The Walkerton Inquiry

Commissioned Paper 9

Wastewater Collection and Treatment

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Toronto

2002

Published by Ontario Ministry of the Attorney General

This paper and other Walkerton Inquiry Commissioned Papers are available on the Walkerton Inquiry CD-ROM and at <www.walkertoninquiry.com> with the complete final report.

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Abstract

Through a comprehensive review of data available for wastewater treatment plants, this paper examines plant characteristics as well as the current costs and revenues associated with the wastewater industry in Ontario. An overview of Canadian and Ontario environmental legislation, available treatment technologies, and wastewater utility best practices is included. Brief attention is also given to the treatment of biosolids and agricultural waste.

Examination of current environmental legislation provides a comparison of practices in Ontario with those in the United States, Europe, and Australia. A review of one of Ontario's major wastewater treatment facilities, the Ashbridges Bay Treatment Plant in Toronto, examines the effects of regulation on plant performance.

Finally, the authors propose recommendations for improvements to the regulation and treatment of Ontario's wastewater.

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1 Survey of Ontario Wastewater Treatment

1.1 Introduction

What is wastewater? Is it domestic sewage produced by individual residences? Should runoff from urban streets be considered wastewater? Is water produced as the by-product of industrial activity wastewater? What about runoff from agricultural lands – is that wastewater?

If these various products are considered wastewater, should they be treated? If so, what constituents should be removed, and why? What technologies can accomplish the required treatment? What do these technologies cost? Will other wastes produced during the treatment processes themselves require disposal?

On the surface, answering these questions might seem easy. Domestic sewage is a wastewater and it should be treated to protect the environment, correct? Yes, to a Grade 2 student who has just been introduced to these issues. This simplistic approach, however, should not be used to make multi-billion-dollar decisions. More precise and quantifiable answers are required, and they are not trivial.

Wastewater can be defined as the water by-product of human activities that can no longer be used directly without treatment. Domestic sewage is an easy example. High quality, potable water enters a home to be used by the resident for drinking and cooking, for cleaning of bodies and utensils, and for removing waste materials. The wastewater from cleaning processes is certainly no longer useable for cleaning, although perhaps it could be used to remove waste materials, and certainly wastewater containing human waste is no longer suitable for any other use in the home. The wastes must be removed.

We can use this definition for wastewater to classify industrial waters as well. If the water by-product can no longer be used, it is wastewater. Engineers are slowly beginning to recognize that, while a water by-product might no longer be suitable for one use, it could be satisfactory for another, less demanding use. At some point, however, the water quality will have deteriorated sufficiently that the water cannot be further used without treatment and it must be considered wastewater.

This paper has been prepared for discussion purposes only and does not represent the findings or recommendations of the Commissioner.

Runoff from urban and agricultural areas is harder to classify. Such waters are not being directly used by humans, but they come into contact with areas affected by humans. However, the same criterion can be applied: if the runoff water is no longer suitable for human use without treatment, say for irrigation or drinking, then it is wastewater.

Once wastewater has been identified, a decision must be made as to whether it requires treatment – but only after considering what impact, if any, it would have if left untreated. The main consideration is the impact on the receiving environment. The environmental impact of an untreated wastewater is a function of a number of factors, including the types and concentration of contaminants in the wastewater, the total mass of the contaminants, the nature of the receiving environment, and the sensitivity of the receiving environment to the contaminants.

Much effort has been expended in Ontario to define the acceptable limits of environmental impacts, to convert these limits to quantifiable contaminant concentration values, and to develop and implement technology to achieve these limits cost-effectively. This first chapter will provide an overview of wastewater treatment in Ontario today. Subsequent chapters will delve into the other issues.

1.2 Sources of Information

The Ontario Ministry of the Environment (MOE), Environmental Monitoring and Reporting Branch, maintains data about municipal wastewater treatment facilities and industrial direct dischargers in Ontario. These data are not currently available directly on the Internet, but they are available to the public electronically as database files or spreadsheets for a processing fee. Unless otherwise identified, the information presented in tables 1–1 through 1–13 is generated from 1998 data, the most recent available from the MOE at the time of writing this paper.

The MOE data sets consulted for this section do not contain all of the information submitted by wastewater dischargers. For more detailed information about a specific facility, a person would have to contact the MOE district office or the facility itself. More detailed information on a provincial basis would require contacting all of the district offices or individual facilities.

Additional sources of information used to prepare this chapter include personnel from the MOE and the Regional Municipality of Halton. Relevant acts and guidelines (see chapter 2) were also consulted.

1.3 Number and Size of Systems

In 1998 more than 600 facilities in Ontario discharged treated wastewater into Ontario waters. The Ontario Clean Water Agency (OCWA) operated 243 municipal facilities and approximately 25 other facilities (municipal and industrial). Municipalities operated 207 facilities, either directly or through contract to an agency other than OCWA. Individual industries operated another 163 facilities, 152 of which discharged treated process wastewater.

1.3.1 Municipal Wastewater

The municipal wastewater treatment capacity in 1998 was over 6,780,000 cubic meters per day (m^3/d). Treatment capacity differs from actual treated amount because treatment facilities typically treat less than their capacity. For example, the capacity for the Ashbridges Bay treatment plant in Toronto, the largest in the province, was 818,280 m^3/d in 1998, but the average daily flow was only 669,530 m^3. In rare cases average daily flow exceeded capacity, such as in the Greenway Water Pollution Control Plant in London with an average daily flow of 143,950 m^3 (rated capacity, 133,930 m^3/d). For this analysis, average treatment capacity is used for two reasons. First, average capacity indicates the maximum average discharge that should occur and therefore represents the worst case from the standpoint of environmental effects. Second, actual average daily flows were not reported for all facilities.

Although 447 facilities reported, most of the wastewater treatment occurred in a small number of facilities (see table 1-1). For example, the Ashbridges Bay plant in Toronto accounted for over 12% of the treatment capacity in the province. The ten largest facilities accounted for over 50%. In fact, over 80% of Ontario's treatment capacity was accounted for by approximately 10% of the facilities. The average capacity of all of the facilities was about 15,000 m^3/d. Approximately 90% of the municipal wastewater treatment facilities in Ontario had a capacity of less than 26,000 m^3/d, but the ten largest facilities had capacities greater than 130,000 m^3/d.

The capacity of any given municipal treatment facility does not necessarily correlate to environmental impact. A small facility can have a more intense environmental impact than a large facility, depending on the size of the receiving water and the treatment technology used. The following sections examine this issue more closely.

1.3.2 Industrial Wastewater

Almost 4,000,000 m^3/d of industrial process wastewater were discharged into Ontario surface waters in 1998 (see table 1-2). As was the case with municipal wastewater facilities, a small number of large industrial facilities produced most of the wastewater discharged. The single largest discharger produced 23% of the total, while the top ten dischargers produced 62%. Over 90% of the total discharge came from the largest 30% of the facilities. The average discharge for all facilities was 26,280 m^3/d. Approximately 81% of the industrial facilities in Ontario discharged less than 26,000 m^3/d, but the largest ten facilities discharged more than 89,000 m^3/d.

Table 1-1 Summary of Largest Municipal Facilities, 1998

	% of total facilities	Capacity (m^3/d)	% of total capacity	Population served	% of total population served
Largest facility	0.2	818,280	12.1	1,250,000	12.8
Largest 10 facilities	2.2	3,572,479	52.7	4,498,558	45.9
Largest 20 facilities	4.5	4,418,908	65.1	5,437,309	55.5
Largest 45 facilities	10.1	5,481,131	80.8	6,754,650	68.9

Table 1-2 Summary of Largest Industrial Dischargers, 1998

	% of total facilities	Effluent discharge (m^3/d)	% of total discharge
Largest facility	0.7	919,339	23.0
Total of largest 10 facilities	6.6	2,476,694	62.0
Total of largest 20 facilities	13.2	3,000,957	75.1
Total of largest 45 facilities	29.6	3,629,286	90.9

The discharge from the single largest industrial facility was larger than that from the single largest municipal facility. However, as in municipal facilities, the discharge from any given industrial facility does not necessarily correlate with environmental impact. As with municipal plants, a small facility can have a more intense environmental impact than a large facility, depending on the industry producing the wastewater, the size of the receiving water, and the treatment technology.

1.4 Municipal Systems Discharging to Surface Waters

1.4.1 Details of Municipal Discharges

Of the 447 municipal treatment facilities for which MOE collected data, all but 11 discharged treated effluent to surface waters. These surface waters are also used to some extent as sources of drinking water. The information in table 1-3 summarizes discharges to Ontario surface waters (based on treatment capacity) that received discharges from five or more facilities or from any one discharge greater than 20,000 m^3/d.

Only 35% of wastewater treatment facilities account for almost 90% of the discharge capacity to Ontario surface waters. Discharges directly to Lake Ontario alone accounted for over 38% of all discharge capacity in the province. If discharges to portions of Lake Ontario such as Hamilton Harbour are included, the percentage increases.

Table 1-4 shows additional discharges with capacity greater than 10,000 m^3/d, but not included in table 1-3. The total capacity of these smaller discharges is relatively small overall, accounting for only 3.2% of the total discharge capacity for the province. This information is relevant, however, because the receiving waters for these discharges might in some cases be more sensitive than waters that receive much greater flows. Smaller communities discharging into potentially sensitive receiving waters may have fewer financial resources to construct and operate the technology required to meet effluent criteria.

1.4.2 Treatment Technologies

The treatment technologies employed at a municipal wastewater treatment facility are selected in response to the its effluent targets. Effluent targets are a

Table 1-3 Summary of Major Discharges to Ontario Surface Waters

Receiving water	Number of discharges	% of total	Discharge capacity (m^3/d)	% of total	Population	% of total
Lake Ontario	23	5.1	2,598,565	38.3	3,564,802	36.4
Ottawa River	10	2.2	592,832	8.7	555,044	5.7
Redhill Creek	1	0.2	409,140	6.0	352,000	3.6
Grand River	12	2.7	363,494	5.4	413,271	4.2
Thames River	12	2.7	301,226	4.4	385,838	3.9
St. Lawrence River	8	1.8	176,609	2.6	144,812	1.5
Detroit River	3	0.7	173,039	2.6	160,869	1.6
Welland Canal & River	4	0.9	124,591	1.8	140,770	1.4
Kaministikwia River	1	0.2	109,104	1.6	101,527	1.0
Hamilton Harbour	1	0.2	93,193	1.4	120,100	1.2
Lake Simcoe	5	1.1	84,858	1.3	80,740	0.8
Lake Erie	6	1.3	84,731	1.2	100,595	1.0
Junction Creek	2	0.4	84,125	1.2	89,662	0.9
St. Clair River	4	0.9	74,022	1.1	80,550	0.8
St. Mary's River	2	0.4	72,736	1.1	160,000	1.6
Bay of Quinte	3	0.7	72,011	1.1	54,861	0.6
Chippawa Power Canal	1	0.2	68,200	1.0	67,835	0.7
Speed River	2	0.4	63,871	0.9	93,392	1.0
Twelve Mile Creek	1	0.2	61,412	0.9	75,690	0.8
Trent River	3	0.7	60,969	0.9	69,661	0.7
Georgian Bay	6	1.3	60,494	0.9	43,275	0.4
Lake Nipissing	1	0.2	54,480	0.8	48,000	0.5
Little River	1	0.2	36,368	0.5	72,100	0.7
Mattagami River	2	0.4	35,715	0.5	43,437	0.4
Don River	1	0.2	34,090	0.5	85,000	0.9
Kettle Creek	2	0.4	27,840	0.4	32,037	0.3
Saugeen River	7	1.6	27,767	0.4	27,280	0.3
Avon River	1	0.2	27,276	0.4	28,600	0.3
Niagara River	2	0.4	26,791	0.4	15,265	0.2
Mississippi River	2	0.4	24,555	0.4	10,883	0.1
Lake Huron	6	1.3	19,705	0.3	19,030	0.2
No Surface Discharge	11	2.5	14,182	0.2	17,890	0.2
Ausable River	5	1.1	8,331	0.1	10,513	0.1
South Nation River	5	1.1	4,683	0.1	5,305	0.1
Total	**156**	**34.9**	**6,071,005**	**89.5**	**7,270,634**	**74.2**

function of the total effluent flow from the treatment facility, the flow or volume of the receiving water (the ability of the receiving water to dilute the effluent), and the sensitivity of the receiving water to a contaminant of concern.

As described in chapter 4, wastewater treatment technologies are typically grouped as primary, secondary, and tertiary. Primary treatment removes only contaminants that can be settled, typically without chemical enhancement. Secondary treatment mainly removes dissolved organic compounds that can be consumed by micro-organisms. Tertiary treatment mainly removes additional soluble constituents that can be precipitated by addition of chemicals, as well as non-dissolved materials that are too small to be removed by primary or secondary processes. Any given treatment facility might have a non-linear combination of processes to meet its effluent targets. For example, a chemically

Table 1-4 Smaller Dischargers and Receiving Waters

Municipality	Receiving water	Discharge capacity (m^3/d)	Population
Dundas	Cootes Paradise	18,184	20,300
Kenora	Winnipeg River	18,184	12,000
Lindsay	Scugog River	17,184	15,176
Cobourg	Cobourg Brook	16,047	5,500
Elliot Lake	Esten Lake	16,000	13,390
Simcoe	Lynn River	15,456	13,355
Smiths Falls	Rideau River	14,700	9,235
Orangeville	Credit River	14,400	19,350
Midland	Midland Bay	13,638	12,000
Kirkland Lake	Murdock Creek	13,638	12,500
Halton Hills	Silver Creek	13,638	20,100
Milton	Oakville Creek	12,911	23,203
Georgina	Cook Bay (L. Simcoe)	12,070	17,843
Valley East	Vermilion River	11,365	17,404
Wallaceburg	Sydenham River	10,800	11,532
Total		**218,215**	**222,888**

enhanced primary treatment facility could be considered a combination of primary and tertiary treatment.

The principal treatment technologies used in Ontario are summarized in table 1-5. Over 94% of the plants are represented by these 12 technologies (the top three account for over 68% of the municipal facilities in Ontario). Another ten technologies make up the remaining 6% of plants. Each of these other technologies is each used at four or fewer facilities – in some cases, such as anaerobic lagoon or trickling filter, at only one facility.

Only 96 municipal facilities did not have another treatment process in addition to the principal processes noted in table 1-5. All but two of these facilities had treatment capacities of less than 10,000 m^3/d. Of the 351 facilities with an additional process, 250 had continuous phosphorus removal, typically via chemical precipitation, and 55 lagoons had batch phosphorus removal. The other 46 facilities used a variety of additional processes.

Although only 21.3% of the total facilities in the province used conventional activated sludge, it was used at nine of the ten largest facilities, 14 of the 20 largest, and 33 of the 45 largest. On a treatment volume basis, conventional activated

Table 1-5 Principal Wastewater Treatment Technology in Ontario

Technology	Number of plants	% of total
Extended aeration	109	24.4
Conventional lagoon – seasonal	101	22.6
Conventional activated sludge	95	21.3
Primary	23	5.1
Aerated cell plus lagoon	19	4.3
Conventional lagoon – continuous	15	3.4
Contact stabilization	14	3.1
Conventional lagoon – annual	14	3.1
Oxidation ditch	10	2.2
Aerated lagoon	8	1.8
Exfiltration lagoon	8	1.8
Rotating biological contactor	5	1.1

sludge was the predominant technology. However, of the 45 largest facilities, four were primary treatment facilities with continuous phosphorus removal (Windsor, Thunder Bay, Sarnia, and Cornwall), one was primary treatment only (Sault Ste. Marie), and one was primary treatment with dechlorination (Timmins).

1.4.3 Performance

The treatment technologies discussed in section 1.4.2 are selected to meet specific performance criteria cost effectively. These criteria typically take two forms: the effluent concentration of specific constituents of concern, and the mass loading into the receiving water of specific constituents of concern. The Provincial Water Quality Objectives (PWQO) identify the constituents and concentrations of concern in receiving waters, but the concentration and loading to any specific receiving water from a given wastewater treatment plant must be determined on a case-by-case basis. While the PWQO specify maximum desirable concentrations of constituents in the receiving water, translating that to allowable effluent concentrations involves the assimilative capacity of the receiving water. For example, a wastewater treatment plant discharging a volumetrically small flow into a large, flowing river may be allowed higher concentrations and loading of certain constituents than a plant discharging a large flow into a small lake. The certificate of approval (COA) for a facility will specify the maximum concentrations and loadings allowed for that facility.

Certain constituents – such as biochemical oxygen demand (BOD), suspended solids (SS), total phosphorus (TP), nitrogen in different forms, and bacterial counts – are of common concern for many receiving waters. Performance, then, is typically measured with respect to these constituents.

Performance evaluation requires data, which are generated from measurements conducted by the municipalities. Facility operators periodically collect influent and effluent samples, which are then analyzed for constituents of interest. A large municipality might have a central municipal laboratory for analysis while a small municipality might use an outside laboratory.

A typical large municipality collects four random 24-hour composite samples per month from the influent and treated effluent. The parameters measured include BOD, SS, TP, phosphate-phosphorus, pH, total Kjeldahl nitrogen (TKN), ammonia+ammonium-nitrogen, un-ionized ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, chloride, conductivity and *E. coli.* The average of the four samples are reported to the MOE district office. The constituents reported will be as required by the COA. The MOE district office determines whether the facility is in compliance and forwards the data to the Environmental Monitoring and Reporting Branch for inclusion in the yearly report.

At the provincial level, performance with respect to three parameters (BOD, SS, and TP) was summarized for 1998: monthly average influent and effluent concentrations, loading (equal to concentration multiplied by flow rate), constituent removal percentages (monthly and annual), and the concentration limits (monthly and annual). A notation as to whether the facility complied with its limits on a quarterly and annual basis was included.

Table 1-6 provides examples of the data available for four typical municipal wastewater treatment facilities of different sizes, technologies, and performance criteria. Of these four examples, three had non-compliance events in which the monthly average performance did not meet the performance limit. This led to a non-compliance for the quarter in which the month occurred. Note that, although information about other constituents might have been reported (for example, bacterial counts and nitrogen concentrations in different forms), this information was not available in the province-wide summary and would have to be obtained from the district offices or from the treatment facilities.

A summary of the overall annual compliance status for municipal wastewater treatment facilities in 1998 is presented in table 1-7. For simplicity, a facility was considered not to comply overall if it did not meet any one or more of the three compliance parameters (BOD, SS, TP) for the year. For almost 60% of the facilities, insufficient data were available at the provincial level to assess compliance status. Sufficient data might be available at district level.

The results summarized in this section are based on self-reported data from the municipalities and give rise to two concerns. First, the integrity of the data must be assumed. This should be a valid assumption for most if not all municipalities. However, it can be tested only with periodic measurements conducted by people from outside the municipality. Second, by its inherent nature, a limited sampling regime could miss significant deviations beyond the criteria. Measurements of random 24-hour composite samples collected only four days a month might not necessarily reflect performance the other 24 to 27 days of the month. Ideally, continuous on-line measurements would eliminate this concern. However, certain parameters cannot be measured on

Table 1-6 Facility Performance Examples

Facility ID	Capacity (m^3/d)	Technology	Parameter	Criteria (mg/L)	Criteria (% removal)	Actual (mg/L)	Actual (% removal)	Compliance
120000391	818,280	CAS + P [a]	BOD	25		6.2		Y
			SS	25		12.9		Y
			TP	1		0.65		Y
110000766	34,095	Primary [b]	BOD		30	39.7	45.4	N (Q1)
			SS		50	46.9	62.0	N (Q2)
			TP		0	1.96	38.0	Y
120001489	7,560	CAS + P [a]	BOD	25		10.9		Y
			SS	25		16.1		Y
			TP	1		0.87		N (Q1, Q2)
120001684	559	CLA [c]	BOD	25		9.5		Y
			SS	25		9.7		Y
			TP	1		0.93		N (Q3, Q4)

[a] Conventional activated sludge with phosphorus removal.
[b] Primary treatment only.
[c] Conventional lagoon annual discharge.

line, and those that can need installation, operation, and maintenance of instrumentation. Alternatively, mathematical tools should be used to determine the frequency of sampling necessary to provide defined levels of certainty about the results.

1.4.4 Combined Sewer Issues

Wastewater treatment facilities – particularly in older urban areas – often receive runoff, in addition to wastewater, during storm or snowmelt events. Runoff waters are collected into combined sewers, producing a large flow (compared to wastewater alone) of a diluted wastewater. Periodically, these combined flows will exceed the overall capacity of the treatment facility. To protect the treatment processes and avoid flooding the treatment facility, the untreated, but more dilute, wastewater will be directed to bypass the facility and discharge directly into the receiving water.

There is no question that urban areas require storm sewers to remove storm and snowmelt waters quickly and effectively, thereby eliminating or minimizing potential for damage from flooding. Historically, storm sewers also served as sewers for *all* wastewater. The thinking was to make most efficient use of engineering infrastructure. When the need to treat wastewater was recognized and wastewater treatment facilities were constructed, the existing combined sewers (in older urban areas) were used. The need to bypass was recognized, but the belief was that in a storm event sufficient dilution would occur so that the bypassed flow would not affect the receiving water. There was also a belief that runoff waters were themselves innocuous.

