310</u>(1), 173-201A-400(4), and 173-201A-410 (1)(c)). The following site-level considerations do not, however, override the temperature criteria established for waters in subsection (1)(c) of this section or WAC <u>173-201A-602</u>:

(A) Moderately acclimated (16-20°C, or 60.8-68°F) adult and juvenile salmonids will generally be protected from acute lethality by discrete human actions maintaining the 7-DADMax temperature at or below 22° C (71.6°F) and the 1-day maximum (1-DMax) temperature at or below 23° C (73.4°F).

(B) Lethality to developing fish embryos can be expected to occur at a 1-DMax temperature greater than $17.5^{\circ}C$ (63.5°F).

(C) To protect aquatic organisms, discharge plume temperatures must be maintained such that fish could not be entrained (based on plume time of travel) for more than two seconds at temperatures above 33° C (91.4°F) to avoid creating areas that will cause near instantaneous lethality.

(D) Barriers to adult salmonid migration are assumed to exist any time the 1-DMax temperature is greater than $22^{\circ}C$ (71.6°F) and the adjacent downstream water temperatures are $3^{\circ}C$ (5.4°F) or more cooler.

(viii) Nothing in this chapter shall be interpreted to prohibit the establishment of effluent limitations for the control of the thermal component of any discharge in accordance with 33 U.S.C. 1326 (commonly known as section 316 of the Clean Water Act).

(d) **Aquatic life dissolved oxygen (D.O.) criteria.** The D.O. criteria are measured in milligrams per liter (mg/L). Table 200 (1)(d) lists the 1-day minimum D.O. for each of the aquatic life use categories.

Table 200 (1)(d)

Aquatic Life Dissolved Oxygen Criteria in Fresh Water

Category	Lowest 1-Day Minimum
Char Spawning and Rearing	9.5 mg/L
Core Summer Salmonid Habitat	9.5 mg/L
Salmonid Spawning, Rearing, and Migration	8.0 mg/L
Salmonid Rearing and Migration Only	6.5 mg/L
Non-anadromous Interior Redband Trout	8.0 mg/L
Indigenous Warm Water Species	6.5 mg/L

(i) When a water body's D.O. is lower than the criteria in Table 200 (1)(d) (or within 0.2 mg/L of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the D.O. of that water body to decrease more than 0.2 mg/L.

(ii) For lakes, human actions considered cumulatively may not decrease the dissolved oxygen concentration more than 0.2 mg/L below natural conditions.

(iii) Concentrations of D.O. are not to fall below the criteria in the table at a probability frequency of more than once every ten years on average.

(iv) D.O. measurements should be taken to represent the dominant aquatic habitat of the monitoring site. This typically means samples should:

(A) Be taken from well mixed portions of rivers and streams; and

(B) Not be taken from shallow stagnant backwater areas, within isolated thermal refuges, at the surface, or at the water's edge.

(e) **Aquatic life turbidity criteria.** Turbidity is measured in "nephelometric turbidity units" or "NTUs." Table 200 (1)(e) lists the maximum turbidity criteria for each of the aquatic life use categories.

Table 200 (1)(e)

Aquatic Life Turbidity Criteria in Fresh Water

Category	NTUs
Char Spawning and Rearing	Turbidity shall not exceed:
	• 5 NTU over background when the background is 50 NTU or less; or
	• A 10 percent increase in turbidity when the background turbidity is more than 50 NTU.
Core Summer Salmonid Habitat	Same as above.
Salmonid Spawning, Rearing, and Migration	Same as above.
Salmonid Rearing and Migration Only	Turbidity shall not exceed: • 10 NTU over background when the background is 50 NTU or less; or
	• A 20 percent increase in turbidity when the background turbidity is more than 50 NTU.
Non-anadromous Interior Redband Trout	Turbidity shall not exceed: • 5 NTU over background when the background is 50 NTU or less; or
	• A 10 percent increase in turbidity when the background turbidity is more than 50 NTU.

Indigenous Warm Water Species	 10 NTU over background when the background is 50 NTU or less; or
	• A 20 percent increase in turbidity when the background turbidity is more than 50 NTU.

(i) The turbidity criteria established under WAC <u>173-201A-200</u> (1)(e) shall be modified, without specific written authorization from the department, to allow a temporary area of mixing during and immediately after necessary in-water construction activities that result in the disturbance of in-place sediments. This temporary area of mixing is subject to the constraints of WAC <u>173-201A-400</u> (4) and (6) and can occur only after the activity has received all other necessary local and state permits and approvals, and after the implementation of appropriate best management practices to avoid or minimize disturbance of in-place sediments and exceedances of the turbidity criteria. A temporary area of mixing shall be as follows:

(A) For waters up to 10 cfs flow at the time of construction, the point of compliance shall be one hundred feet downstream from the activity causing the turbidity exceedance.

(B) For waters above 10 cfs up to 100 cfs flow at the time of construction, the point of compliance shall be two hundred feet downstream of the activity causing the turbidity exceedance.

(C) For waters above 100 cfs flow at the time of construction, the point of compliance shall be three hundred feet downstream of the activity causing the turbidity exceedance.

(D) For projects working within or along lakes, ponds, wetlands, estuaries, marine waters or other nonflowing waters, the point of compliance shall be at a radius of one hundred fifty feet from the activity causing the turbidity exceedance.