Table 1-7 Annual Overall Compliance for 1998

Status	Number of facilities	% of total
In compliance [a]	127	28.4
Did not comply [b]	28	6.3
No discharge in 1998	9	2.0
No surface discharge	18	4.0
Insufficient data	265	59.3
Total	**447**	**100.0**

[a] All parameters for which data existed.
[b] For at least one parameter; six facilities did not comply with two or more parameters.

Today, we realize that urban runoff waters contain suspended and dissolved materials that, if not treated, can harm receiving waters. The combination of more concentrated wastewaters with runoff waters only increases the environmental impact. The practical challenge is the cost of changing existing systems. New communities can be constructed with separate storm and sanitary sewers, but older communities require expensive retrofitting. While communities examine these issues, determine cost-effective solutions, and implement those solutions, bypassing existing wastewater treatment plants will continue to occur.

Municipalities report bypasses to the MOE. In 1998, 83 facilities were included in the report, with 43 facilities reporting a bypass of either primary treatment (and therefore essentially all of the treatment facility), secondary treatment (after receiving primary treatment), or both. The flows bypassed and the length of time that bypasses occurred are summarized in table 1-8.

The numbers presented in table 1-8 do not appear particularly large, considering the total quantity of wastewater treated. In 1998 the treatment capacity for the province was 6,784,016 m^3 per day. The total bypassed flow from both primary and secondary treatment in 1998 was 13,173,419 m^3, the equivalent of less than two days' processing for one year's worth of bypass flows.

A more appropriate comparison, though, would be to calculate approximate flow rates by dividing the total annual bypass flows by the total bypass time incurred. The average equivalent flow rate for primary bypasses was 39,917 m^3/d. A plant required to treat this flow rate would be the 32nd largest plant in the province. The average equivalent flow rate for secondary bypasses (71,024 m^3/d) would require the 18th largest plant. However, the greatest flow from secondary bypasses occurred in the 18 plants that only bypassed secondary treatment. The

Table 1-8 Summary of Wastewater Treatment Bypasses, 1998

Treatment bypassed	Number of facilities	Bypass volume (m^3)		Total bypass time (h)	
		primary	secondary	primary	secondary
Primary	17	1,893,172		987	
Secondary	18		8,067,835		1,645
Primary & secondary	8	2,048,663	1,163,749	1,383	1,474
Total	**43**	**3,941,835**	**9,231,584**	**2,370**	**3,120**

average equivalent flow rate was 117,686 m^3/d. Treating this flow rate in one plant would require the 12th largest facility in the province.

The bypass flow data do not include constituent concentrations. Because bypasses are caused by extra runoff entering the sewer, the concentrations of undesirable constituents, in particular bacterial counts, will be lower than in normal raw wastewater but higher than in treated effluent. Flows that bypass secondary treatment have received primary treatment and will have lower concentrations of particulate constituents than the untreated flow. Flows that bypass primary treatment have received essentially no treatment and will contain similar constituent concentrations as the untreated flow.

1.5 Industrial Systems Discharging to Surface Waters

1.5.1 Details of Industrial Discharges

While many municipal wastewaters have similar characteristics, each industry produces wastewater with its own particular characteristics. To account for industry-specific differences, nine industrial sectors were identified as part of

Table 1-9 Summary of Industrial Direct Dischargers, 1998

Sector	Number of facilities	Process effluent (m^3/d)	Once-through cooling water (m^3/d)	Combined effluent (m^3/d)	Other discharges (m^3/d)	Building effluent (m^3/d)
Mining	43	467,307	4,394			
Pulp and paper	25	1,156,490	269,799			
Industrial minerals	24	119,219			32,950	
Organic chemicals	21	134,301	442,664	512,920		
Inorganic chemicals	20	337,309	909	57,924		
Electric power	13	157,303				1,168,664
Iron and steel	7	1,523,425	2,160,477	416,612		
Petroleum	7	72,908	516,820			
Metal casting	3	26,502	274		152,286	
Total	**163**	**3,994,764**	**3,395,337**	**987,456**	**185,236**	**1,168,664**

the Municipal-Industrial Strategy for Abatement (MISA). See table 1-9 for a summary of the discharges for each sector in 1998.

As table 1-9 shows, industrial discharges can take different forms. "Process effluent" is wastewater that, by design, comes in contact with an industrial process. "Once-through cooling water" is used to remove heat from industrial processes, but should not come in contact with process materials. "Combined effluent" occurs when process effluent is deliberately combined with another flow, such as cooling water or storm runoff water. "Other discharges" are industry specific, and "building effluent" was reported only in the electric power generation sector. The total of all reported discharged waters from industry in Ontario in 1998 was 9,731,457 m^3/d.

Certain sectors produced more process effluent than others. The iron and steel sector, with less than 5% of reported facilities, produced over 38% of the process effluent. The pulp and paper sector, with over 15% of the total reported facilities, produced 29% of the process effluent, but the mining sector, with the most facilities (over 28% of the total), produced only about 12% of the total process effluent.

The once-through cooling water discharge was almost 3.4 million m^3/d. But because it should not have contacted industrial processes, the impact of this water on the receiving waters should be confined to temperature effects.

The combined effluent discharge was almost 1 million m^3/d. The organic chemicals sector discharged some 3.8 times as much combined effluent as process effluent. Similarly, the metal casting sector discharged 5.7 times more "other discharges" than process effluent, and the building effluent discharged from the electric power generation sector was over 7.4 times its process effluent.

Within most sectors, one or two facilities accounted for most of the sector process effluent. Table 1-10 shows the ten largest process effluent dischargers overall, as well as the largest dischargers in the remaining, smaller sectors. The two largest dischargers were from the iron and steel sector, accounting for over 94% of the sector's discharge and almost 36% of the total industrial discharges. The iron and steel sector also discharged more than 63% of the once-through cooling water.

The flow from the two largest inorganic-chemicals-sector facilities was 87% of the sector's process effluent discharge, while the largest electric power generation discharger accounted for over 62% of the sector's discharge. In contrast, the five largest pulp and paper dischargers accounted for only 56% of the sector's discharge.

1.5.2 Performance and Treatment Technologies

The performance criteria for industrial wastewater take a similar form to those for municipal wastewater: effluent concentration of specific constituents of concern, and mass loading into the receiving water of specific constituents of concern. One principal difference is that the constituents of concern for industrial wastewater vary by sector. Another difference is the wide scope of constituents that are of concern for industrial wastewater and the measurements conducted. Certain industries may be required to measure – in addition to

Table 1-10 Largest Industrial Dischargers in 1998

Sector	Process effluent (m^3/d)	% of sector	% of total
Top 10 dischargers overall			
Iron and steel	919,339	60.3	23.0
Iron and steel	516,507	33.9	12.9
Inorganic chemicals	204,400	60.6	5.1
Pulp and paper	191,042	16.5	4.8
Pulp and paper	120,168	10.4	3.0
Pulp and paper	116,458	10.1	2.9
Pulp and paper	113,408	9.8	2.8
Pulp and paper	108,201	9.4	2.7
Electric power	98,106	62.4	2.5
Inorganic chemicals	89,065	26.4	2.2
Top dischargers in remaining sectors			
Mining	69,231	14.8	1.7
Organic chemicals	56,878	42.4	1.4
Metal casting	26,416	99.7	0.7
Industrial minerals	21,432	18.0	0.5
Petroleum	20,937	28.7	0.5

BOD, nitrogen in different forms, and phosphorus – such substances as dioxin, chloroform, toluene, metals, residual particulate matter, adsorbable organic halides (AOX), and phenol, for example. Furthermore, acute lethality may also have to be measured using aquatic organisms such as *Daphnia magnia* and trout. Surrogate measurements such as bacterial counts, used for pathogenic organisms, are normally not required for industrial wastewater, which would contain pathogens only if sanitary sewage from the facility were mixed with the process effluent or if the wastewater were generated from certain agricultural operations. While mixing of sanitary sewage with process effluent might occur in some instances, the dilution volume from industrial effluent would typically be large.

The performance of industrial facilities must be determined by comparing discharge data to compliance limits, as is the case with municipal wastewater treatment facilities. The industrial data available from the MOE are structured differently from data available for municipal systems. Specifically, the data for the municipal systems are summarized overall and the performance could readily be determined. Industrial systems, on the other hand, are presented on a facility-by-facility basis (data for the 163 industrial facilities reporting discharges in 1998 are in 163 separate spreadsheet files – one per facility). Although the files are grouped by sector, there are no summaries, even within sectors. The performance and compliance of any individual facility can be readily determined, but the performance and compliance of an overall sector would require extensive manipulation of the existing data.

The treatment technology required for a given industrial facility depends on the constituents to be removed. For example, the pulp and paper sector often uses variations of activated sludge treatment because a number of constituents in pulp and paper wastewater are amenable to biodegradation. The same treatment might be inappropriate for the mining sector, for which metals in the effluent would be of greater concern; some type of physicochemical process, such as lime precipitation, could be more appropriate. Unlike the MOE data for municipal wastewater treatment, the data for industrial facilities do not identify the treatment technology used. Each industrial facility or MOE district would have to be contacted directly to determine that information.

There are several other limitations to the available industrial data. First, only direct dischargers are included; if an industrial facility discharges wastewater to a municipal wastewater treatment facility, its data do not appear. Discharges of industrial wastewater to municipal systems must be managed carefully to ensure that the attributes of the industrial effluent do not harm the biological processes used in the municipal system or the receiving waters of the municipal system.

Second, only data from direct dischargers in the nine identified sectors are available. A food-processing facility, for example, could generate substantial wastewater flows containing, in particular, BOD, nitrogen in various forms, and phosphorus and possibly pathogens (especially from a livestock processing facility). Because the food-processing industry is not included in the existing sectors, data are not readily available.

Finally, the results presented in this section are based on self-reported data from the industries themselves. The integrity of the data must be assumed, as must the sampling frequency be assumed sufficient to provide a reasonable average value. As is the case with municipal systems, continuous on-line measurements would reduce these concerns. Because many industries already have sophisticated control systems to manufacture their products, implementation of such capability for their wastewater treatment systems might be more easily achieved than for a municipal facility.

1.6 Systems Discharging to Groundwater

Treated wastewater may also be discharged directly to groundwater. The regulation and monitoring of discharges to groundwater depends on the size and ownership of the facility. If a sewage works

- has a design capacity greater than 10,000 L/d (10 m^3/d), or
- is a combination of several sewage works on one parcel of land with a design capacity greater than 10,000 L/d, or
- is not located entirely on the same property as the building or facility that generates the sewage, then

the regulation and monitoring of the sewage works is the responsibility of the MOE. Construction and operation must be approved by the MOE.

Information about facilities meeting the foregoing criteria was included in the municipal treatment facility database previously discussed in section 1.4. Of the 447 municipal wastewater treatment facilities in that database, 11 did not discharge to surface waters directly in 1998 but instead discharged in some manner to the ground. Combined, these 11 facilities had treatment capacity for 14,182 m^3/d (0.21% of the total capacity) and served 17,890 people. In eight of the facilities, treated wastewater entered the ground through exfiltration lagoons. Two facilities used spray technology to apply treated wastewater to the ground, and one facility was a communal septic tank using a subsurface leaching bed.

If a sewage works

- has a design capacity less than 10,000 L/d (10 m^3/d), or
- is a combination of several sewage works on one parcel of land with a design capacity less than 10,000 L/d, and
- is located entirely on the same property as the building or facility that generates the sewage, then

the regulation and monitoring of the sewage works is the responsibility of the local municipal building department (in southern Ontario) or the health unit or conservation authority (in northern Ontario).

These smaller facilities will often be septic tanks with leaching beds or other small on-site systems. The properties they serve will not be near a collection system that can transport wastewater to a centralized treatment facility. Ongoing inspection and monitoring is not required of these systems after installation. Information about them will not be collected in a central location but will have to be obtained from the individual municipalities.

The guidelines for discharge to groundwater were implemented in 1998 as per the *Water and Sewage Services Improvement Act* of 1997.[1] Before that, smaller systems were governed under Regulation 358 and required certificates of approval issued by a health inspector, not the MOE. Historical records of facilities installed before 1998 are scattered among the health units that approved them. Monitoring of these facilities after installation was not systematic, if it occurred at all.

The small size of these essentially unregulated systems discharging to groundwater could provide a false sense of security. They are installed primarily in areas where public services for wastewater and drinking water are unavailable. Owners of these systems likely obtain their drinking water from wells that are also on site. Some small systems might happen to be near surface water, and

[1] Ontario, Ministry of Environment and Energy, 1997, *Responsibility for Sewage Systems* [online], [cited December 2000], <www.ene.gov.on.ca/envision/water/3593e.pdf>.

substances released from them might move slowly with the groundwater into the nearby surface water. As long as these small systems were installed properly and perform properly, the risk to groundwater used for drinking water and to nearby surface water should remain small. Their long-term performance cannot be assured, however, without ongoing monitoring.

1.7 Municipal Wastewater Solids Treatment and Disposal

The goal of wastewater treatment is to remove unwanted constituents from wastewater before discharge. The removed constituents are either collected in solid form or converted to benign products such as carbon dioxide and water. The constituents collected in solid form contain pathogens from the wastewater stream, non-pathogenic micro-organisms responsible for removing dissolved biodegradable constituents, and precipitated inorganic materials, including metals and phosphorus. These solid materials must be disposed of.

A consolidated report on the treatment and disposal of wastewater treatment solids is not readily available at the provincial level. The data in table 1-11 were

Table 1-11 Historical Summary of Ontario Solids Treatment and Disposal, 1995/96

Treatment process	Mass (dry tonnes)
Anaerobic digestion & dewatering	120,000
Anaerobic digestion	75,000
Aerobic digestion	7,400
Aerobic digestion & dewatering	1,200
Lagoon	1,100
Other – thermal conditioning, no treatment, etc.	70,300
	275,000
Disposal option	
Incineration	115,000
Land Application	93,000
Landfill	67,000
Total	**275,000**

provided by MOE staff in personal communication. These data were collected before the changeover of the Ashbridges Bay plant in Toronto from incineration to land application as a disposal option.

The disposal option that could have the greatest impact on water supplies is land application. *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Lands* provides the detailed requirements that must be met to apply solids from wastewater treatment plants directly to land.[2] In summary, the producer of the solids, the municipalities in this case, must receive a certificate of approval from the MOE district office for an "organic soil conditioning site." The solids must meet the criteria specified in the guidelines, and the site must be suitable to receive solids. This COA should specify the maximum application rate for the site as well as the acceptable constituent concentrations. A COA is also required to haul the solids, and the hauler must have an Organic Waste Management System certificate to transport the solids.

There is no central database that summarizes the land application of municipal wastewater solids. However, the solids generators must keep permanent records that detail "the location of all fields receiving biosolids or other wastes, the amount of biosolids or other wastes applied to each field, [and] biosolids or other waste analyses."[3] The solids generator must also supply the landowner with information on annual average concentrations of metals in the biosolids, if requested by the landowner. Additionally, the generator must sample and analyze the solids with sufficient frequency to establish representative values and for all pertinent parameters as approved by the MOE district office.

Once the appropriate certificates are in place with the requisite sampling and analysis schemes, land application of solids can commence. The MOE's involvement is then minimal, consisting of responses to complaints that may be brought about the land application activity. Monitoring of runoff from sites receiving solids is not conducted routinely, if at all. Presumably, as long as solids are applied in accordance with the issued certificates of approval and the ministry guidelines, no unacceptable impact to the environment or waters that may be used for drinking is expected.

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[2] Ontario, Ministry of the Environment and Ministry of Agriculture, Food and Rural Affairs, 1998, *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* [online], [cited August 2001], <www.ene.gov.on.ca/envision/gp/3425e.pdf>. This electronic revision of the original 1996 document includes regulatory amendments to October 1997.

[3] Ibid.

1.8 Agricultural Solids Treatment and Disposal

For the purpose of this paper, agricultural solids are defined as manures from livestock. As with municipal wastewater solids, agricultural solids are not expected to enter directly into Ontario waters. Risks to both surface water and groundwater arise when agricultural solids are applied to the land. Runoff and tile drains can carry contaminants to surface waters, while percolation can carry contaminants into groundwater. Although agricultural solids are not directly linked to the wastewaters that are the primary focus of this paper, a brief overview of their production, treatment, and disposal is presented here to provide a rough comparison of their impact with that of wastewater.

1.8.1 Summary of Production

The numbers of livestock in Ontario estimated by Statistics Canada are summarized in table 1-12. The animals are in three groups, each of which contains several subsets. For example, "all cattle and calves" includes bulls, milk cows, beef cows, dairy heifers, beef heifers, steers, and calves less than one year old. Similarly, "all pigs" includes boars, sows and litters, and all other pigs at different growth stages.

Table 1-12 Livestock in Ontario

Animal	Number	Approximate unit production of manure [a] (dry kg/d per animal)	Total manure produced (dry kg/d)	Approximate BOD [b] (kg/d)
All cattle and calves [c]	2,050,000	4.65	9,500,000	3,400,000
All pigs [d]	3,251,800	0.45	1,500,000	530,000
Chickens [e]	174,853,000	0.02	4,300,000	1,500,000

Source: Statistics Canada, 2000, *Primary Industries: Agriculture* [online], [cited December 2000], <www.statcan.ca/english/Pgdb/Economy/primar.htm#agr>.
Note: The data related to cattle, pigs, and chickens on this Statistics Canada site currently reflect updated 2001 statistics and will differ somewhat from the numbers used in table 1-12.
[a] Assumes an average animal.
[b] Assumes 0.33–0.38 kg BOD/kg dry solids.
[c] July 2000.
[d] April 2000.
[e] 1999.

[4] Agriculture and Agri-Food Canada, 2001, *Miscellaneous Facts and Figures* [online], [cited August 2001], <http://res2.agr.ca/initiatives/manurenet/en/facts.html>.

The amount of manure that animals produce varies with their age and activity. For example, dairy cattle produce approximately 5.45 kg (dry) of manure per animal per day while beef cattle produce approximately 3.86 kg (dry) per animal per day.[4] Similarly, the amount of manure produced per pig depends on the age and size of the animal. The approximation shown in table 1-12 was determined by assuming a uniform distribution of animals in the different activities, ages, and sizes. The BOD equivalent of the manure was estimated by assuming that the 0.33–0.38 kg BOD per kg dry solids used for pigs was suitable for other manures as well.[5]

The total BOD produced in Ontario from manure is approximately 5.4 million kg/day. For comparison, the BOD produced in Ontario that enters municipal wastewater treatment plants is approximately 1.2 million kg/day (determined using the 1998 municipal wastewater treatment plant capacity of 6,784,000 m^3/d and an average influent BOD concentration of 170 mg/L). Therefore, livestock produce approximately 4.5 times more BOD per day than enters municipal wastewater treatment facilities. However, most (over 85%) of the BOD entering a wastewater treatment plant is removed and does not enter receiving waters. Because agricultural solids are also not discharged directly to receiving waters, the amount of BOD entering those waters should also be only a small fraction of the total.

1.8.2 Treatment and Disposal

Livestock absorb approximately 25% of the nutrients they consume.[6] The remainder is excreted. The resulting manure contains the excreted nutrients – in particular nitrogen, phosphorus, and potassium – as well as organic matter that contributes to BOD.

Land application, the principal disposal option for agricultural solids, has historically provided benefit to the land receiving the solids. Farmers have applied manure to agricultural lands for hundreds if not thousands of years. In modern terminology, manure has been beneficially reused as a fertilizer and

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[5] Ibid. See downloadable "Excel spreadsheet on swine manure quantities," prepared by Tom Richard, Department of Agricultural and Biosystems Engineering, Iowa State University.

[6] H. Fraser, 1985, *Manure Characteristics* [online], (factsheet) Ontario Ministry of Agriculture, Food and Rural Affairs [cited December 2000], <www.gov.on.ca:80/OMAFRA/english/livestock/swine/facts/85-109.htm>.

soil conditioner. Guidelines for land application have been published by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA).[7]

The land application of fertilizer of any type, manure or chemical, must be conducted so that nutrient losses to runoff and percolation are minimized. Unlike chemical fertilizers, however, agricultural solids also contain BOD, pathogenic micro-organisms such as the bacterium *Escherichia coli* O157:H7, and protozoa such as *Cryptosporidium.* Although pre-treatment is not currently required under Ontario law, agricultural solids can be treated before land application to reduce their BOD and pathogen content.

A number of treatment processes for agricultural solids exist. Some, which reduce the water content of manure to reduce storage space and transportation costs, generally do not remove BOD or pathogens directly and therefore will not be discussed here. Processes that remove BOD are typically classified as aerobic (requiring oxygen) and anaerobic (occurring in the absence of oxygen).

Aerobic composting requires the addition of a dry material with a high carbon content to produce a material that behaves like a solid.[8] During composting, the operator periodically mixes the windrows to enable oxygen transfer to the organic-degrading micro-organisms. In some cases air is blown or sucked through the windrows. Properly operated, aerobic composting reduces the volume of manure significantly and will reduce pathogenic content if temperatures are maintained above 55°C for enough time. The aerobic degradation of organic material naturally generates the heat. A disadvantage of composting is the odour associated with the volatilization of ammonia. Additionally, no products other than compost are produced.

Aerobic digestion differs from composting in that it is done on material with a higher water content and requires active aeration in insulated tanks, where temperatures up to 70°C can be generated. If maintained for a sufficient time, this heat can significantly reduce the pathogenic content of the manure. Care must be taken to avoid exceeding 70°C, above which temperature the thermophilic

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[7] D. Hilborn, 1992, *Land Application of Liquid Manure in an Environmentally Responsible Manner* [online], (factsheet) Ontario Ministry of Agriculture, Food and Rural Affairs [cited December 2000], <www.gov.on.ca:80/OMAFRA/english/livestock/dairy/facts/92-164.htm>.

[8] Ontario, Ministry of Agriculture, Food and Rural Affairs, 1995, *Guide to Agricultural Land Use* [online], [cited December 2000], <www.gov.on.ca:80/OMAFRA/english/landuse/facts/guide_ag_use.htm>.

bacteria conducting the reactions will also be inactivated. This technology is currently available at a large scale and is being investigated in Ontario at the 'farm scale' by Agriculture Canada.[9] Volatilization of ammonia is a disadvantage of this process. It also "requires a high energy input," according to the *Guide to Agricultural Land Use*.[10]

Traditional *anaerobic* treatment processes operate at mesophilic (35°C) or ambient temperatures and convert the organic content into methane gas, carbon dioxide, and water. Because of the non-thermophilic temperatures, little inactivation of pathogens occurs. The methane produced has energy value, but "this practice is currently not considered to be economically feasible to produce gas for energy."[11] Thermophilic anaerobic treatment processes also exist, but they have rarely been applied to agricultural solids.

These treatment technologies are available in Ontario and are being voluntarily used to varying degrees. None achieves all the desired goals of agricultural manure treatment: cost-effective retention of nutrient content, BOD removal, and pathogen inactivation. Additionally, no central database documents which treatments are being used where.

Table 1-13 Licence Classes and Requirements for Wastewater Treatment Plant Operators

Class	Education	Examination	Prior licence
Operator in training	Grade 12 or equivalent	pass appropriate exam	none required
I	same + 1 year experience	pass appropriate exam	none required
II	same + 3 years experience	pass appropriate exam	class I or II
III	same + 2 years training [a] + 4 years experience [b]	pass appropriate exam	class II or III
IV	same + 4 years training [c] + 4 years experience [b]	pass appropriate exam	class III or IV

[a] May substitute up to one year of experience as an operator in charge.
[b] Including two years of experience as an operator in charge of a class II, III, or IV facility in addition to any years applied to training requirement.
[c] May substitute up to two years of experience as an operator in charge.

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[9] Personal communication with G. Lazarovits, Agriculture Canada, November 16, 2000.
[10] Ontario, Ministry of Agriculture, Food and Rural Affairs, 1995.
[11] Ibid.

1.9 Staff Training

All wastewater treatment plant operators must be licensed in accordance with Ontario Regulation 435/93, enacted July 26, 1993, under Section 75 of the *Ontario Water Resources Act.* The regulation was amended by Regulations 154/98 and 539/98 in 1998.[12]

There are four classes of operator licence plus an operator-in-training classification (see table 1-13). The classification of the wastewater treatment facility determines the classification of operator required. The owner must ensure that an operator responsible for operating the facility holds a licence of the same class or higher than the facility class. For example, operators responsible for operating a class IV facility (the highest class) must hold a class IV licence, while operators responsible for operating a class II facility may hold a class II, III, or IV licence.

The requirements to obtain each class of licence are also indicated in table 1-13. The examinations are the property of the Association of Boards of Certification (a North American organization that prepares examinations for wastewater treatment certification) but have been modified by the MOE to be specific for Ontario.

Once licensed, an operator maintains the licence by paying a licence fee periodically, receiving 40 hours of training per year, and accumulating ongoing experience over the previous five-year period. The required annual training can be quite broad, including specific training in safety, operations, computers, or other relevant subjects. It need not be offered by an outside organization, but can be conducted by the owner of the facility.

The MOE no longer provides training courses. It has contracted an outside agency – the Ontario Environmental Training Consortium, which is affiliated with the Colleges of Ontario Network for Education and Training – to manage and administer the certification exams. Specific training courses are not required for certification. In preparation for examination, operators may take formal training courses offered by educational organizations and institutions or they may prepare on their own using available material.

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[12] Ontario Environmental Training Consortium, 2000, *Water Works and Sewage Works* [online], Regulation 435/93 made under the Ontario *Water Resources Act,* (training edition) [cited December 2000], <www.oetc.on.ca/regmail.html>.

There is no direct penalty for an operator who works illegally without an appropriate licence. The facility owner, however, can be fined by the MOE. Therefore, it is the responsibility of the facility owner to ensure that facility operators have appropriate licences.

1.10 Costs of Ontario Wastewater Treatment

1.10.1 Introduction

This section has two objectives. The first is to review and comment on the current level of costs and revenues in the water and wastewater industry in Ontario.[13] The second is to provide information on expected levels of investment that will be required in the future. Several existing studies on this subject provide a basis for examination and comment.

Some terminology should be explained. On the cost side there is a difference between operations, maintenance, and administration costs (collectively termed OM&A or 'operating' costs) and capital costs. OM&A costs relate to the operation of the system. They include such items as labour, energy, chemicals, and fees, and they are generally ongoing. Capital costs are one-time investments required to build facilities (infrastructure) such as treatment plants, storage, pumping stations, hydrants, service connections, and mains. Once built, the infrastructure must be maintained and repaired. Infrastructure repair is an OM&A cost, whereas infrastructure provision or replacement is a capital cost.

On the revenue and financing side, municipalities have a great deal of freedom to set water and wastewater user rates, to charge fees, or to use property tax revenues to support water and wastewater systems. But legislation is much more specific and detailed when it comes to paying the cost of infrastructure needed for system growth arising from increasing population. Provincial legislation sets out what capital charges are allowable and limits how they must be calculated. Capital charges include frontage, connection, and development charges.

Above-ground facilities and below-ground facilities tend to be considered differently. Planning and cost estimation is usually easier for above-ground facilities, which comprise water treatment plants, water wells, sewage treatment plants, pumping stations, and storage. These facilities are visible, must be

[13] Due to limited time and data, the analysis uses 1997 figures.

operated, and require ongoing maintenance. They are critical to good water quality and sewage treatment. They are the focus when it comes to regulating quality, and they were central to the inspections carried out in all water systems by the MOE in 2000.

Expansion and upgrading of underground facilities, which include mains and service pipes, tends to be more difficult because they are out of sight and, often, little is known about their age, materials of construction, or condition. This makes accurate cost estimation difficult.

The provincial government has jurisdiction over water supply and sewage treatment. During the 1990s it delegated these functions to municipalities, over which it has jurisdiction and whose responsibilities it defines. The province also enacts the legislation that defines how municipalities may recover water and wastewater system costs; it monitors municipal finances; and it requires annual financial reporting.

Annual financial reporting includes the Financial Information Return (FIR), submitted annually by every municipality. FIRs constitute the base information source for the current financial status of municipal water and wastewater systems in Ontario. The reports provide comprehensive information on expenditures and revenues by municipalities, including segregated information on water and wastewater systems. They can be used to extract factual information on the current water and wastewater system financial status. Some of the existing studies reviewed in this paper also quote FIR information. To clarify the approach used in interpreting the reported numbers, this section explains wastewater utility financial reporting in general and the FIR in particular.[14]

Unless otherwise identified, the information presented in the tables and figures in this section is generated from data presented in the Sewage and Water Inspection Program database and from data provided by the Ontario Ministry of Municipal Affairs and Housing in response to requests by the author of this paper.

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[14] For current information on Ontario's Financial Information Return, see <www.mah.gov.on.ca/FIR/index-e.asp> on the Ministry of Municipal Affairs and Housing Web site.

1.10.2 Organization of Financial Information Returns

FIRs divide costs into two categories: capital fund and revenue fund.

Capital Fund

The capital fund is fairly easy to understand. It provides information on how the cost of building or replacing capital facilities (infrastructure) is funded. It covers the cost of construction of all water and wastewater infrastructure built by the municipality. It does not include the cost of works built and paid for by developers (i.e., local servicing) or the costs of private property. The financing sources are revenue sources, reserve funds, and debt financing.

Revenue sources Revenue sources include user rates, property taxes, fees, grants, and capital charges. Some revenue sources, such as user rates and property taxes, first appear in the revenue fund (see following subsection) and a portion is transferred for use in the capital fund by means of an entry called "transfers to own funds."

Reserve funds Funds from the revenue sources can be put aside in reserve funds to be applied when required. One such reserve fund comes from current revenues (referred to as "transfers to own funds" in the FIR). Another common reserve fund comes from development charges.

Debt financing Repayment of infrastructure cost can be delayed by means of debt financing, commonly referred to as debenturing, which spreads the cost of capital facilities over future years. Repayment includes the original principal borrowed plus interest charges.

Unfortunately, FIR capital fund summaries for water and wastewater identify only grant information separately – all the municipal financing sources (revenue sources, reserve funds applied, and debt financing) are combined into one number.

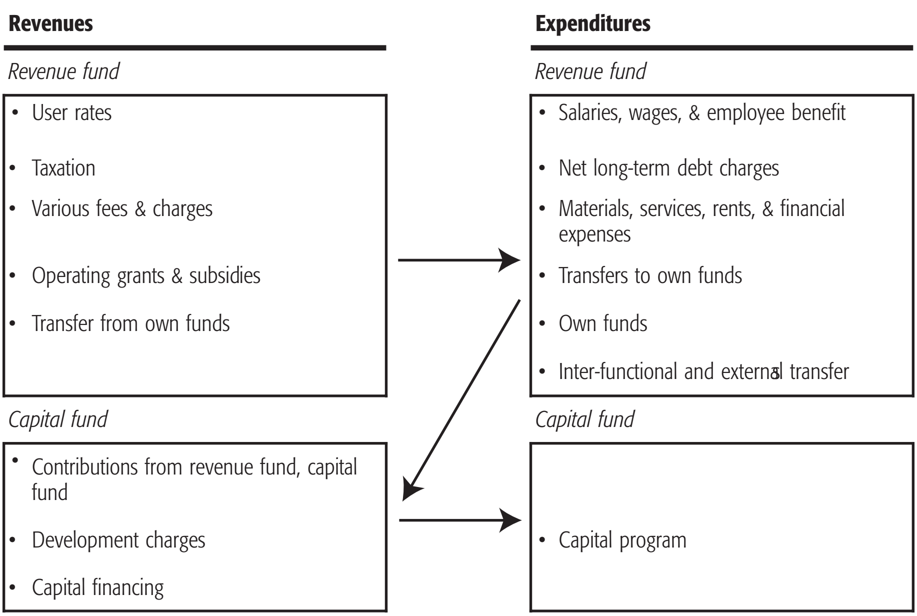
Revenue Fund

The revenue fund statement reports on current expenditures, including OM&A costs, debenture debt, and transfers to own funds (essentially capital contributions), as well as payments for overhead charges or to other agencies. Information is also provided on user-rate revenues, charges, fees, and grants.

The costs reported in each of the capital and revenue funds, and the relationship between the two, are illustrated in figure 1-1.

FIRs can be used to determine annual investment in Ontario water and wastewater systems, but not simply by adding the revenue fund and the capital fund – the total would overstate the capital investment. Although the capital fund reports actual cash outlays for capital investment in the year, the revenue fund also includes two capital-related items: "net long-term debt" and "transfers to own funds." Because the capital fund represents capital investment before debt financing, double counting would result if the total included "net long-term debt" and the capital fund component financed through debenturing. Thus, net long-term debt charges are deducted from the total. And because the "transfers to own funds" portion of the revenue fund becomes a source of funds for the capital program, it is also deducted from the expenditure total.

Figure 1-1 Relationship between Revenue Fund & Capital Fund



Source: Ontario, Ministry of Municipal Affairs and Housing, 2000, *Financial Information Return* [online], [cited October 2001], <www.mah.gov.on.ca/FIR/index-e.asp>.

The total annual expenditures are calculated as follows:

> Cash expenditures = revenue fund + capital fund – transfers to own fund – net long-term debt charges.

A Note on Depreciation

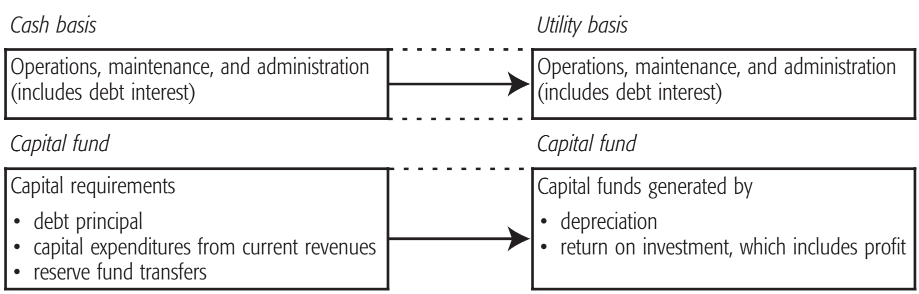
Questions sometimes arise as to whether infrastructure depreciation costs are properly covered. The term is often used loosely to refer to the cost of replacement of facilities. If that were the meaning intended, a different, more precise term, such as 'replacement costs,' would be better. Depreciation in financial terms is the spreading of the original cost over the life of the item. Depreciation is not charged in the cash-based accounting system used by Ontario municipalities.

In the wastewater industry, two approaches are used to account for costs: the cash basis and the utility basis. Both methods treat operating, maintenance, and administration costs in the same way.[15]

Figure 1-2 illustrates the relationship between the cash and utility bases of accounting.

Municipalities across Canada commonly use the cash basis to report costs; it is the method used by Ontario municipalities. Expenditures are recorded based on actual cash outlays during the year. Capital costs are charged based on items

Figure 1-2 Cash Basis versus Utility Basis of Accounting



[15] The utility basis differs in the recording of capital outlays. Basically, the utility method distributes the cost of capital over the life of the investment and includes items such as depreciation and return on investment. Utilities and businesses normally use the utility method.

such as debt repayment, capital outlays, and reserve fund transfers. Because Ontario municipalities use the cash basis for accounting, categories such as depreciation and return on investment are not reported.

1.10.3 Current Annual Investment

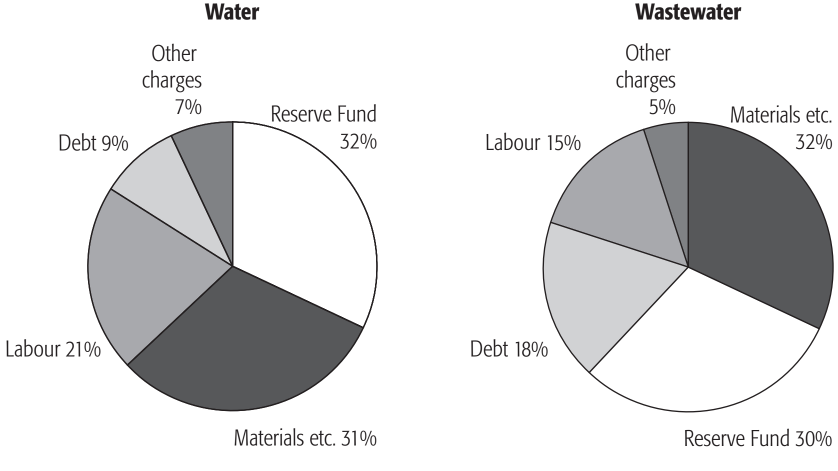
See table 1-14 for the 1997 water and wastewater revenue fund expenditures for all municipal systems in Ontario.

The total revenue fund expenditures for municipal wastewater systems in Ontario

Table 1-14 Ontario Water and Wastewater Revenue Fund Expenditures,

	Water	Wastewater
Salaries, wages, & employee benefits	191,479,876	133,268,118
Net long-term debt charges	77,615,831	152,259,721
Materials, services, rents, & financial expenses	285,241,983	271,195,028
Transfers to own funds	289,761,292	258,362,368
Other transfers	8,253,602	8,870,270
Inter-functional transfers	58,078,782	37,510,222
Total	**910,431,366**	**861,465,727**

Figure 1-3 Breakdown of Revenue Fund Expenditures



was $861 million ($910 million for water). “Inter-functional transfers” relate to overhead-type charges, and the “other transfers” are charges by outside organizations. The percentage share of each cost category is illustrated in figure 1-3.

The wastewater debt load, at 18%, is much higher than the 9% in water systems. Total capital investment from current revenues (debt + transfers to own funds) is 48%, or almost half the revenues for wastewater, 41% for water. The difference is primarily made up in labour, where wastewater is lower at 15% compared with water at 21%

The capital fund investment for wastewater was $496,043,739 ($425,655,599 for water).

Figure 1-4 Breakdown of Total Water & Wastewater Cash Investments, 1997

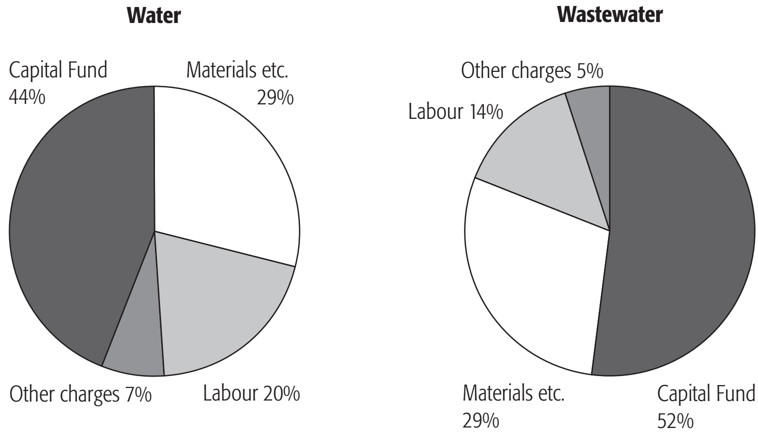


Table 1-15 Ontario Municipal Water and Wastewater Systems Cash Expenditures, 1997 ($)

	Water	Wastewater
Salaries, wages, and employee benefits	191,479,876	133,268,118
Materials, services, rents, and financial expenses	285,241,983	271,195,028
Other transfers	8,253,602	8,870,270
Inter-functional transfers	58,078,782	37,510,222
Capital fund	425,655,559	496,043,739
Total	**968,709,802**	**946,887,377**

See table 1-15 for the combined net cash outlays for water and wastewater systems in 1997. The table is constructed by adding revenue fund and capital fund outlays less "transfers to own funds" and debt charges (to avoid double counting). It would be preferable to leave debt charges in and deduct capital costs financed by debenturing, but, as this information is not available, the debt adjustment is used as an approximation.

Thus, the total 1997 expenditure by municipalities in water systems was about $969 million. Of that, $426 million, or 44%, was capital investment (see figure 1-4). For wastewater the total capital investment was $496 million, or 52% of total outlays. Note that these figures do not include the cost of facilities contributed by developers, which would be recovered from the sale of property.

1.10.4 Cost Recovery

A summary of revenue sources is provided in table 1-16.

The outside contributions by means of grants are not large and have been decreasing. See figure 1–5 for the percentage contribution of the various revenue sources.

Note that there is a greater reliance on property taxes for wastewater system funding, at 12% of revenues. This is likely because sewer costs were historically recovered from property taxes. When the regions were formed in the 1970s, they chose to move to a more user-pay approach with a shift toward a sewer surcharge. It appears that the transition is still not complete. There is actually some justification for including some water costs – the portion that provides for fire protection – on the property tax. Many municipalities do this; it is a legitimate approach supported by the AWWA and allowed in provincial legislation. There is no parallel for sewers.