(f) **Aquatic life total dissolved gas (TDG) criteria.** TDG is measured in percent saturation. Table 200 (1)(f) lists the maximum TDG criteria for each of the aquatic life use categories.

Table 200 (1)(f)

Aquatic Life Total Dissolved Gas Criteria in Fresh Water

Category	Percent Saturation
Char Spawning and Rearing	Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection
Core Summer Salmonid Habitat	Same as above.
Salmonid Spawning, Rearing, and Migration	Same as above.
Salmonid Rearing and Migration Only	Same as above.
Non-anadromous Interior Redband Trout	Same as above.
Indigenous Warm Water Species	Same as above.

(i) The water quality criteria established in this chapter for TDG shall not apply when the stream flow exceeds the seven-day, ten-year frequency flood.

(ii) The TDG criteria may be adjusted to aid fish passage over hydroelectric dams when consistent with a department approved gas abatement plan. This plan must be accompanied by fisheries management and physical and biological monitoring plans. The elevated TDG levels are intended to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The following special fish passage exemptions for the Snake and Columbia rivers apply when spilling water at dams is necessary to aid fish passage:

• TDG must not exceed an average of one hundred fifteen percent as measured in the forebays of the next downstream dams and must not exceed an average of one hundred twenty percent as measured in the tailraces of each dam (these averages are measured as an average of the twelve highest consecutive hourly readings in any one day, relative to atmospheric pressure); and

• A maximum TDG one hour average of one hundred twenty-five percent must not be exceeded during spillage for fish passage.

(g) Aquatic life pH criteria. Measurement of pH is expressed as the negative logarithm of the hydrogen ion concentration. Table 200 (1)(g) lists the pH levels for each of the aquatic life use categories.

Table 200 (1) (g)

Aquatic Life pH Criteria in Fresh Water

Use Category	pH Units
Char Spawning and Rearing	pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units.
Core Summer Salmonid Habitat	Same as above.
Salmonid Spawning, Rearing, and Migration	pH shall be within the range of 6.5 to 8.5 with a human-caused variation within the above range of less than 0.5 units.
Salmonid Rearing and Migration Only	Same as above.
Non-anadromous Interior Redband Trout	Same as above.
Indigenous Warm Water Species	Same as above.

(2) **Recreational uses.** The recreational uses are extraordinary primary contact recreation, primary contact recreation, and secondary contact recreation.

(a) **General criteria.** General criteria that apply to fresh water recreational uses are described in WAC <u>173-201A-260</u> (2)(a) and (b), and are for:

(i) Toxic, radioactive, and deleterious materials; and

(ii) Aesthetic values.

(b) Water contact recreation bacteria criteria. Table 200 (2)(b) lists the bacteria criteria to protect water contact recreation in fresh waters.

Table 200 (2)(b)

Water Contact Recreation Bacteria Criteria in Fresh Water

Category	Bacteria Indicator
Extraordinary Primary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.
Primary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100 mL.
Secondary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 200 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 400 colonies /100 mL.

(i) When averaging bacteria sample data for comparison to the geometric mean criteria, it is preferable to average by season and include five or more data collection events within each period. Averaging of data collected beyond a thirty-day period, or beyond a specific discharge event under investigation, is not permitted when such averaging would skew the data set so as to mask noncompliance periods. The period of averaging should not exceed twelve months, and should have sample collection dates well distributed throughout the reporting period.

(ii) When determining compliance with the bacteria criteria in or around small sensitive areas, such as swimming beaches, it is recommended that multiple samples are taken throughout the area during each visit. Such multiple samples should be arithmetically averaged together (to reduce concerns with low bias when the data is later used in calculating a geometric mean) to reduce sample variability and to create a single representative data point.

(iii) As determined necessary by the department, more stringent bacteria criteria may be established for rivers and streams that cause, or significantly contribute to, the decertification or conditional certification of commercial or recreational shellfish harvest areas, even when the preassigned bacteria criteria for the river or stream are being met.

(iv) Where information suggests that sample results are due primarily to sources other than warmblooded animals (e.g., wood waste), alternative indicator criteria may be established on a site-specific basis by the department. (3) **Water supply uses.** The water supply uses are domestic, agricultural, industrial, and stock watering.

General criteria. General criteria that apply to the water supply uses are described in WAC <u>173-</u> <u>201A-260</u> (2)(a) and (b), and are for:

(a) Toxic, radioactive, and deleterious materials; and

(b) Aesthetic values.

(4) **Miscellaneous uses.** The miscellaneous fresh water uses are wildlife habitat, harvesting, commerce and navigation, boating, and aesthetics.

General criteria. General criteria that apply to miscellaneous fresh water uses are described in WAC <u>173-201A-260</u> (2)(a) and (b), and are for:

(a) Toxic, radioactive, and deleterious materials; and

(b) Aesthetic values.

[Statutory Authority: RCW 90.48.035. 06-23-117 (Order 06-04), § 173-201A-200, filed 11/20/06, effective 12/21/06. Statutory Authority: Chapters 90.48 and 90.54 RCW. 03-14-129 (Order 02-14), § 173-201A-200, filed 7/1/03, effective 8/1/03.]


All Skillings Connolly reports are printed on recycled paper to help conserve our state's natural resources.