The analysis of 1997 revenue sources reveals that fully 96% of water revenues and 95% of sewer revenues are from local sources. Only $38 million, or 4%, of water revenues and $45 million (5%) of sewer revenues came in the form of grants from outside sources. Thus, most of the costs are locally funded. The adequacy of investment in municipal water systems may be questioned, but the recovery of current investment levels is very close to full cost recovery

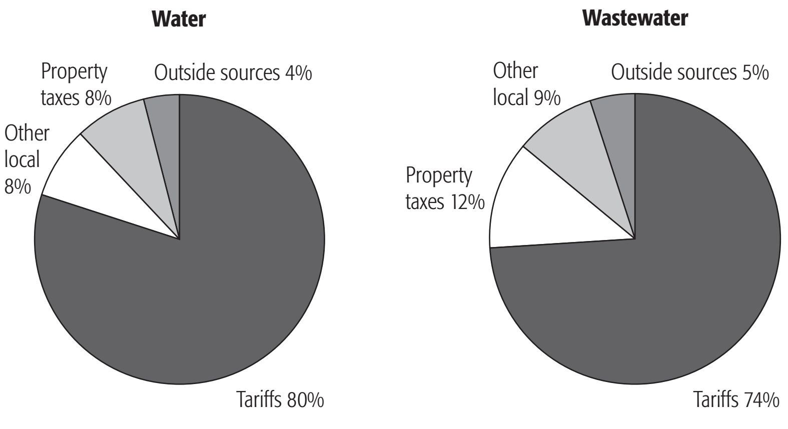
The concept of recovering water and wastewater system costs as much as possible through user rates is often promoted. Advantages include the promotion of

Table 1-16 Ontario Municipal Water and Wastewater Systems Funding Sources, 1997 ($)

	Water	Wastewater
Local financing		
User rates		
Residential	480,393,724	420,345,959
Non-residential	296,916,281	276,421,883
Total user rates	**777,310,005**	**696,767,842**
Other local sources		
Fees	29,993,896	32,450,278
Other (including property taxes)	79,563,776	117,401,066
Municipal contribution	31,005,494	18,166,605
Net financing (net impact of application or accumulation of reserve funds, including development charge receipts)*	12,414,386	37,449,579
Total local financing	**930,287,558**	**902,235,369**
Outside contributions		
Ontario grants	34,178,148	41,187,893
Canada grants	4,244,096	3,464,115
Total outside contributions	**38,422,244**	**44,652,008**
Total (local and outside)	**$968,709,802**	**$946,887,377**

* The net financing is the residual after other known revenue sources are deducted. It is a combination of the net inflow and outflow of reserve funds and the difference between debt repayment and financing. The details of these transactions are not reported for water and wastewater.

Figure 1-5 Ontario Municipal Water and Wastewater System Funding Sources, 1997



conservation and clearly visible costs.

There are also other legitimate user-pay methods of cost recovery. Capital costs are often recovered up-front for new servicing through frontage and connection charges, development charges, and contributions by developers. And other fees and charge revenues are based on services rendered. Thus, it should not be assumed that user rates should be carrying the total burden for water and wastewater costs.

1.10.5 Future Investment Requirements

A number of studies have focused on the question of future water and sewer investment needs in Ontario. Their findings vary, which is not surprising given the lack of detailed knowledge of current conditions and historical infrastructure investment. No single answer is apparent, and there are many unknowns. In fact it is not feasible to arrive at a definitive result. Consideration of individual municipal capital plans illustrates this clearly. Municipalities can only estimate their capital programs for the following year, and their five-year plans often bear little relationship to reality. Actual costs for projects can vary widely from estimates, particularly since projects are often delayed or postponed. Furthermore, cost estimates for projects that deal with rehabilitation or expansion of sewers or watermains cannot be finalized until the pipes are exposed. Most municipalities lack detailed knowledge of the age, material, or condition of underground infrastructure. Consequently, province-wide totals of such estimates, using limited factual information, are unlikely to be consistent.

Note also that studies vary in the infrastructure standards they expect to achieve. Examples of assumed variables include level of treatment, quality of facilities, changes in servicing standards (increasing populations using existing infrastructure), technological standards, growth rates, and degree of servicing.

Following are summaries of five studies conducted to estimate future investment levels needed in Ontario water and sanitary sewer systems.

Ontario Ministry of Environment & Energy (1996)

A draft paper, prepared for discussion, included estimates of Ontario water and wastewater investment requirements. There is no indication that the information in this paper achieved any official status, and it may have been subsequently changed. However, the information is worth noting, as it appears to result from a detailed analysis of the actual condition of water and sewage treatment facilities in Ontario (see table 1-17).

The paper, which does not deal with underground infrastructure, advances the philosophy of full-cost pricing – that all water and wastewater costs should be recovered solely from user rates. Using FIR data for 1993, the differential between user-rate revenues and revenue fund expenditures is calculated (see

Table 1-17 Water and Wastewater Treatment Plant Infrastructure Needs, 1995–2005 ($ Millions)

	Deficiencies	Rehabilitation	Growth	Total
Wastewater treatment plants				
Upgrade 21 primary treatment plants to secondary	746			746
Offset flow capacity deficiencies	595			595
1995 to 2000		785	492	1,277
2000 to 2005		911	671	1,582
Total wastewater	**1,341**	**1,696**	**1,163**	**4,200**
Water treatment plants				
Offset flow capacity deficiencies	329			329
1995 to 2000		376	229	605
2000 to 2005		535	376	911
Total water	**329**	**911**	**605**	**1,845**
Total	**1,670**	**2,607**	**1,768**	**6,045**

Source: Ontario, Ministry of Environment and Energy, Economic Services Branch, 1996, *Infrastructure Need for Water and Sewage Treatment Services in Ontario 1995–2005*, [draft paper, April 9, 1996] (Toronto: MOEE).

Table 1-18 Water and Wastewater – Differential between Revenue Fund Expenditures and User-Rate Revenues, 1993

	($ millions)	($/m^3)
Expenditures	1,707	0.93
User-rate revenues	1,272	0.69
Differential	435	0.24

table 1-18). The unit rate is calculated from a total flow of 1.84 billion m^3. The differential of $435 million is offset by other revenue sources, primarily property tax revenues, but including as well other fees, charges, and grants.

The paper also calculates the impact on user rates of recovering the annual operating deficit plus the $6,045 million in capital costs for the infrastructure needs outlined in table 1-17. The capital costs are financed over 40 years at 7.75% interest, giving an annual capital cost requirement of $493 million ($342 million for wastewater and $151 million for water treatment).

The report concludes that user rates would have to be increased on average in the province by 73% to meet the objective of recovering both the costs now recovered from other revenue sources and the anticipated capital costs (see table 1-19). The analysis includes the cost of growth, but does not take into account the effect of growth on revenues or revenues from capital charges such as frontage and connection or development charges. It does not include an allowance for additional future capital costs for underground infrastructure works.

Canadian Water and Wastewater Association (1998)

Municipal Water and Wastewater Infrastructure: Estimated Investment Needs 1997 to 2012 was prepared by the CWWA with support from the Canada Mortgage and Housing Corporation (CMHC). This report estimated annual Canadian investments in municipal water and sewer systems at $1.84 billion for water and $4.09 billion for wastewater, for a 15-year total of $27.6 billion and

Table 1-19 Impact on User Rates of Full Cost Recovery

	($ millions)	**($/m³)**
User-rate revenues	1,272	0.69
Differential	435	0.24
Wastewater treatment*	342	0.19
Water treatment*	151	0.08
Total	**2,200**	**1.20**
Required user-rate increase	+73%	

* Based on the traditional MOE financing approach of 40-year debentures, in this case using 7.75% interest rate. This long repayment period is counter to current financing practice. In any case, municipalities are unlikely to finance expenditures related to rehabilitation.

$61.4 billion, respectively. The estimates were based on extending water and sewer servicing to all urban residents, meeting the Canadian Drinking Water Guidelines, separating storm and sanitary sewers, and achieving wastewater treatment to level III (tertiary) standards. See table 1-20 for the 1994 levels of wastewater treatment in Ontario.

The report uses information from an Environment Canada municipal survey to calculate investment needed to expand water supplies to achieve full urban servicing. In 1994, approximately 9.3 million people or 85% of the Ontario population (10.9 million) lived in municipalities with populations greater than 1,000. In these municipalities, approximately 91% had water supply and 89% had sewage treatment.

A 1995 CWWA Canadian water utility database had found that on average 193 people are served by each kilometre of watermain. This ratio was used to project needs for both water and wastewater mains (see table 1-21).

Table 1-20 Population Served by Different Levels of Wastewater Treatment, 1994

Level of Treatment	Population served
None	706
Primary	529,110
Secondary	1,348,152
Tertiary	6,442,135
Total	**8,320,103**

Source: Canadian Water and Wastewater Association, 1998, *Municipal Water and Wastewater Infrastructure: Estimated Investment Needs 1997 to 2012* (Ottawa: CWWA).

Table 1-21 CWWA Estimate of Water and Wastewater Mains Requirements

	Water		Wastewater	
	Population	Length (km)	Population	Length (km)
Existing serviced	8,534,258	44,219	8,317,703	43,097
Expanded (servicing of currently unserviced)	745,460	3,862	962,015	4,985
Growth	2,783,915	14,424	2,783,915	14,424

Source: Canadian Water and Wastewater Association, 1998.

In addition to the need for water and wastewater mains the report also provided estimates for total wastewater investment requirements for the 15-year period (see table 1-22). The report assumes that 40% of existing wastewater sewers are combined, and that they would be separated, requiring an additional 17,238 km of pipeline.

The serviced population growth was then projected to be 30% over 15 years, leading to a requirement for 14,424 km of mains to service an additional 2,783,915 people. Required facility construction was based on the population to be served. Estimates for wastewater included upgrading of treatment: primary to tertiary (529,110 people served), secondary to tertiary (1,348,152 people served), and new tertiary (706 people served).

Parameters used to calculate the future investment requirements included the following:

- 0.6% of the existing system is replaced annually.
- Cost of mains expansion: $200 per metre. Cost of replacement including restoration: $300 per metre.
- Cost of treatment plant expansion: $2,000 per capita. Cost of wastewater treatment plant upgrades to tertiary from primary: $1,200 per capita (to tertiary from secondary: $400 per capita).

Table 1-22 CWWA Ontario Wastewater System Investment Requirements, 1997–2015 ($ Millions)

	Replacement	Expansion	Growth	Total
Mains	1,194.0	1,158.5	2,884.8	5,237.3
Combined sewer	12,067.2			12,067.2
Treatment	1,175.6		873.6	2,049.2
Total	**14,436.8**	**1,158.5**	**3,758.4**	**19,353.7**
Annual	962.5	77.5	250.6	1,290.2

Source: Canadian Water and Wastewater Association, 1998.

[16] "Water sector" refers to the infrastructure and services related to municipal water and wastewater (sanitary and storm sewer) systems.

Ontario Sewer & Watermain Construction Association (2000)

OSWCA commissioned an independent study by PricewaterhouseCoopers with the following objectives:

- Undertake a high-level, independent assessment of the percentage amount that user fees would have to be increased to achieve full-cost pricing in Ontario's water sector.[16]
- Identify preliminary mitigation strategies for addressing the impact of full-cost pricing.

Table 1-23 Analysis of Full-Cost Pricing Requirement, 1997 ($ Millions)

	Water	Sewer	Total
Revenues			
Direct billings	780.2	722.9	1,503.1
Fees & service charges	31.6	38.6	70.2
Special charges	12.4	12.4	24.8
Total revenues	**824.2**	**774.0**	**1,598.2**
Operating costs			
Salaries & wages	191.5	147.8	339.3
Net long-term debt charges	78.3	171.1	249.4
Materials, services, rents, fin. exp.	287.8	288.5	576.4
Other transfers	8.3	8.9	17.2
Interfunctional transfers	58.1	43.5	1010.5
Total operating costs	**624.0**	**659.8**	**1,283.8**
Available for capital investment	200.2	114.2	314.3
Sustaining capital expenditures			
Replacement	98.1	400.8	498.9
Expansion	163.9	144.5	308.4
Total sustaining capital expenditure	**262.0**	**545.3**	**807.3**
Additional funding required	61.8	431.2	492.9
Required user rate increase	7.5%	55.7%	30.8%

Source: Ontario Sewer and Watermain Construction Association, 2000, *Full Cost Pricing Gap Review of the Ontario Water Sector* (prepared by PriceWaterhouseCoopers) (Toronto: OSWCA).

The OSWCA study used the 1998 CWWA study for costs and the Ontario FIR database from the Ministry of Municipal Affairs and Housing. The study accepts the CWWA water cost projections, but reduces the sewer cost projections in the area of combined sewer separation.

Using 1997 data as an example, the analysis found that a user rate increase of 31% would be required to put water and sewer financing on a sustainable footing using full-cost pricing (see table 1-23).

Storm sewer costs are included in the sewer analysis. This is curious because storm sewer costs are not recovered on a user-pay basis in Ontario and are not included in the CWWA figures to arrive at the required level of "sustaining capital expenditures." However, removing storm sewer costs from the revenues and operating costs figures does not appear to affect the results to any degree.[17]

State of Ontario's Water Infrastructure (May 2000)

This paper by George Powell provided the following estimate of annual Ontario water and wastewater rehabilitation needs:

Renewal and rehabilitation The worth of Ontario's water and wastewater infrastructure is estimated at $50 billion: $35 billion below ground, $15 billion above ground. Based on a 75-year life for below-ground facilities and 35 years for above-ground facilities, the replacement cost would be $0.895 billion annually ([35 ÷ 75] + [15 ÷ 35]).

Upgrading An MOE needs study completed in the early 1990s identified upgrading needs of $19 billion over 15 years, or $1.3 billion annually, broken down as follows:

- safe drinking water initiative: $2 billion
- universal metering: $0.5 billion
- water and wastewater infrastructure rehabilitation catch-up: $3 billion
- wastewater requirements: $13.5 billion

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[17] The sanitary sewer revenues are $747.8 million and operating costs are $637.0 million, for an "available for investment" amount of $110.8 million, which is close to the $114.2 million reported in table 1-23.

[18] George Powell, 2000, *The State of Ontario's Water Infrastructure* (paper presented at Ontario Municipal Water Association, Windsor conference) (Toronto: OMWA).

If 50% of the catch-up costs are considered to be for water, the average annual cost would be $0.267 billion for water, $1 billion for wastewater.

Growth Although growth-related costs are normally recovered through capital charges to new house owners, there will be an impact on annual expenditures of about $100 million. This is equivalent to annual capital spending for water and wastewater of $2.3 billion.[18]

Association of Municipalities of Ontario (2000)

In June 2000 the AMO issued *AMO Action Plan – Protecting Ontario's Water.* The action plan promotes "a renewed, re-defined partnership between the municipal order of government, the provincial order of government, and the federal government." The AMO wants the provincial government "to recognize the important role of municipalities in planning and managing effective services in Ontario's communities."

Support material for the conclusions includes a figure for investment requirements: "The Ontario Jobs and Investment Board (OJIB) estimates that a five-year rehabilitation program to address the municipal infrastructure deficit for sewer, water, roads and bridges will cost $21.1 billion. Of this amount, $9.1 billion is needed for rehabilitation investment in Ontario's water and sewer systems alone."[19]

The action plan does not really focus on the level of costs or the method of cost recovery. It is more oriented toward overall policies to address water and wastewater system management and planning.

1.10.6 Summary Comments on Cost Data

Current Investment Levels

Total cash outlays by municipalities for water and wastewater systems in 1997 were $969 million and $947 million, respectively. The proportion allocated to capital investment in infrastructure was $426 million for water (44% of the

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[19] Association of Municipalities of Ontario, 2000, *AMO Municipal Action Plan: Protecting Ontario's Water* (policy report) (Toronto: AMO).

total) and $496 million for wastewater (52%). These figures do not include facilities contributed by developers who recover the cost from sales of property.

Current Cost Recovery Levels

Revenues from local sources in 1997 recovered 96% of water costs and 95% of wastewater costs. The remainder was paid by grants, mostly provincial. Thus, the municipalities are close to full cost recovery if grants are considered the only revenue source not part of full cost recovery. User rates recovered 80% and 74% of water and wastewater costs, respectively, with much of the remainder coming from property taxes. Development charges were also a factor, although their impact across the province appears to be minor. Most of the local revenue sources could be considered 'user pay.' In water systems, tying the property tax charge to the cost of providing water for fire protection is an accepted method of recovering these costs. It would appear that there is room to increase wastewater user rates to include the costs now recovered from property taxes. To accomplish this, wastewater tariffs would increase on average 16%.

Large Systems Serve 91% of Population

The population of Ontario serviced by municipal water systems in 1997 was about 8.3 million. Most of these systems are provided by regional governments (72% of the population served) or by cities (19%). Of the remaining population served, 8% are in towns and 1% in villages. Towns generally have a population of about 10,000, villages up to a few thousand. Although the population served in the towns and villages is small, the number of municipalities is large: towns represent 35% of the local communities serviced, villages 28%. The situation in wastewater systems is expected to be similar.

Cost Categories

It is particularly important to identify and recognize the differences between various types of infrastructure costs. These differences can affect the timing of expenditure and the options for cost recovery.

Future infrastructure investments can be divided into three categories:

Deficiencies These are investments needed immediately to bring facilities to current standards. Relating primarily to treatment facilities, they address improved standards, flow capacity deficiencies, and failure to meet current standards.

Rehabilitation Relating to replacement of facilities as they wear out, this type of investment is already ongoing in water and sewer systems. The concern is whether current levels of investment are sufficient. The prevailing view is that they are not and that as systems age the amount required will escalate further.

Growth This relates to increases in the number of customers served resulting either from servicing existing but previously unserviced urban population or from population growth. The CWWA estimates differentiate between the two.

Growth-related costs may have little impact on user rates because Ontario has mechanisms to recover these costs directly from the customers who benefit.

Results of Infrastructure Deficiency Studies

The various sources of information reviewed provide a range of estimates for infrastructure investment needs in Ontario (see table 1-24).

Table 1-24 Summary of Ontario Infrastructure Needs Studies ($ Millions)

	Deficiencies	Rehabilitation (annual)	New servicing (annual)	Comments
MOE (1996)	1,341 total	170	116	Treatment plants only – material not official
CWWA (1998)		963	328	Widely quoted study. Deficiencies not identified separately.
OSWCA (2000)	n/a	481	328	
Powell (2000)	267/year	497	550	Powell is considered authoritative, and his earlier estimates have ovten been quoted
CMA/OJIC (2000)		910	–	Taken as 50% of water and wastewater total spread over five years

The following comments on the results of the infrastructure studies are offered.

Deficiencies

Deficiencies discussed in the reports generally relate to treatment plant issues. Repair of below-ground facilities is considered more of a long-term rehabilitation issue than one of obvious deficiencies. The 1996 MOE estimate is the only one that provides a snapshot of outstanding items that should be fixed immediately. Although it provides detailed information, it is now outdated. Some of the problems have been rectified, but there are now new standards to meet.

Rehabilitation

Rehabilitation costs are normally paid out of current revenues. Revenue fund expenditure in 1997 was $861.5 million (table 1-14), of which $410.7 million was capital-related: $152.3 million debt and $258.4 million "transfers to own funds" (i.e., used for capital). It could be argued, however, that none of the capital-related funds should be available for growth (see next item).

A conservative approach would be to assume that only the $258.4 million transferred funds are used for rehabilitation. On this basis, the three reports that segregated rehabilitation costs would have the impact shown in table 1-25.

Table 1-25 Comparative Annual Wastewater Rehabilitation Cost Estimates

	CWWA	OSWCA	Powell
Funds required ($ million)	962.5	481.2	497
Revenue deficiency from 1997 capital expenditure levels of $258.4 ($ million)	704.1	222.8	
Revenue fund increase required from 1997 level of $861.5	82%	26%	28%
User rate increase from 1997 level of $696.8 if recovered from user rates	101%	32%	34%

Growth – Cost Recovery from New Customers

Ontario legislation provides for recovery of costs expended on new infrastructure needed to satisfy system expansion:

- Servicing on private property is the responsibility of each customer.
- Customers pay service connection pipe costs from sewer mains to the street line. If developers build the connectors, the cost is passed on to customers in the property cost. If the municipality builds them, the cost is recovered by means of connection charges.
- Local mains fronting customer property can also be charged to abutting customers (trunk main capacity cost is not included here). If developers build the local mains, the cost is passed on to customers in the property cost. If the municipality builds them, the cost is recovered by means of frontage charges.
- The utility normally builds major facilities. Development charges can be levied against new development to recover development-related costs.

Thus, mechanisms are available to recover the cost of facilities for new development. Developers commonly construct local facilities and recover costs in the price of the property. These costs do not show up in municipal accounts. Municipal local-servicing costs are also commonly recovered. Development charges are common, but not all municipalities apply them. They are also applied more frequently to residential consumers than to non-residential consumers.

Unfortunately, financial information returns do not show a breakdown of municipal financing sources for the water and wastewater capital funds.

Growth-related costs that appear in the capital funds should be largely offset by capital recovery mechanisms. The impact on the revenue fund and user rates should be minor. Also, the additional user revenues from growth should more than offset any growth-related capital costs that do get passed on to the revenue fund.

Further Refinement of Cost Estimates

It is critical that investments in system rehabilitation be a normal part of wastewater system expenditures. To determine whether current levels are sufficient or what the levels should be, more detailed information on wastewater systems is needed. In the case of above-ground facilities, the MOE has traditionally been well informed, and the current reviews of every wastewater treatment facility in the province should provide a good view of current deficiencies and ongoing rehabilitation needs. In the case of below-ground facilities, a much better inventory of items such as length, size, construction material, age, and condition is necessary to derive meaningful estimates of future rehabilitation needs.

Depreciation

There is some confusion with the term 'depreciation.' It often seems to be used to reflect how much must be invested to replace deteriorating infrastructure. In utility financial reporting, however, it refers to the spreading of capital costs over the life of the item. The term is not applicable in the cash accounting method used by municipalities in Ontario. In any case, depreciation is not sufficient to generate the funds required to replace aging equipment because costs of replacement are frequently higher than the original costs being depreciated.

2 Standards, Guidelines, and Objectives

2.1 Introduction

This chapter outlines the major acts governing the discharge of wastewater in Ontario. Many of them cover air, land, and water environments. This discussion will focus on the water-related sections of the acts.

Phyper and Ibbotson also provide a summary of requirements for environmental compliance in Ontario.[20] Legislation and many of the documents quoted in this chapter are available on the Internet.[21]

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[20] J.-D. Phyper and B. Ibbotson, 1994, *The Handbook of Environmental Compliance in Ontario,* 2nd ed. (Toronto: McGraw-Hill Ryerson).

[21] The following relevant Ontario legislation can be found online on the Ministry of the Environment Web site [cited December 2001], <www.ene.gov.on.ca/envision/env_reg/ebr/acts%20and%20regs/index.htm>: *Environmental Assessment Act, Environmental Bill of Rights, Environmental Protection Act, Water Resources Act.*

2.2 Canadian Standards and Guidelines for Wastewater Discharge and Solid Waste Disposal

2.2.1 Canadian Environmental Protection Act, 1999

The *Canadian Environmental Protection Act, 1999* (*CEPA*) forms the centrepiece of federal environmental legislation. The goal of *CEPA* is to contribute to sustainable development through pollution prevention and to protect the environment and human life and health from the risks associated with toxic substances.[22] The act defines the Government of Canada's powers and its responsibilities to the public. It addresses pollution of air, water, and land, and it outlines penalties for offenders.

In an effort to eliminate the duplication of environmental regulation, *CEPA* allows for Equivalency Agreements, whereby provincial or territorial environmental legislation is deemed equivalent to *CEPA* and thus *CEPA* regulations no longer apply in the province or territory. At this time only Alberta has entered into an equivalency agreement with the federal government.

Administrative Agreements are working arrangements between the federal and provincial governments to streamline efforts in administrating regulations. To date, only Saskatchewan has an administrative agreement with the federal government.

Both Environment Canada and Health Canada have responsibilities under the legislation; the two departments share the task of assessing and managing the risks associated with toxic substances. The act obliges the Minister of the the Environment to establish, operate, and maintain an environmental monitoring system, conduct research and studies, and publish information, including a periodic report on the state of the Canadian environment. The Minister of Health is obliged to research the effects of substances on human health. Environment Canada has established a series of substance inventories or lists which are available on the Internet.[23]

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[22] Canada, Environment Canada, 2001, *Environmental Acts and Regulations: Acts Administered by the Minister of the Environment: Canadian Environmental Protection Act (1999)* [online], [cited December 2001], <www3.ec.gc.ca/EnviroRegs/Eng/SearchDetail.cfm?intAct=1001>.

[23] Canada, Environment Canada, CEPA Environmental Registry, 2001, *Substances Lists* [online], [cited December 2001], <www.ec.gc.ca/CEPARegistry/subs_list/default.cfm>.

The Domestic Substances List has more than 20,000 substances manufactured in, imported to, or used in Canada on a commercial scale. The list is based on substances that were present in Canada between January 1, 1984, and December 31, 1986. In general a substance not on this list is considered new to Canada and is subject to notification such that its toxicity can be assessed. A complementary Non-domestic Substances List, contains more than 50,000 substances that require reduced levels of notification, based primarily on knowledge with respect to their use in the United States.

Under *CEPA* the Ministers of Environment and Health are required to establish a Priority List of Substances to be assessed for toxicity or potential toxicity. The assessments are to be completed within five years. Assessment of an initial list of 44 substances, was completed in 1994, and the assessment of a second list of 25 substances was due for completion in 2000. If a substance is deemed toxic, it is added to a List of Toxic Substances, and regulations are developed to control it.

Under circumstances in which a release of a listed toxic substance into the environment is likely, those responsible for the material must prepare a written report on the matter and submit it to an enforcement officer. They must also take all reasonable measures to maintain public safety and prevent the release, and they must make a reasonable effort to notify the public.

The Export Control List is a listing of substances for which export from Canada is controlled. The list is divided into three parts: substances prohibited from use in Canada, substances seriously restricted for use in Canada, and substances subject to international agreement.

The National Pollutant Release Inventory tracks on-site pollutant releases as well as off-site pollutant transfers from facilities and allows the public access to pollution-release information for facilities in their area.

The ministry also maintains a list of waste or other matter that may be disposed of at sea. It is to be prepared as a mechanism to screen wastes based on their potential effects on human health and the marine environment.

2.2.2 Federal Fisheries Act

The *Federal Fisheries Act* is much shorter than *CEPA* and focuses on preservation of inland and marine fisheries. It prohibits any undertaking that results in harmful alteration of fish habitat. Nevertheless, deposition of deleterious substances may be authorized provided that they do not exceed allowable concentrations. Anyone who contravenes the act is subject, on conviction, to a fine not exceeding $5,000 for the first offence and not exceeding $10,000 for each subsequent offence, and to imprisonment for a term not exceeding two years.

2.3 Ontario Standards and Guidelines for Wastewater Discharge and Solid Waste Disposal

The main Ontario acts are considered briefly in this section. Details are presented through examination of the guidelines, objectives, or other documents derived from the acts.[24]

2.3.1 Ontario Water Resources Act, December 10, 1999

The *Ontario Water Resources Act* (*OWRA*), which governs withdrawal and discharge of water, is the centrepiece of Ontario legislation to regulate and control natural waters. It empowers the Ministry of the Environment (MOE) to supervise, control, and regulate all activities concerning the use of public water, both surface and groundwater, and to regulate environmental impacts of activities that affect natural waters. Provincial natural water quality objectives are based on the provisions of this act, which also stipulates the size of, and constraints placed on, sewage works. The act refers to the Ontario *Environmental Protection Act* for some regulatory issues – in particular the certificate of approval (COA), a legally enforceable document that details the MOE's approval of construction of new works or changes to existing facilities. Sewage systems governed under the *Building Code Act, 1992* are not subject to the *OWRA*.

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[24] Ontario legislation and regulations can be found on the e-Laws Web site <www.e-laws.gov.on.ca/home_E.asp>

Water Management

Water Management: Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy (July 1994, as reprinted in February 1999), commonly known as *Water Management,* is the working instrument of the *OWRA.*[25] It outlines the MOE's policies and guidelines for the management of the provinces water resources and provides direction with respect to managing the quality and quantity of surface waters and ground waters. Although the policies, objectives, and guidelines presented in the document have no formal legal status, they provide direction in assigning the site-specific effluent levels that may be incorporated into legally binding COAs.

Provincial Water Quality Objectives

The provincial water quality objectives (PWQOs) contained in *Water Management* are numerical and narrative water quality criteria representing minimum acceptable levels of water quality for surface waters and for groundwaters that are discharged to surface waters. PWQOs are set at a level of water quality protective of all forms of aquatic life and all aspects of the aquatic life cycle during indefinite exposure to the water. PWQOs for the protection of recreational water uses are based on public health and aesthetic considerations. Narrative objectives are subjective requirements established to manage contaminants that can cause undesirable conditions, but can not easily be identified as specific chemical compounds.

PWQOs are often used to assess ambient water quality conditions, infer use impairments, assist in assessing spills, and act as a starting point in developing waste effluent requirements as part of a COA. A listing of the PWQOs can be found in appendix A of *Water Management.*

The PWQO for indicator micro-organisms is 100 *Escherichia coli* per 100 mL. An indicator micro-organism is one that should be present when pathogens are present and absent when pathogens are absent. H:0157 is a particularly virulent strain of *E. coli* that was first identified about 20 years ago and is commonly associated with tainted hamburger meat. Most *E. coli,* however, comprises non-virulent strains that inhabit the digestive tracts of humans and

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[25] Ontario, Ministry of Environment and Energy, 1994, *Water Management: Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy* [online], [cited August 2001], <www.ene.gov.on.ca/envision/gp/3303e.pdf>.

warm-blooded animals. Identifying all of the potential waterborne microbial pathogens in water is virtually an impossible task. With the advent of rapid, reliable assays, *E. coli* has become the indicator of choice, replacing fecal coliforms. *E. coli* is included in the fecal coliform group.

Policies and Procedures

PWQOs are intended to promote aquatic ecosystem health but do not take into account other factors such as loss of habitat, sedimentation, water quantity regulation, and the introduction of indigenous species that may have a significant impact on the aquatic ecosystem. In addition to PWQOs, consideration of other factors, such as the additive effects of more than one chemical or the protection for other uses, may lead to more stringent requirements.

The following policies are stated in *Water Management*:

- "In areas which have water quality better than the Provincial Water Quality Objectives, water quality shall be maintained at or above the Objectives" (sec. 3.2.1).

- "Water quality which presently does not meet the Provincial Water Quality Objectives shall not be degraded further and all practical measures shall be taken to upgrade the water quality to the Objectives" (sec. 3.2.2).

- "Prevent the release, in any concentration, of hazardous substances that have been banned" (sec. 3.3).

- "Ensure that special measures are taken on a case by case basis to minimize the release of hazardous substances that have not been banned." (sec. 3.3)

- "Mixing zones should be as small as possible and not interfere with beneficial uses. Mixing zones are not to be used as an alternative to reasonable and practical treatments" (sec. 3.4).

- "To protect the quality of groundwater for the greatest number of beneficial uses" (sec. 4.0).

- "To ensure the fair sharing, conservation and sustainable use of the surface and ground water of the province" (sec. 5.0).

Pollutants enter the water from numerous sources including industrial and municipal wastewater discharges, runoff from urban and agricultural areas, deposition of air pollutants, and lake filling. *Water Management* identifies the following procedure for establishing effluent requirements for discharges to surface waters:

- Site-specific receiving water assessments will be conducted to access existing conditions and determine effluent requirements based on the waste assimilative capacity of the receiver.

- The site-specific effluent requirement, so derived will be compared, where applicable, to appropriate federal or provincial regulations or guidelines for effluent discharges and the most stringent requirement will be applied.

- The effluent requirement derived from the above procedures, expressed as waste loadings and/or concentrations, will be incorporated into a Certificate of Approval or other control document.

- For existing discharges in areas where water quality is degraded and does not meet the Provincial Water Quality Objectives, the Ministry may develop a pollution control program with each discharger to meet the effluent requirement determined from the above procedures.[26]

Waste control requirements for proposed regulated sources of pollution are established on a case-by-case basis. Activities that do not require specific approval under the *OWRA* or *Environmental Protection Act* but have the potential to contribute to groundwater contamination include non-point-source activities (crop fertilization, manure application, road de-icing), salt storage areas, unlicensed and closed landfills, leaks, spills, and decommissioning clean-up.[27]

2.3.2 Environmental Protection Act, May 14, 1999

The purpose of the *Environmental Protection Act* is to provide for the protection of the natural environment, including air, water, and land.

The act reiterates many of the policies, regulatory statements, and principles of the *OWRA*. With respect to wastewater discharge, the principal statement in the act is that "no person shall discharge into the natural environment any

[26] Ontario, Ministry of Environment and Energy, 1994, sec. 3.5.1.
[27] Ibid., sec. 4.1.1.

contaminant, and no person responsible for the source of contaminant shall permit the discharge into the natural environment of any contaminant from the source of contaminant, in an amount, concentration, or level in excess of that prescribed by the regulations" (sec. 6.1). However, the general provisions for liquid and solid waste management are explicitly stated not to apply to animal wastes that are disposed of in accordance with normal farming practices.

The COA required to construct and operate a wastewater facility is formally issued under the auspices of the *Environmental Protection Act.* Discharge limitations and other requirements included in the COA are set with respect to the water quality objectives. COAs may include effluent requirements and monitoring requirements.

Approval of Water and Sewage Works

Guide for Applying for Approval of Municipal and Private Water and Sewage Works (August, 2000) provides guidance for applicants requesting approval of municipal and private water and sewage works under sections 52 (water) and 53 (sewage) of the *OWRA.* It outlines the approvals process, information requirements of particular forms, and technical information requirements for various applications.[28] In addition to prohibiting the operation of unapproved sewage works, section 53 states that the sewage works approval requirements do not apply to

- a sewage works from which sewage is not to drain or be discharged directly or indirectly into a ditch, drain or storm sewer or a well, lake, river, pond, spring, stream, reservoir or other water or watercourse;
- a privately owned sewage works designed for the partial treatment of sewage that is to drain or be discharged into a sanitary sewer;
- a sewage system that is subject to the *Building Code Act, 1992;*
- a sewage works the main purpose of which is to drain agricultural lands;

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[28] Ontario, Ministry of the Environment, Environmental Assessment and Approvals Branch, 2000, *Guide for Applying for Approval of Municipal and Private Water and Sewage Works* [online], [cited August 2001], <www.ene.gov.on.ca/envision/WaterReg/Pibs4063.pdf>.

- a drainage works under the *Drainage Act,* the *Cemeteries Act,* the *Public Transportation and Highway Improvement Act,* or the *Railways Act;* or

- such sewage works as may be exempted therefrom by regulations made under this act.

Minor water and sewage works, including watermains and sewer service connections and appurtenances, as well as stormwater management facilities designed to serve a single lot or parcel of land (excluding industrial land) and discharge into a storm sewer (but not a combined sewer), are also exempted.

Approval requirements do apply to a sewage works for the distribution of sewage on the surface of the ground for the purpose of disposing of the sewage. A 1997 amendment to Section 53 of the *OWRA* stipulates that the approval requirements also apply to sewage works from which sewage is not to drain or be discharged directly or indirectly into a ditch, drain, or storm sewer or a well, lake river, pond, spring, stream, reservoir or other water or watercourse if

- the sewage works has a design capacity in excess of 10,000 L/d;

- more than one sewage works is located on a lot or parcel of land and they have, in total, a design capacity in excess of 10,000 L/d; or

- the sewage works are not located wholly within the boundaries of the lot or parcel of land on which is located the residence or other buildings of the facility served by the works.

This recent addition has brought under the approval requirements all communal and large individual sewage collection and treatment systems with subsurface effluent disposal (large septic tank and leaching bed systems).

A public hearing is mandatory when proposed works cross a municipal boundary. If the works do not cross a municipal boundary but, in the director's opinion, are expected to generate significant public interest, the director may order a public hearing. Construction or modifications of sewage works that are subject to the *Environmental Assessment Act* do not require a public hearing.

The responsibility for construction and operation of water or sewage works lies with the legal owner of the entity, be it public or private. Review of applications for sewage works can be transferred to a designated municipal authority on behalf of the ministry. Municipal authorities included in the transfer of review are generally the larger municipalities in Ontario and are listed in appendix C of the *Guide.*

The approval process generally consists of pre-application consultation, technical review, and approval.

Pre-Application Consultation The pre-application consultation is a dialogue between the proponent, the ministry, and possibly the public before an application for approval of a project is submitted. Its purpose is to assist the proponent in defining the environmental objectives for the project including effluent, source water, technology, and public consultation and notification requirements.

Pre-application consultation is required for all projects that relate to construction or modification of sewage or wastewater treatment works. At this stage much of the preliminary work must be complete if the proponent is to discuss the proposal details, potential environmental impacts, and applicable statutes.

The ministry will assist the proponent in identifying all provincial environmental legislation, policies, objectives, and guidelines applicable to the project. The ministry will also determine if a groundwater or surface water impact assessment is required and outline the scope of such an assessment, determine if a Permit to Take Water is required, advise on the required characterization of the water source, and discuss with the proponent any special concerns that must be dealt with in the application for approval.

A surface water impact assessment is required for any wastewater treatment facility that will discharge to surface water, including wetlands. Projects that do not discharge directly to surface water but that might have a significant environmental impact (e.g., treated sewage effluent spray irrigation, exfiltration or subsurface disposal, or water treatment plant waste stream discharge) do not require an approved environmental assessment before they can be submitted for approval. However, the ministry must be satisfied that all required data have been made available to allow a thorough evaluation of the impacts of the project. Otherwise, the application may be deemed incomplete.

After the pre-application stage, the submitted application is screened for completeness and payment of applicable fees. The proponent is advised of any deficiencies in data or information. Any project subject to the *Environmental*

Bill of Rights must have a minimum 30-day public-comment period in the approval process.

Technical Review After the application is screened it undergoes detailed technical review by a review engineer. The engineer reviews detailed design documentation and other supporting information to ensure that sound engineering practices have been followed and that the proposal complies with relevant environmental acts, regulations, policies, objectives, and guidelines. Specific technical information requirements for various types of water and sewage works proposals are outlined in part III of the *Guide*.

Approval Once the review engineer's recommendations have been considered, the approving director may choose to grant approval, refuse to grant approval, or grant approval for the project on such terms and conditions deemed necessary. The director grants approval for a project by issuing one of the following documents:

- a new certificate of approval
- an amended certificate of approval
- a notice of amendment to certificate of approval

A new COA is issued for approval of new water and sewage works, or for alteration, extension, or replacement of existing works. An amended COA, which replaces the existing COA, is issued for replacements and major alteration or extension of existing previously approved works. A notice of amendment to COA is issued to approve modifications to existing previously approved works or to impose new or modified terms and conditions of the existing COA; it becomes part of the amended COA.

Providing false information to the ministry can result in fines for individuals of up to $10,000 for the first conviction and up to $25,000 for each subsequent conviction; the penalties increase to $50,000 and $100,000, respectively, for corporations.

Environmental Impact Analysis In conducting an environmental impact analysis for a proposed sewage works, the most important aspect is the anticipated impact of the effluent on the receiving water and its potential users. The proponent must assess the assimilative capacity of the receiver (the receiving water), determine the actual and potential users of the receiver, and derive the effluent quality and discharge criteria for the proposed works.

As part of the assimilative capacity assessment for the receiving water the proponent must provide the following information:

- limiting conditions within the receiving water body
- proposed effluent quantity and flow rate (design daily and monthly flow), and actual historical average daily and monthly flow based on at least one year's monitoring, if available
- proposed effluent quality expressed as maximum expected daily and monthly loading at design flow and highest expected concentration in the effluent under normal operating conditions for all parameters of concern
- receiver impact analysis
- proposed receiver mixing zone defined as "the area of water continuous to the point source where the water quality does not comply with the Provincial Water Quality Objectives," which should be mapped for the proposed maximum effluent discharge rate

The MOE provides a number of documents containing guidelines for design of various water, wastewater, and stormwater treatment facilities. The ministry is also a member of the Great Lakes–Upper Mississippi River Board of Public Health and Environmental Managers (GLUMRB) and subscribes to the board's recommendations for sewage and water works. GLUMRB is a consortium, initially composed of authorities from ten states, that has spent over 50 years developing water and wastewater treatment guidelines.

The Municipal-Industrial Strategy for Abatement (MISA) is responsible for a set of *Environmental Protection Act* regulations that classify discharge limits by industrial sector. MISA regulates nine sectors: petroleum, pulp and paper, industrial minerals, organic chemical, iron and steel, inorganic chemical, metal casting, electric power generation, and metal mining. Effluent parameter limits may be set on a sector-wide basis or on a facility basis.

Combined sewers convey sanitary wastewater (domestic, commercial, and industrial) and stormwater runoff in a single pipe. Discharge from this system without treatment is a combined sewer overflow (CSO), which occurs when surface runoff during rainfall enters the sewer system and exceeds its capacity. No new CSOs or increased volume for existing CSOs are allowed.

In undeveloped areas, recommendations of appropriate ministries such as the Ministry of Natural Resources, conservation authorities, or local municipalities must be obtained for stormwater management.

To obtain a COA, the proponent must pay fees to the Government of Ontario. The fee structure is outlined in appendix F of the guide.

Certificates of Approval

The MOE has prepared several procedures and guidelines that provide further information that may be applicable to a proponent applying for a COA. The following are major points in relevant procedures and guidelines.[29]

Levels of Treatment for Municipal and Private Sewage Treatment Works Discharging to Surface Waters (Guideline F-5), April 1994[30]

- The normal level of treatment required for municipal and private sewage treatment works discharging to surface waters is secondary treatment or equivalent (see table 2-1). Relaxation of the normal level of treatment can be allowed on a case-by-case basis. Under no circumstances will the level of treatment required be less than primary treatment; higher than normal levels of treatment may also be imposed. More stringent treatment can be imposed as a result of a site-specific assessment.

- Effluent requirements are assigned on a site-specific basis.

- New treatment plants are subject to the procedures outlined previously in this subsection to determine the COA limits. Existing sewage treatment works are subject to review and amendment of their COAs.

- A comprehensive monitoring program of sewage works with regular sampling of effluents is required.

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[29] See the online *Manual and Guidelines Catalogue* [cited December 2001], <www.ene.gov.on.ca/envision/gp>.
[30] Ontario, Ministry of the Environment, 1994e, *Levels of Treatment for Municipal and Private Sewage Treatment Works Discharging to Surface Waters* [online], Guideline F-5 [cited August 2001], <www.ene.gov.on.ca/envision/gp/F5.pdf>.

Table 2-1 Secondary Treatment Levels

Treatment level and process	Effluent design objectives [a] (mg/L)				Guidelines [b] (mg/L)	
	BOD_5	SS	TP	NH_4-N	BOD_5	SS
Secondary Treatment or Equivalent						
Conventional activated sludge without TP removal	15	15	-	-	25	25
Conventional activated sludge with TP removal	15	15	1.0	-	25	25
Contact stabilization without TP removal	20	20	-	-	25	25
Contact stabilization with TP removal	20	20	1.0	-	25	25
Extended aeration without TP removal	15	15	-	-	25	25
Extended aeration with TP removal	15	15	1.0	-	25	25
Continuous discharge lagoon without TP removal	25	30	-	-	30	40
Continuous discharge lagoon with TP removal	25	30	1.0	-	30	40
Seasonal retention lagoon without TP removal	25	30	-	-	30	40
Seasonal lagoon with TP removal by batch chemical dosage	15	20	0.5–1.0	-	25	25
Seasonal retention lagoon with TP removal by continuous chemical dosage	25	30	1.0		30	40
Physical-chemical treatment	20	20	1.0		25	25
Advanced treatment						
Conventional activated sludge with TP removal and filtration	10	5	0.3	-	[c]	[c]
Conventional activated sludge with nitrification	15	15	-	<1.0 [d]	[c]	[c]
Extended aeration with TP removal and filtration	5	5	0.3	-	[c]	[c]

Source: Ontario, Ministry of the Environment, [1994c], table 1.

BOD_5: 5-day biochemical oxygen demand; SS: suspended solids; TP: total phosphorus.

[a] Expected effluent quality under optimum conditions when treating raw sewage with BOD_5 = 170 mg/L, soluble BOD_5 = 50%, SS = 200 mg/L, TP = 7 mg/L, (NH_3+NH_4)-N = 20 mg/L.

[b] Criteria that the average annual effluent quality should not exceed (based on performance data collected in 1983 of sewage treatment works in operation in Ontario).

[c] Effluent quality and permissible periods of discharge will be stipulated as a result of receiving water assessment studies. Where effluent BOD_5 and SS concentrations are not found to be critical, effluent guideline BOD_5 and SS concentrations of 25 and 25 mg/L, respectively, should be used.

[d] Expected warm weather effluent concentration.

Determination of Treatment Requirements for Municipal and Private Sewage Treatment Works Discharging to Surface Waters (Procedure F-5-1)[31]

- Secondary treatment can be provided by biological processes including variations of the activated sludge process or lagoon systems, physical-chemical treatment, or combinations of these processes (see table 2-1). Effluent quality objectives vary as indicated in the table.

- Assessments of receiving water must be performed in all cases. Bypassing sewage from nominally separate sewerage systems is not allowed except in emergency situations. It is recognized that some overflows will occur in a combined sewer system, but all municipalities serviced with these systems must prepare plans for staged reduction of CSOs.

- Sewage treatment works should be able to produce an annual average effluent quality approximately equal to the effluent design objectives shown in table 2-1, but not to exceed the effluent guidelines criteria.

- Primary sewage treatment plants will eventually be upgraded to secondary treatment. The interim guidelines for performance of a primary plant are BOD_5 and SS removals of 30% and 50%, respectively. If the primary plant is to achieve TP removal, then BOD_5 and SS removals of 50% and 70%, respectively, are specified.

Relaxation of Normal Level of Treatment for Municipal and Private Sewage Works Discharging to Surface Waters (Procedure F-5-2)[32]

- Relaxation of normal levels of treatment for municipal and private sewage works discharging to surface waters is permitted only on a case-by-case basis, and proponents are advised to make their intentions known well in advance of a normal submission.

- The onus of justification lies with the proponent, who should demonstrate a substantial economic benefit afforded by a lower level of treatment.

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[31] Ontario, Ministry of the Environment, [1994c], *Determination of Treatment Requirements for Municipal and Private Sewage Treatment Works Discharging to Surface Waters* [online], Procedure F-5-1 [cited August 2001], <www.ene.gov.on.ca/envision/gp/F5-1.pdf>.

[32] Ontario, Ministry of the Environment, [1994g], *Relaxation of Normal Level of Treatment for Municipal and Private Sewage Works Discharging to Surface Waters* [online], Procedure F-5-2 [cited August 2001], <www.ene.gov.on.ca/envision/gp/F5-2.pdf>.

- Current and future utility rates relating to sewage treatment for the normal and proposed levels of treatment should be indicated. Receiving-water assessment studies must be conducted and data submitted.

Derivation of Sewage Treatment Works Effluent Requirements for the Incorporation of Effluent Requirements into Certificates of Approval for New or Expanded Sewage Treatment Works (Procedure F-5-3)[33]

- Both effluent loading and effluent concentration limits are to be incorporated into a COA for new sewage treatment works, expansions, or modifications. Other requirements may also be stipulated as necessary.

- When a limiting parameter controls, other parameters might not be incorporated into the COA. For example when total phosphorus is set at 0.3 mg/L, experience has shown that SS and BOD_5 criteria will be met, and the latter two will not be incorporated into the COA.

- If existing sewage treatment works cannot comply with the assigned effluent requirements, regional staff should develop an upgrading schedule with the operating authorities to satisfy the effluent requirements as soon as possible.

Determination of Treatment Requirements for Municipal and Private Combined and Partially Separated Sewer Systems (Procedure F-5-5)[34]

- The goals of this procedure are to eliminate the occurrence of dry-weather overflows, minimize the potential for impacts on human health and aquatic life resulting from CSOs, and achieve, as a minimum, compliance with body-contact recreational water quality objectives (PWQOs for *E. coli*) at beaches affected by CSOs for at least 95% of the four-month period June 1 to September 30 for an average year.

- A Pollution Prevention and Control Plan should be developed to meet the goals of the procedure.

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[33] Ontario, Ministry of the Environment, [1994a], *Derivation of Sewage Treatment Works Effluent Requirements for the Incorporation of Effluent Requirements into Certificates of Approval for New or Expanded Sewage Treatment Works* [online], Procedure F-5-3 [cited August 2001], <www.ene.gov.on.ca/envision/gp/F5-3.pdf>.

[34] Ontario, Ministry of the Environment, [1994b], *Determination of Treatment Requirements for Municipal and Private Combined and Partially Separated Sewer Systems* [online], Procedure F-5-5 [cited August 2001], <www.ene.gov.on.ca/envision/gp/F5-5.pdf>.

Effluent Disinfection Requirements for Sewage Works Discharging to Surface Waters (Procedure F-5-4)[35]

- Ensure that both public health and aquatic life are adequately protected from sewage works discharges in a most cost-effective manner.

- Disinfection requirements apply to all municipal, institutional, and private communal sewage works discharging to surface waters (unless otherwise exempted).

Sampling and Analysis Requirements for Municipal and Private Sewage Treatment Works (Liquid Waste Streams Only) (Procedure F-10), April 1994[36]

- Samples from the liquid waste streams of sewage treatment works must be taken and analyzed regularly in such a way as to reflect actual operating conditions and to permit evaluation of treatment works performance and compliance with effluent requirements.

- The sampling and analysis must be performed at least once a month. Special (more frequent) sampling and analysis requirements (additional parameters) may be specified if the receiving water is classified as sensitive.

- Sampling and analysis requirements for proper operational control purposes are the responsibility of the operating authority.

Procedures for Sampling and Analysis Requirements for Municipal and Private Sewage Treatment Works (Liquid Waste Streams Only) (Procedure F-10-1)[37]

- The document outlines sampling and analysis requirements for screening purposes only, to decide if and when more intensive sampling is required.

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[35] Ontario, Ministry of the Environment, [1994d], *Effluent Disinfection Requirements for Sewage Works Discharging to Surface Waters* [online], Procedure F-5-4 [cited August 2001], <www.ene.gov.on.ca/envision/gp/F5-4.pdf>.
[36] Ontario, Ministry of the Environment, 1994h, *Sampling and Analysis Requirements for Municipal and Private Sewage Treatment Works (Liquid Waste Streams Only)* [online], Procedure F-10 [cited August 2001], <www.ene.gov.on.ca/envision/gp/F10.pdf>.
[37] Ontario, Ministry of the Environment, [1994f], *Procedures for Sampling and Analysis Requirements for Municipal and Private Sewage Treatment Works (Liquid Waste Streams Only)* [online], Procedure F-10 [cited August 2001], <www.ene.gov.on.ca/envision/gp/F10-1.pdf>.

- MOE laboratories will accept samples for analysis associated with routine (screening) sampling programs.

- Operating authorities that use their own analytical equipment or submit samples to commercial laboratories must still submit samples to MOE laboratories for purposes of quality control auditing, at least until the capability and accuracy of the alternative laboratory is established.

- Eventually, all data from sewage treatment works sampling programs will be entered in a MOE database.

Use of Farm Pollution Advisory Committee (Procedure F-11), April, 1994[38]

- As noted previously, disposal of manure from farms by normal practice is exempt from regulations. However, the MOE can make determinations that pollution from individual farming operations is of concern.

- When the MOE has been unable to reach agreement with a farmer on a voluntary basis with regard to a livestock-related pollution problem, the parties may seek the advice of the Farm Pollution Advisory Committee, with the concurrence of the Ministry of Agriculture and Food (MAF).

- The committee will prepare and submit a report to the MOE and MAF, with copies provided to the concerned parties. The regional MOE director will decide on appropriate abatement and enforcement action after reviewing the report.

2.4 Public Consultation and Environmental Assessment

Two acts described in this section set out the requirements for public consultation and environmental assessments for waste disposal operations.

2.4.1 Environmental Bill of Rights, 1994

The major purposes of the *Environmental Bill of Rights* (*EBR*), as outlined in the act, are

[38] Ontario, Ministry of the Environment, 1994i, *Use of Farm Pollution Advisory Committee* [online], Procedure F-11 [cited August 2001], <www.ene.gov.on.ca/envision/gp/F11.pdf>.

- to protect, conserve, and, where reasonable, restore the integrity of the environment;
- to provide sustainability of the environment; and
- to protect the right to a healthful environment by means provided in the act.

Thirteen ministries of the Government of Ontario are subject to the *EBR*.[39] To fulfill its purposes the act provides the following:

- means by which residents of Ontario may participate in the making of environmentally significant decisions by the Government of Ontario
- increased accountability of the Government of Ontario for its environmental decision-making
- increased access to the courts by residents of Ontario for the protection of the environment
- enhanced protection for employees who take action in respect of environmental harm

This act describes minimum levels of public participation that must occur before the Government of Ontario can make decisions on specified environmental matters. The establishment and operation of an environmental registry is mandated with the purpose of providing a means of giving information about the environment to the public. The registry includes notice of proposals for policies, acts, and regulations under consideration by a ministry and deemed to have a significant impact on the environment if implemented, unless they are predominately financial or administrative in nature.

An *instrument* is defined as any document of legal effect issued under the act. Instruments include permits, licences, approvals, authorizations, directions, or orders issued under the act, but do not include regulations. Proposals for instruments must be classified as class I, II, or III, based on an assessment of the level of risk and extent of potential harm to the environment involved. When a ministry is considering a proposal for an instrument, the minister involved is obliged to do everything in his or her power to give notice to the public at least thirty days before a decision is made whether or not to implement the proposal. The minister may give more than 30 days notice and may also consider enhancing public participation in a number of ways including public meetings, oral presentations, and mediation.

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[39] Ontario, Ministry of the Environment, 2001, *General Information About the EBR* [online], [cited December 2001], <www.ene.gov.on.ca/envision/env_reg/ebr/general/minlist.htm>.

As part of the act the Lieutenant Governor appoints an environmental commissioner, who reviews implementation of the act and compliance of ministries with the act, provides guidance to the ministries and public with respect to the EBR, and reports annually on activities of the office. The environmental commissioner holds office for a term of five years and may be reappointed for further terms.

Any two persons resident in Ontario may apply to the environmental commissioner for a review of a policy, regulation, or instrument in order to protect the environment. The application is forwarded to the appropriate ministry and the minister determines whether the public interest warrants a review based on criteria established in the *EBR*.

Any two persons resident in Ontario may also apply to the environmental commissioner for an investigation when it is believed that an environmental policy, act, regulation, or instrument has been contravened. This application is also referred to the appropriate minister, who will investigate the matter to the extent considered necessary.

The act affirms the right of any resident of Ontario to bring action against any person who has contravened an environmental act or will imminently cause significant harm to a public resource of Ontario. With respect to an actual contravention, an action may not be brought unless the plaintiff has applied for an investigation into the contravention and has not received the required response or has received an unreasonable response.

Any person may file a complaint with the Ontario Labour Relations Board alleging that an employer has taken reprisals against an employee on a prohibited ground. Under the EBR, prohibited ground refers to actions taken because the employee in good faith did or may do any of the following:

- participate in decision making about a ministry statement of environmental values, policy, an act, a regulation or an instrument
- apply for a review
- apply for an investigation
- comply with or seek the enforcement of a prescribed act, regulation, or instrument
- give information to an appropriate authority for the purposes of an investigation, review, or hearing related to a prescribed policy, act, regulation, or instrument

- give evidence in a proceeding under this act or under a prescribed act

It is then the responsibility of the Labour Relations Board to investigate the complaint.

2.4.2 Environmental Assessment Act, 1994

The purpose of the *Environmental Assessment Act,* created under the auspices of the *Environmental Protection Act* and *OWRA,* is the betterment of the people of the whole or any part of Ontario by providing for the protection, conservation, and wise management of the environment. The act applies to undertakings, which are defined as enterprises, activities, proposals, plans, or programs on behalf of both public and private bodies.

The proponent of an undertaking or project for which the act applies is required to submit an environmental assessment of the project. The project may not proceed until the environmental assessment has been accepted and the Minister of the Environment has given approval to proceed.

An environmental assessment must consist of

- a description of the purpose of the undertaking;

- a description of and a statement of the rationale for the undertaking, the alternative methods of carrying out the undertaking, and the alternatives to the undertaking;

- a description of the environment that will be affected or that might reasonably be expected to be affected, directly or indirectly, and the effects that will be caused or that might reasonably be expected to be caused to the environment, and the actions necessary or that might reasonably be expected to be necessary to prevent, change, mitigate, or remedy the effects upon or the effects that might reasonably be expected upon the environment, by the undertaking, the alternative methods of carrying out the undertaking and the alternatives to the undertaking; and

- an evaluation of the advantages and disadvantages to the environment of the undertaking, the alternative methods of carrying out the undertaking, and the alternatives to the undertaking.

When an environmental assessment of an undertaking is submitted to the Minister of the Environment, the minister must prepare a review of the assessment. On completion of the review any person may inspect the assessment and review and make written submissions or require a hearing by the environmental assessment board. Whether a hearing is required is the decision of the minister.

On acceptance of an environmental assessment for an undertaking, the minister, with approval of the Lieutenant Governor, may choose to give approval for the project to proceed, give approval for the project to proceed subject to specified terms and conditions, or refuse to give approval for the project to proceed.

An environmental assessment board comprises at least five members appointed by the Lieutenant Governor in Council. Board members cannot be employed in the public service of Ontario in any ministry. The board may appoint technical experts to report and assist the board with respect to matters before it. Any final decision of the board is deemed to be the decision of the Minister of the Environment.

2.5 Building Code Act, 1992

The *Building Code Act, 1992* applies to the design, construction, and operation of sewage treatment systems generally found in rural areas where a sewer system is unavailable. Wastewater from these systems must be discharged on site through various disposal options stipulated under the code, or the wastewater may be collected in a holding tank to be hauled to a sewered system. Establishments in these situations may range from large operations (such as airports, docking facilities, or factories) to individual family residences. The act specifies design constraints for various on-site systems.

2.6 Municipal Bylaws for Waste Disposal

Municipalities can impose regulations on discharges that enter their sewer systems. Fees and penalties can be prescribed in the bylaws. As an example, the sewer use bylaw of the City of Ottawa (formerly the Regional Municipality of Ottawa-Carleton) is described here.[40]

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[40] Ottawa, City Services, 2001, *The Sewer Use By-law* [online], [cited December 2001], <city.ottawa.on.ca/city_services/waterwaste/sewer_use/sewer_use_4_en.shtml>.

All residential, industrial, and commercial users that discharge waste to sewers are subject to the bylaw. The focus of the law, however, is on industrial users. All wastewaters from the partially separate and combined sewer system are treated at the local sewage treatment works.

The bylaw lists substances – ranging from roof drainage to toxic substances – that are prohibited from being discharged into sewers. It also lists restricted substances that may be discharged to sewers with restrictions. Discharge limits for restricted substances are shown in table 2-2.

In addition to periodic visits to industrial facilities, compliance officers monitor and sample key sewers and discharge locations to identify pollutants of concern within an area. Spills and unusual discharges are to be reported immediately to a 24-hour information line, followed by a written report. The city has the authority to charge an individual or industrial facility that does not comply

Table 2-2 City of Ottawa Sewer Discharge Limits (Sanitary and Combined)

Substance	Limit (mg/L)	Substance	Limit (mg/L)
Antimony	5	Molybdenum	5
Arsenic	1	Nickel	3
Biochemical oxygen demand	300	Oil & grease (animal or vegetable)	150
Bismuth	5	Oil & grease (mineral or synthetic)	15
Cadmium	1	pH (no units)	5.5–9.5
Chlorides	1,500	Phenolic compounds	1
Chromium	5	Selenium	5
Cobalt	5	Silver	5
Copper	3	Sulphates	1,500
Cyanide	2	Sulphide	2
Fluorides	10	Temperature	65° C
Iron 50	50	Total phosphorus	10
Kjeldahl nitrogen	100	Total suspended solids	350
Lead	5	Vanadium	5
Manganese	5	Zinc	3
Mercury	0.1		

Source: Ottawa, City Services, 2001.

with the sewer use bylaw. An industrial facility wishing to discharge non-toxic, treatable waste in excess of the limits can apply for a Special Discharge Agreement, for which an annual fee will be charged to the facility to cover the additional cost of treating the waste at the wastewater treatment plant.

2.7 Wastewater Treatment Residuals Management

When solids residuals are sent off site, their disposal is subject to part V of the *Environmental Protection Act.* A COA is required to operate a waste management system or waste disposal site. This section of the act does not apply to storage or disposal of private domestic waste on an individual's own property unless, in the opinion of the director, the storage or disposal will cause a nuisance.

2.7.1 Applying Biosolids and Other Wastes on Agricultural Land

The guidelines in *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* were devised in March 1996 through a joint effort of the Ontario ministries of the Environment (MOE) and of Agriculture, Food and Rural Affairs (OMAFRA).[41] The purpose was to facilitate the use of biosolids and other waste materials on agricultural land, while protecting environmental quality, consumer and animal health, food quality, and the productivity of the land.

Criteria in this document must be met before biosolids or other waste materials can be considered for use on agricultural land. The producers of potentially usable waste materials must obtain a COA before the material may be applied to agricultural land. As part of the COA the applicant may be required to provide a suitable field monitoring program and routine analysis for specified parameters of concern as well as ensuring that each batch produced is of uniform, consistent, and acceptable quality.

Potentially desirable constituents in waste materials include nitrogen, phosphorus, and potassium. Before applying waste to agricultural land, farmers should be advised of the nutrient concentrations to allow possible waste material and fertilizer application rate adjustment.

[41] Ontario, Ministry of the Environment and Ministry of Agriculture, Food and Rural Affairs, 1998. This electronic revision of the original 1996 document includes regulatory amendments to October 1997.

To ensure proper and continued spreading of sewage biosolids and other wastes on agricultural land, standards have been developed to limit the application of many potentially undesirable elements, including sodium, boron, and metals. The metals of principal concern to agriculture and the maximum permissible concentrations are listed in table 2-3. The guidelines are designed to restrict the accumulation of metals such that the metals would take 25 to 55 years to reach the maximum recommended limits in typical Ontario soils. See table 2-4 for application guidelines.

Spreading rates are regulated to ensure that application of wastes is beneficial to the agricultural land where they are applied and do not cause any short- or long-term harmful effects. All sites for spreading waste material must be approved by the MOE. In an effort to minimize the risk of contamination to

Table 2-3 Ontario Criteria for Metal Content in Sewage Biosolids

	Anaerobic biosolids		Aerobic biosolids [b]	
	Minimum ratios [ammonium-N + nitrate-N]/[Metal]		Maximum permissible concentrations (mg/kg of solids)	
Metal [a]	**Current**	**Targets [c]**	**Current**	**Targets [c]**
Arsenic	100	480	170	35
Cadmium	500	4,200	34	4
Chromium	6	32	2,800	530
Cobalt	50	220	340	77
Copper	10	45	1,700	380
Lead	15	75	1,100	220
Mercury	1,500	8,400	11	1.4
Molybdenum	180	1,700	94	1.2
Nickel	40	210	420	80
Selenium	500	2,800	34	6
Zinc	4	20	4,200	840

Source: Ontario, Ministry of the Environment and Ministry of Agriculture, Food and Rural Affairs, 1998.
[a] Acceptability of biosolids will be judged on the basis of the average concentrations of nitrogen, metals, and solids during the preceding 12 months.
[b] All dewatered and dried biosolids must meet the appropriate biosolids criteria before dewatering and drying.
[c] The long-term targets are based on the assumption that metal additions to soil from waste materials is undesirable and that application rates of metals should be reduced in the future.

Table 2-4 Ontario Criteria for Metal Content in Soils

Metal	Mean metal content in uncontaminated Ontario soils [a] (mg/kg)	Maximum permissible metal content in soils receiving waste materials [a] (mg/kg)	Maximum permissible metal addition to uncontaminated soil [b] (kg/ha)	Maximum permissible metal application per 5 years [c,d] (kg/ha)	Minimum time to reach max. recommended metal content in soil [b,c] (yr.)
Arsenic	7	14	14	1.4	50
Cadmium	0.8	1.6	1.6	0.27	30
Chromium	15	120	210	23.3	45
Cobalt	5	20	30	2.70	55
Copper	25	100	150	13.60	55
Lead	15	60	90	9.0	50
Mercury	0.1	0.5	0.8	0.09	45
Molybdenum	2	4	4	0.80	25
Nickel	16	32	32	3.56	45
Selenium	0.4	1.6	2.4	0.27	45
Zinc	55	220	330	33.0	50

Source: Ontario, Ministry of the Environment and Ministry of Agriculture, Food and Rural Affairs, 1998.

[a] Based on dry weight at 105oC.

[b] Columns 4 and 6 take into account the mean metal content of uncontaminated soil (column 2). These numbers are examples because most soils are unlikely to have exactly the mean metal contents listed in column 2.

[c] Based on anaerobic biosolid applications providing 135 kg/ha of ammonium plus nitrate nitrogen, or aerobic biosolid applications providing 8 t of dry solids per hectare per five years, as outlined in these guidelines. The number of years is rounded to the nearest five.

[d] Column 4 divided by column 6 will give the metal application for one year. To obtain the figures in column 5 the yearly metal application figures are multiplied by five.

surface watercourses, groundwater, wells and residences the site location, land and soil characteristics, and proposed site management methods are assessed.

A separate COA is required for storage of biosolids or other waste, which may be required during times when land application is not possible.

2.8 Enforcement and Violations of Certificates of Approval

A COA is a legally enforceable document. With information obtained from the MOE, the Sierra Legal Defence Fund has prepared a comprehensive report outlining violations of the COAs in the period 1996–1998.[42] The report notes that violations increased from just over 1,000 in 1996 to 2,234 in 1997 and more than 3,300 in 1998. The violations occurred in 167 facilities. The number of violations is not related to changes in monitoring or reporting. The number of prosecutions in 1997 and 1998 has not been released by the MOE. There was only one public prosecution known to the report compilers in 1998.

The majority of violations were for environmental parameters such as BOD_5, total suspended solids, nitrogen, or phosphorus; violations for toxicity, metals, and indicator bacteria were also recorded. At least 14 plants had more than 50 violations each in 1998.

3 Wastewater Utility Best Practices

3.1 Introduction

When reviewing best practices used to collect and treat wastewater, one must examine all the elements managed by a wastewater utility. These elements include the receiving water, the treatment process, the wastewater collection system, the services provided to the customers and community, and the environmental effect. Some have a more direct link than others to the discharge quality of the wastewater, but all affect the service provided to customers and the community.

Wastewater utilities perform many activities to meet the collection, treatment, and disposal needs of their customers. These activities depend on factors such as

[42] Sierra Legal Defence Fund, 2000, *Who's Watching Our Waters?* (Toronto: Sierra Legal Defence Fund).

seasonal climatic conditions in the community (e.g., Windsor versus Timmins), topography, customer expectations, and utilities management philosophy.

Best practices continuously evolve in response to ongoing changes in wastewater treatment technology, equipment, materials, communication methods, regulations, detection capabilities, etc. No single utility can provide the best practices in all of its operations. Rather, the best-practice utility has a complete, continuous improvement program to monitor, benchmark, and implement best practices.

A wastewater utility has four main operational functions:

- wastewater operations
- business operations
- organizational operations
- customer and government relations

Each of these functions is further broken down in the following sections to examine the best wastewater utility practices. The AWWA *QualServe Program Guidance Manual* is the primary reference.[43]

3.2 Wastewater Operations

Wastewater operations include all aspects of wastewater collection, wastewater treatment and maintenance of the wastewater facilities and associated equipment, the effluent discharge system, and wastewater quality management programs.

3.2.1 Wastewater Collection System

The best-in-class utility has a reliable wastewater collection system. Its capacity and its ability to deal with higher than normal flows (e.g., wet weather) should contribute to lower home and business insurance rates. The utility's senior management must understand the complexities of wastewater collection and transportation and the importance of investment in maintenance, repair, and retrofits. The least amount of disruption to the buried sewer infrastructure will

[43]American Water Works Association and Water Environmental Federation, 1998, *QualServe Program Guidance Manual,* parts 1, 2, and 3 (Denver: AWWA).

provide for a more reliable system. Rehabilitation, replacement, and maintenance of sewers or other wastewater appurtenances must be coordinated with other utilities. Coordination reduces inconvenience to residents from traffic diversions, and helps reduce costs. Up-to-date information on the collection system is important for appropriate and timely repairs. Most best-in-class utilities now have computerized geographic information systems, with location, depth, pipe material, and repair records of the wastewater collection system components directly available.

The flow and quality of wastewater in the collection system must be measured on an ongoing basis. The best-in-class utility will have continuous monitoring capability at pumping stations and critical areas throughout the system to identify problems such as excessive infiltration. Continuous monitoring will normally involve SCADA (Supervisory Control And Data Acquisition) systems. Specific wastewater parameters may also be monitored to ensure industry compliance with sewer-use bylaws. To gain understanding of flows and residual capacities, the utility must model wastewater collection systems, large and small alike. Modelling in turn makes possible better decision making for rehabilitation or replacement of sewers or updating of wastewater treatment processes.

A best-in-class utility will also have a program to identify and minimize the risk to public health of potential cross connections between wastewater and drinking water. Formal preventive maintenance programs will include visual and camera inspection, and sewer flushing. A best-in-class wastewater utility will have a formal sewer rehabilitation and replacement program. This program will be linked directly to a long-term capital and financial planning program to assure adequate funding. No-dig and trenchless technologies for rehabilitation of sewers are also common in best-in-class utilities.

A best-in-class utility will invest in computerized maintenance management systems and technologies to support its field maintenance operations. Bar code technology can make maintenance of pumps and other appurtenances used in the wastewater collection system more efficient, as data are downloaded at the end of the day from hand-held computers used by maintenance staff.

3.2.2 Wastewater Treatment and Maintenance

The treatment component of a wastewater operation has various aspects: a workforce, the treatment processes, operation of the facilities, and maintenance of the facilities and equipment. A utility must constantly strive to improve treatment plant operation and maintenance.

Human resource development programs for operators and maintenance personnel are key. A best-in-class utility will have a formal operator training program to help staff achieve certification. The utility will make certain its operators are properly trained on new equipment and new systems as they are selected and put into operation. Changes in treatment processes might be pilot-tested before implementing on a plant scale.

Senior management will understand the complexities of the treatment system and the importance of investment in maintenance, repair, and retrofits.

The wastewater treatment facility will have sufficient capacity to meet peak demands. Customers must have confidence that the treatment plant meets or exceeds all discharge quality standards and is able to meet all quality concerns. Compliance records must always be available to regulatory agencies and customers. A best-in-class wastewater utility will be able to find and correct problems before non-compliance issues arise. The operations of large and small facilities alike will be appropriately computerized and automated. Sufficient equipment redundancy must be available to ensure reliable operation at all times. Backup systems should be in place to avoid service interruptions during unplanned equipment outages.

A well-run treatment facility will routinely measure its performance. Instrumentation logs and charts and computerized equipment and systems should assist in attaining high effluent quality and efficient operation of the plant equipment. Depending on the size and complexity of the wastewater facility, either continuous monitoring or routine testing on a shift or daily basis must follow a formal program.

Maintenance of equipment must be carried out in accordance with appropriate preventive, predictive, and run-to-failure types of maintenance programs. A predictive maintenance program covers all major rotating equipment such as pumps, drives, motors, generators, and compressors. Preventive maintenance programs may operate on the basis of seasonal use, equipment run-time, weekly, monthly, quarterly or yearly periods, or quantity of flow pumped. Run-to-failure maintenance can include items not immediately critical to the operation, or that are backed up by redundant equipment. These are normally pieces of equipment that can be easily repaired or replaced from stock in inventory, and for which replacement at failure makes more economic sense than ongoing maintenance.

Most best-in-class utilities have computerized maintenance management systems that track maintenance activities and provide the utility with a variety of strategies to maintain the equipment. Such systems allow a utility to plan for suitable maintenance frequency and to monitor the effectiveness of its maintenance activities.

A best-in-class utility will also have a formal energy management plan – for both the treatment facilities and pumping stations within the collection system. Energy is one of the three main financial costs in wastewater treatment and disposal, along with labour and chemical supply. An aggressive program to reduce energy consumption will involve real-time control, monitoring of energy consumption, and periodic energy audits. Energy efficiency should also be a factor when selecting pumps, drive systems, lighting systems, aeration blowers, and other high energy users. A best-in-class utility will explore alternative energy efficiency methods, the most obvious being the use of digester gas for plant heating or cogeneration.

3.2.3 Water Discharge System

The plans of a best-in-class utility for protecting receiving water bodies are an integral part of local and regional watershed management. The utility must manage discharge rates and protect against potential contamination of the receiving water. To deal with potential contamination, it must have regularly updated contingency and emergency plans and a process to activate such plans when required. The utility must also develop discharge forecasts and plan development of receiving water to maintain quality.

The utility will cooperate with multi-jurisdictional watershed management bodies, including conservation authorities, neighbouring municipalities, private and public landowners, and any other entities that depend on the receiving water body for water supply or recreational use. Discussions with other authorities or entities must address land use and development within the discharge area. In communities where water resources are limited, re-use programs (for uses such as agricultural irrigation) are also gaining prominence as best practice.

3.2.4 Water Quality Management

Quality of treated wastewater is one of the most critical objectives for any wastewater system. Because regulatory agencies often change treated wastewater quality standards, a proactive utility will plan to exceed provincial and federal regulations. To stay abreast of emerging issues, wastewater utilities should create informal partnerships with regulators and industry associations. Relevant interest groups should be consulted if a substantial treatment process adjustment is required. Avoiding or reducing sewer bypasses to receiving streams during peak flow periods is accomplished by best-in-class utilities through good planning and properly designed and operated sewer systems.

A best-in-class utility will work in collaboration with the municipality to promote necessary bylaws and standards to control improper activities in the wastewater collection system, such as surface runoff connections and cross connections with the water system. Whether it has its own laboratory or uses a private laboratory for water quality analysis, the utility must ensure that laboratory practices meet industry standards and that staff are properly certified.

3.3 Business Operations

Business operations of a wastewater utility include

- strategic planning
- capital improvement programs
- engineering
- fiscal management
- facilities management
- information management systems
- purchasing and inventory management

3.3.1 Strategic Planning

Regardless of a utility's size, it must plan its business. It must answer the crucial questions that deal with its long-term future, mission, functions, capital programs, financial and human resources, performance improvement strategies, and customer service. The plan will deal with the most difficult issues facing the utility. Management and staff must support the plan and be able to articulate it clearly to customers. The plan will clearly define which groups or departments are responsible for which tasks. It will identify the resources necessary (people, money, etc.) to meet its goals, and it will anticipate changes in regulations. The plan should extend to social, economic, and environmental issues associated with future development across the region or community. The plan will consider treatment and collection facilities and the utility's customer base.

A best-in-class utility will also benchmark its business and strategic planning process with other wastewater utilities or similar types of industries. It will invite all relevant interest groups (customers, governing bodies, staff, etc.) to participate in the strategic planning process. Staff in turn should feel a sense of ownership for these long-range plans.

3.3.2 Capital Improvement Programs

To have a best-in-class capital improvement program, a utility must have a formal process to evaluate the condition of existing infrastructure and to determine its replacement and rehabilitation needs. The capital improvement program must account for the utility's regulatory compliance requirements. It must be able to prioritize capital spending by taking into account operational needs, the consequences of customer and business disruption, social costs, watershed pollution, and timing with other infrastructure projects.

A capital improvement program should be forecast well in advance (five to ten years) to ensure adequate funding and the opportunity for customers and other stakeholders to provide input for capital planning. The program must assess the cost effectiveness of new technologies. Best-in-class utilities will use value-engineering and other similar methods to confirm the cost effectiveness of complex capital improvement programs.

3.3.3 Engineering

All utilities, regardless of size, tend to use engineering consulting firms when it makes economic and operational sense. The process of identifying and selecting engineering consultants must be well documented. It is important that this process consistently result in the selection of well-qualified firms. Pre-approval of engineering consultants enables utilities to respond quickly to emergencies.

The utility must have the means to monitor costs and quality during the engineering and construction phases of a project. Larger utilities in particular should use computer-based project management systems.

3.3.4 Fiscal Management

Good financial management for wastewater utilities implies a true user-pay system. Billings may still be linked to water consumption, but the system should allow for rate surcharges where individual discharges or pollutant concentrations take a disproportionate share of system capacity. Regardless of the rate structure, full cost recovery must be the objective.

The best-in-class utility exhibits sound financial management, usually reflected in the ratings of bond-rating agencies and investment groups. The utility will have certified public accountants measure its financial performance on a quarterly or yearly basis and be subject to audit.

To ensure that its operating costs and capital works can be funded without interruption, a best-in-class utility will regularly review its rate structure, revenue generation projections, and capital requirements. It meets its financial obligations on time – payroll, debt service, contract payments, etc. – and is recognized as a professional organization.

A best-in-class utility will have an effective revenue collection system. For fiscal responsibility, publicly owned utilities ensure that their capital expenditures and operating expenses are managed separately from other departments, and that appropriate costs are assigned against activities shared at the municipal level. A best-in-class accounting system gives staff the measurable and objective information needed for decision making.

3.3.5 Facilities Management

'Facilities' refers to all infrastructure associated with the wastewater system, including treatment plants, pumping stations, and sewers. The utility must have current real estate maps, plot plans, engineering drawings, inventories, and information on all tangible assets. A best-in-class utility will use geographic information system (GIS) mapping technology to record and display data on its complete infrastructure. The system should be accessible to all staff. For property management purposes, GIS data must accurately document all utility properties, easements, rights of way, etc.

Measures must be taken to protect property from unauthorized entry or activity. Property management of the facilities must be kept up to date with an inventory of its plant, real property, rights-of-way, and easements.

As part of its strategic plan, the utility should have a formal process to identify future real estate requirements. The utility should also participate in local and regional land use planning to balance future property requirements with other legitimate uses.

3.3.6 Information Management Systems

Information management systems improve the quality and availability of information. Typically, they are computer based and include

- billings,
- rate structure,
- average and peak flow forecasts,
- collection system hydraulic modelling,
- influent and effluent quality,
- maintenance and repair development and scheduling,
- capital project management,
- project design,
- emergency management,
- payroll,
- records management,
- human resources information,
- finances,
- supervisory control and data acquisition (SCADA),
- a geographic information system (GIS),
- computerized maintenance management systems (treatment plant equipment and collection system),
- a laboratory information management system (LIMS),
- inventory and requisition/purchasing systems,
- a customer inquiries tracking system, and
- a Web site

Systems must be appropriate to the size and needs of the utility, with the single aim of improving efficiency. Communications capability between individual management systems is important for an efficiently run utility. For example, human resource, payroll, inventory, and preventive maintenance systems can be linked to provide relevant activity-based costing information.

Technical support is critical for computer-based management systems. Staff must have direct computer access for them to perform their job functions efficiently and to communicate effectively within the organization and with their customers.

3.3.7 Purchasing and Inventory Management

A best-in-class utility will solicit competitive bids for materials and equipment. The utility will authorize staff to make credit-card purchases for supply gaps or emergencies.

Warehouse inventory for spare parts and supplies should be minimized, based on supplier availability, delivery time, importance of the equipment, and redundancy in the system. Blanket orders with suppliers should be in place for consumables. A best-in-class utility will have a just-in-time chemical delivery system that minimizes the inventory of hazardous chemicals on site and saves on stocking costs.

Larger utilities will have warehouses or make use of suppliers' warehouses distributed throughout their geographic area to reduce delivery times for supplies. The purchasing and inventory information management system should be automated for ordering stock equipment and materials.

3.4 Organizational Operations

Organizational operations relate to human resources and corporate activities:

- leadership
- human resource management
- continuous improvement
- health and safety, and loss control management
- emergency planning and response

3.4.1 Leadership

Best practices in leadership begin with a mission statement that includes a strong commitment to high quality service and continuous improvement. Leadership involves communicating the mission statement and goals and objectives to staff, customers, governance groups, investors where applicable, and other stakeholders. The goals and objectives must be meaningful to staff who, in turn, should be able to articulate how they relate to their roles and responsibilities.

Managers and supervisors must recognize that communication with staff is an important requirement of their positions. Staff should be comfortable discussing work-related issues at all levels within the organization. They should be able to ask questions and make suggestions. They should be encouraged to offer input on operational matters and capital works programs.

Staff must work together to ensure that things get done correctly and on time. Team problem solving is a core competency of any best-practice utility. Every member must feel essential to the team. Management and peers must ensure that there are no barriers to innovation and creativity.

Management must ensure employee recognition and establish award programs that cover both individual and team environments. In larger utilities especially, it is important that senior staff be known by all employees and that they lead by example.

3.4.2 Human Resource Management

Training for all levels of staff is critical in any organization. The utility should offer formal programs toward professional certification. All training programs must be measured to ensure that they are meeting the needs of trainees. Various modes of training are available, including formal classroom exercises, self study, on-the-job experience, rotational assignments, technical certification, management and professional skill development programs, and active participation in professional, community, and industrial associations. Training must be encouraged and supported financially.

Good leadership means that managers participate in training and professional development. Individual training and education plans should be developed for each employee. Senior management must have an understanding of the distribution of skills in its current workforce and guide those skills to the future needs of the utility. A successful utility must plan for shortfalls resulting from retirements, new skill requirements, and changing credentials or education requirements.

Appropriate compensation for all levels of staff is important for a best-practice utility. Each staff member must receive regular annual written performance reviews. Staff should also have regular meetings with their direct supervisors. Performance reviews must address training and career development requirements. Staff should understand the process and criteria used for appraising their performance.

Recruiting and retaining staff at all levels is important. The best-practice utility is committed to equal opportunity and equal treatment of all employees regardless of age, sex, race, religion, or other workforce diversity factors. A fair and impartial posting process for job and promotional opportunities must meet the needs of all staff. Salaries and benefits must be equitable and comparable to those offered in similar work environments, but may be different from one community to another.

All staff will be able to understand the workplace policies and rules in a best-in-class utility. Policies and procedures must be reviewed periodically and updated as necessary. Staff must be informed and aware of the principles and application of laws and related rules governing safety, discrimination, sexual harassment, disabilities, and drug and alcohol screening.

Compliance with policies and rules requires leadership in their enforcement. Managers must discuss policies and work procedures regularly with labour representatives. Processes should be available for discussion of any labour relations issues with staff or their bargaining units. Management and the bargaining units should have strategies in place to form partnerships or teams to develop performance and quality improvements. Issues such as privatization and competition must be discussed candidly and constructively.

3.4.3 Continuous Improvement

Continuous improvement is a key best practice for all good utilities. A best-practice utility establishes realistic and formal long-range improvement goals for water quality, operational efficiencies, operational productivity, and so on. Communication – of how these goals are to be met and what benefits will accrue to the organization – is important for success.

A best-practice utility uses ongoing metric and process benchmarking. Internal metric benchmarking refers to reviews within the organization (e.g., comparisons of yearly maintenance costs for individual pieces of equipment). External benchmarking employs external comparisons (e.g., comparison of treatment costs with those of a comparable utility in another jurisdiction).

Process benchmarking follows priorities set by the organization, such as effluent quality parameters or the efficiency of sewer repair crews. It also involves inspecting other utilities or similar industrial operations that are known throughout the industry for their efficiency, safety record, high customer satisfaction, etc. A best-practice utility will have procedures for evaluating specific processes. Such procedures include determining requisite levels of staff, mapping the activity, overcoming bottlenecks and dealing with issues, and implementing team suggestions. Benchmarking results are reviewed to see if goals have been met. Process benchmarking by a best-practice utility is an ongoing activity.

Ongoing improvement programs of a best-in-class utility promote a work environment conducive to change. They empower staff to make improvement-related decisions. They do require, however, employee training in quality management and continuous improvement practices. Management must allocate resources – training, money, time, staff skills, etc. – to allow staff to achieve their improvement goals.

3.4.4 Health and Safety and Loss-Control Management

Each utility must have a formal health and safety program that includes training, guidance documents, and prominently posted operational procedures. Health and safety must be a high priority and part of everyday work practices and procedures. A best-in-class health and safety program monitors safety on the job, investigates all accidents and near misses, and reviews findings to determine whether staff have been properly instructed and trained. The program includes a complete loss-control program that considers health and safety issues and those arising from environmental codes. Staff should know where to find information they need when concerned about safety.

A best-practice utility also has special programs to manage short-term disabilities of personnel and to provide assistance and physical therapy for staff injured in the workplace.

Staff must be properly trained and reminded continuously of policies and procedures for entering confined spaces. The utility will have in place policies and procedures for electrical and mechanical maintenance activities, including lockout and tagging. Staff must also be trained in the use and handling of process chemicals.

Trench safety is also key to any best-practice utility. Staff must be aware of the Ontario Ministry of Labour's industrial and construction regulations.

3.4.5 Emergency Planning and Response

A best-practice utility will have formal documented emergency preparedness procedures, and staff who are trained in their application. The training will be coordinated with the local emergency response network (fire, police, ambulance, etc.). All staff must understand their roles in any emergency situation.

Emergency response plans take into account equipment breakdowns, accidents, natural disasters, catastrophes, and any other circumstance that could disrupt normal utility operations. Specific measures must be taken to contain spills of hazardous materials. Coordination with emergency response agencies requires formal documented mutual-aid procedures. Formal corrective action plans should be developed following an emergency to prevent or minimize the probability of a reoccurrence.

3.5 Customer and Government Relations

3.5.1 Government Relations

A best-practice utility will maintain regular contact with local, provincial, and federal government departments and agencies, as well as other entities involved in linear municipal infrastructure, such as gas and telecommunications companies. Good relationships lead to good coordination within easements and road allowances.

The utility should also hold regular meetings with the local health authorities to discuss such matters as biosolids disposal and receiving-water quality and recreational use. The utility must build good working relationships with local regulators and other provincial jurisdictions. Best-in-class utilities will be aware of emerging issues through involvement with industry organizations such as the CWWA (Canadian Water and Wastewater Association), the WEF (Water Environment Federation), and the WEAO (Water Environment Association of Ontario).

The utility should voice its opinion during the development of regulations, local ordinances, and bylaws. It should attempt to participate formally in rule making – or have industry organizations participate – to make clear its concerns, and those of its customers. The utility must also have a formal process for incorporating new rules and regulatory requirements that are then turned into policies, procedures, and daily operating practices.

3.5.2 Community Relations

Community relations programs should suit the size of the utility and the community it serves. A best-in-class utility will have formal programs to respond to potential issues of odour, noise, safety, traffic, and recreational use of receiving waters. It should publish annual reports on all aspects of its operations. The utility should make community education programs available to all interested parties, and it should work directly with the local school board on programs for students.

The utility must inform the public about specific issues such as the risks associated with the recreational use of receiving waters or the application of biosolids to agricultural lands.

The utility could promote formal community advisory groups as a means to disseminate information and gain understanding of local community issues. It should also be prepared to respond to media calls to interview staff on specific health or community concerns.

3.5.3 Business Relations

The utility must inform business owners of scheduled infrastructure repairs that might affect their operations. It should have formal procedures to give affected businesses enough time to take whatever measures necessary to minimize interruption.

A best-in-class utility will work with the community and business leaders to attract development through the promotion of an extensive and reliable sewer system. An advisory group could help guide the utility in its communication with the business community.

3.5.4 Customer Service

Customer service must be part of a utility's mission statement, and management must communicate its importance to staff. Communications to staff must include all aspects of positive and negative responses from customers. Positive responses from customers should be published within the organization so that staff can share in customer appreciation.

Utility personnel must develop the mindset that serving customers is everyone's responsibility. Every employee must be provided with customer service guidelines covering everything from telephone etiquette to field repairs and response times, from general information about the wastewater services provided to appropriate customer follow-up procedures. Staff should be encouraged to recommend improvements in customer service guidelines. Staff should have a broad knowledge of utility operations and know where to refer customers for specific information.

Field customer personnel must be courteous and appear professional. A best-in-class utility will use customer satisfaction surveys and complaint follow-ups. Follow-up should be part of a service personnel work-order system that in turn should be linked to a quality assurance system. The quality assurance system should verify that work orders have been properly closed and that customer inquires have been taken care of. A follow-up call or written correspondence to customers can ensure satisfaction.

A proactive utility will have a customer call centre with one number. Call-centre staff should be able to answer most customer inquiries about such things as billings, effluent compliance data, sewer lateral service, and construction schedules. Customer service representatives should be briefed on any extraordinary or visible works. Larger utilities may have different service representatives for residential and commercial or industrial customers.

Response to complaints or inquiries might require site investigations. Field personnel must be dispatched as quickly as possible. Field staff must also notify customers of scheduled repairs, replacements, and rehabilitation work in the area. They must be equipped to assist customers affected by repairs.

3.6 Accreditation and Certification

Accreditation means that the utility has been officially recognized as meeting specific criteria established by a recognized standards organization.

3.6.1 ISO (International Organization for Standardization)

Information on ISO programs can be found from a wide number of sources including *The ISO 14000 Essentials* by the Canadian Standards Organization[44] and *ISO 14001 Guidance Manual,* published by the National Centre for Environmental Decision-making Research.[45]

The objective of ISO is to promote development of world standards to facilitate international exchange of goods and services. There are a number of ISO series, the most common in the wastewater industry being the 9000 and 14000 series. The ISO 9000 series focuses primarily on quality management system standards and deals with customer needs. The ISO 14000 series focuses on environmental management system standards and deals with the needs of a broad range of interested parties and the evolving needs of society for environmental protection.

ISO 14001 shares common management system principles with the 9000 series but does not include requirements for occupational health and safety management. As such, certification to ISO 14001 standards applies only to environmental management systems.

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[44] Canadian Standards Association, 1996, *The ISO 14000 Essentials: A Practical Guide to Implementing the ISO 14000 Standards* (Etobicoke, Ont.: CSA).
[45] R. Martin, 1998, *ISO 14001 Guidance Manual* [online], technical report NCEDR/98-06 (prepared for the National Centre for Environmental Decision-making Research) [cited July 2001], <www.ncedf.org/pdf/ISO14001.pdf>.

ISO 14001

Best-in-class wastewater utilities aim to control the effect their activities, products, and services may have on the environment, taking into account their corporate environmental policies and objectives. To ensure that it meets its legal and policy requirements, a utility will undertake reviews or audits. To be effective, audits must be conducted within a structured management system and integrated with overall management activities. The success of ISO standards depends on the commitment from all levels within the organization.

ISO 14001 does not establish absolute requirements for environmental performance; two utilities carrying out similar activities but having different environmental policies may both comply with ISO 14001. As a result, the adoption of ISO 14001 does not in itself guarantee optimal environmental performance.

Where appropriate and economically feasible, environmental systems for a best-in-class utility should encourage implementation of best available technologies.

Compliance with ISO 14001 is determined by a registrar or auditor with evidence that procedures have been established, maintained through periodic reviews, and revised as necessary. It is the utility's responsibility, not the auditor's, to determine the effectiveness of the procedures.

ISO 14001 is a good tool for utilities to monitor environmental performance using a structured and recognized process. Certification to ISO 14001 standards does not automatically qualify a utility for recognition as best in class, but the designation is viewed as good practice.

3.6.2 Laboratory Accreditation

The Standards Council of Canada (SCC) was established in 1970 by parliament under the *Standards Council of Canada Act* to promote voluntary standardization in Canada that would facilitate domestic and international trade and further international cooperation. The SCC represents Canada in international standards organizations such as the ISO and the International Laboratory Accreditation Co-operation (ILAC).

In 1994 the SCC and the Canadian Association for Environmental Analytical Laboratories (CAEAL) entered into an accreditation partnership agreement for the accreditation of Canadian environmental testing laboratories. Under the terms of the agreement, CAEAL, a not-for-profit association, carries out assessments and operates the proficiency-testing program, which targets high-volume testing in the major disciplines of inorganic chemistry, organic chemistry, toxicology, occupational health, and microbiology. Accreditation is therefore based on satisfactory participation in an assessment program plus satisfactory participation in proficiency testing. The program is recognized internationally by ISO. It provides formal recognition of the competence of a laboratory to manage and perform the specific tests or types of tests listed on its accreditation certificate.

The Canadian accreditation program (CAN-P-4D) was revised in 1999 to meet the latest ISO/IEC 17025 requirement. Today there is a trend for both government and private-sector contracting policies to specify laboratory accreditation. Since August 2000 all Ontario laboratories performing analyses on municipal water and wastewater samples have had to be accredited by CAEAL/SCC.

Most Ontario utilities are too small to justify the investment required to build and operate an accredited testing laboratory, and choose to contract with private laboratories. Some of the larger utilities, however, operate their own laboratories.

Section 4.1.4 of CAN-P-4D, the official Canadian accreditation protocol, states:

> If the laboratory is part of an organization performing activities other than testing and/or calibration, the responsibilities of key personnel in the organization that have an involvement or influence on the testing and/or calibration activities of the laboratory shall be defined in order to identify potential conflicts of interest.[46]

Section 4.1.4, note 1, goes on to say:

> Where a laboratory is part of a larger organization, the organizational arrangements should be such that departments having conflicts of

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[46] International Organization for Standardization/International Electrotechnical Commission, 1999, *General Requirements for the Competence of Testing and Calibration laboratories,* ISO/IEC 17025 (n.p.: IHS Inc.). This document is equivalent to the Canadian Procedural Document CAN-P-4D, which is no longer available at no charge from the Canadian Standards Council. ISO/IEC 17025 can be purchased on line from IHS, Inc. on its Global Engineering Documents Web site [cited December 2001], <http://global.ihs.com>.

interest, such as production, commercial marketing or finance do not adversely influence the laboratory's compliance with requirements of this International Standard.

This section is of particular interest to municipal laboratories.

3.7 Partnerships and Professional Associations

Best-in-class utilities form partnerships to handle specific issues and reduce costs while allowing the knowledge gained to be disseminated to all participants. Leveraging financial support for research projects, for example, is often accomplished through partnerships. The knowledge gained as a result contributes to a utility's continuous improvement. Partnerships take various forms and can include local, provincial, and federal agencies and private industry.

In the wastewater industry, being a member of various associations provides the participants with access to a range of information and expertise. Most regulators, municipal wastewater utilities, private wastewater utilities, consultants, suppliers, and academia hold memberships in some of the key wastewater associations. They include the WEF (Water Environment Federation), the CWWA (Canadian Water and Wastewater Association), the OMWA (Ontario Municipal Water Association), and the WEAO (Water Environment Association of Ontario).

4 Wastewater Treatment Technologies

4.1 Why We Treat Wastewater

The move to wastewater collection and disposal was originally driven by negative public reaction to the sight and smell of untreated sewage. Lakes and rivers were used to dilute and carry the waste stream away. Early forms of treatment beyond dilution were aimed at removing floating solids, primarily on aesthetic grounds. As links between untreated waste and disease were demonstrated, more responsible methods of wastewater disposal were adopted in an effort to increase the separation distance between wastewater and drinking water. Dilution, however, remained the primary form of treatment for reducing the concentrations of infectious bacteria entering drinking water supplies.

Chlorine was first used to disinfect drinking water at the beginning of the twentieth century. Its effectiveness, however, was limited to reasonably good quality raw water in which concentrations of pathogenic organisms were relatively low. As urban populations grew, improved wastewater treatment practices were required to maintain the quality of receiving waters. Dilution alone was not sufficient.

Urban wastewater collection systems were not the sole source of pollution. In recognition that good wastewater treatment practices alone would not ensure the safety of drinking water supplies, drinking water treatment technologies were progressively developed. This did not lessen any responsibility for achieving high effluent discharge qualities, but in terms of public health, emphasis moved more toward the potential for contracting disease through recreational water use. And aesthetic quality objectives remained a strong driving force behind good wastewater practices.

Having the technology to achieve high quality effluent, Ontario, along with much of the developed world, recognized that human beings were not the only claimants to a clean environment. In 1970 the Ontario Water Resources Commission (OWRC) published *Guidelines and Criteria for Water Quality Management in Ontario*,[47] which was subsequently incorporated in 1978 (revised in 1984) into the Ministry of the Environment (MOE) 'blue book' entitled *Water Management Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment.*[48]

In Ontario most wastewater re-enters the environment through direct discharge to surface water (lakes and rivers). The blue book states very clearly and simply the MOE goal for water quality: "To ensure that the surface waters of the Province are of a quality which is satisfactory for aquatic life and recreation." The logic is that if this goal is achieved, there should be little or no concern about using the same water for other beneficial purposes, including drinking water.

[47] Ontario Water Resources Commission, 1970, *Guidelines and Criteria for Water Quality Management in Ontario* (Toronto: OWRC).

[48] Ontario, Ministry of Environment and Energy, 1984, *Water Management Goals, Policies, Objectives and Implementation Procedures of Ministry of the Environment* (Toronto: Queen's Printer for Ontario). This document was subsequently updated in 1994, but maintains the original policy directions: see Ontario, Ministry of Environment and Energy, 1994 (this electronic version of *Water Management: Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy* is the 1999 reprinted version, which includes corrections to October 1998).

The MOE makes a significant distinction between the management of surface- and groundwater quality. The goal itself is simply stated: "To protect the quality of groundwater for the greatest number of beneficial uses." And the blue book makes the point that human consumption will be the most important of these uses. The preamble, however, in alluding to the complexity and cost of restoring groundwater quality, states that "current evaluation techniques are not sufficiently advanced to adequately determine … what waste loadings are allowed [to] meet water quality criteria at points down gradient."

The inference is that groundwater may be considered water suitable for consumption without further treatment. Protection of groundwater quality depends on a combination of dilution and natural decay processes that, as discussed previously, represent the most basic form of treatment for surface water supplies. The simplest example of how this groundwater goal is translated into regulation is in the design of septic tank tile fields and their required separation from private wells.

In Ontario there are few, if any, municipal examples of land-based wastewater disposal systems in which a level of treatment has been imposed through the MOE approval process based solely and specifically on the need to protect groundwater. The problem of groundwater contamination is typically associated with smaller rural communities that rely on private or communal wells and septic tanks. Increased water use and development tends to push the limits of dilution as an acceptable means of protecting their drinking water, recognizing in the MOE's own words the inadequacy of current evaluation techniques.

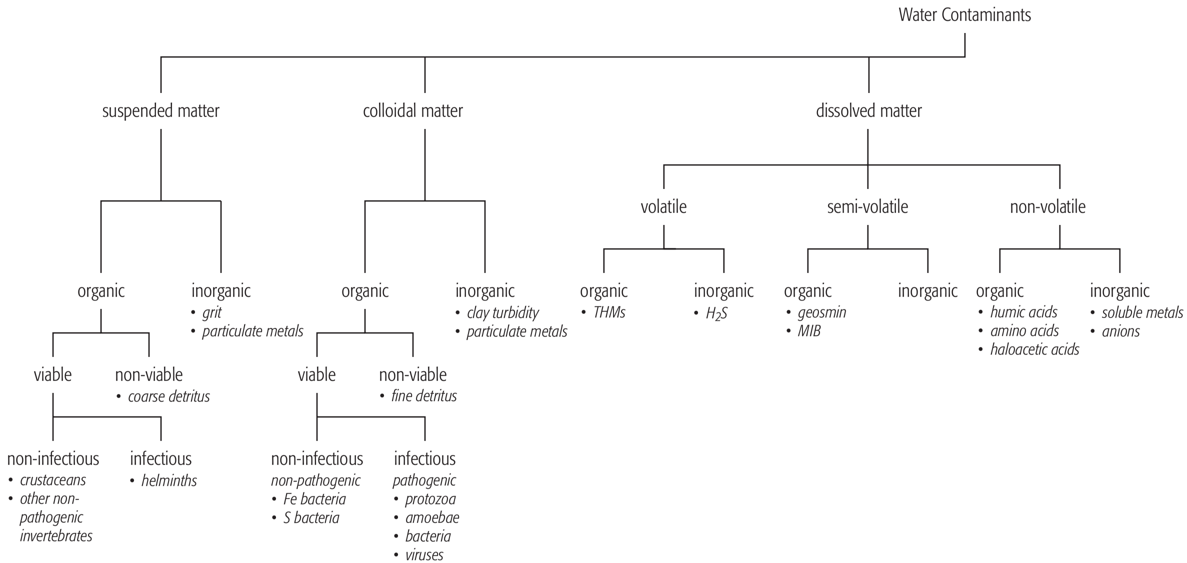
Other potential sources of groundwater pollution include untreated agricultural waste (see section 1.8), and the land application of municipal biosolids for which treatment and disposal practices are regulated.

4.2 Wastewater Treatment Concepts

4.2.1 Wastewater Contaminants

Wastewater contaminants are categorized as suspended, colloidal, and dissolved (see figure 4-1). Within each stream, material can be either organic or inorganic. Biodegradable organic matter consumes oxygen and nutrients in complex biochemical reactions until rendered inert. The process begins in the water stream that carries domestic wastes through the collection system to the

Figure 4-1 Classification of Water Contaminants



Source: S.E. Hrudey, 1999, *Water Quality Parameter Summary*, prepared for the Cooperative Research Centre for Water Quality and Treatment (Adelaide, Australia: CRCWQT).

treatment plant or point of discharge. If discharged without treatment, the waste stream continues to consume dissolved oxygen from the receiving water, thus exerting a biochemical oxygen demand (BOD), which is one of the fundamental parameters used to regulate effluent quality.

Without oxygen, aquatic life cannot survive; hence the need to satisfy BOD before the waste stream is discharged to the receiving water.

As oxygen concentrations fall to zero, a condition that often occurs in long sewer systems, the resulting chemical environment tends to reduce sulphates to sulphides. Hydrogen sulphide – the usual source of odour complaints commonly associated with wastewater plant operation – is often one of these resultant compounds.

Inorganic matter includes both inert and oxidizable materials. Removing it from the waste stream before discharge is warranted both on aesthetic grounds and because its encapsulation of bacteria hinders disinfection. Removal of inorganics, together with degraded organics, is regulated through the measurement of suspended solids (SS). Bacterial quality is usually regulated through limits for *E. coli* and fecal and total coliforms.

In Ontario and many other jurisdictions, especially where effluent discharges to inland surface water, phosphorus is specifically targeted for removal. Phosphorus (P) is a nutrient that promotes the growth of aquatic vegetation, or algae. High nutrient concentrations promote high microbiological activity, in which case the receiving water is deemed eutrophic. These conditions tend to deplete oxygen to a point where chemical reducing processes can render the water body unsuitable for use as a source for drinking water. Washing detergents were once a major source of phosphorus (in the form of phosphates), but this source has been eliminated through regulation. Phosphorus in wastewater from other sources, however, continues to be a significant contributor to the total loading on receiving water.

Nitrogen (N) also promotes the growth of aquatic vegetation. It is present in wastewater in both organic and ammonium forms that are usually combined for reporting purposes as Total Kjeldahl Nitrogen (TKN). The ammonia (NH_3) form is toxic to fish life and is often regulated through specific requirements for a non-toxic effluent with limits on TKN.

In summary, the primary contaminants targeted in municipal wastewater treatment plants are biochemical oxygen demand (BOD), total suspended solids

(TSS), total phosphorus (TP), total nitrogen (TKN), and bacteria as *E. coli* and fecal and total coliforms. The treatment processes used to reduce concentrations of these contaminants are also able to deal with many of the compounds generated by industry. However, hazardous and industrial contaminants are primarily regulated by sewer-use bylaws enacted by individual municipalities. The bylaws place limits on compounds and their discharge concentrations based on the ability of treatment plants to deal with the waste. In many cases industry is required to pre-treat its waste stream.

The composition of domestic wastewater varies widely. The values in table 4-1, however, are typical for domestic wastewater, assuming minimal infiltration of groundwater or wet-weather surface water.

4.2.2 Wastewater Treatment Processes

Unit processes used in wastewater treatment can be categorized as either reactors or separators, which in turn are either passive or active. Reactors oxidize, reduce, solubilize, immobilize, or physically condition their contents and create gaseous products. Separators create two product streams, one of high concentration and one of low concentration. These are not necessarily precise or exclusive definitions because reactions are known to occur in separators and separation can occur in reactors. In general, however, this is a convenient way of characterizing unit processes.

Table 4-1 Domestic Wastewater Characteristics

Contaminant	**Influent concentration (mg/L)**
Total suspended solids (TSS)	200
5-day biochemical oxygen demand (BOD_5)	170
Total Kjeldahl Nitrogen (TKN)	30
Total phosphorus (TP)	7
Pathogenic organisms	(number per mL)
Total coliforms (TC)	10^5–10^6
Fecal coliforms (FC)	10^4–10^5
Enteric viruses	10–100

Source: Ontario, Ministry of the Environment, [1984], *Design Guidelines for the Design of Water Treatment Plants and Sewage Treatment Plants* (manual) ([Toronto: MOE]); Metcalf and Eddy Inc., 1991, *Wastewater Engineering, Treatment, Disposal, and Reuse*, 3rd ed. (New York: McGraw-Hill).

Reactors and separators are combined in various configurations to form treatment plants that can be classified generally as primary, secondary, or tertiary. The terms reflect the progressive improvement in effluent quality that can be achieved as the process train increases in complexity. Although there are no absolute delineations between the three levels, it is generally accepted that primary plants rely on separation alone, secondary plants include reactors, and tertiary plants add another level of solids separation.

Unit process efficiencies are usually ranked in terms of 'percent removal.' Effluent limits, however, are usually defined in terms of 'concentration with an allowable time-based mass loading' (e.g., TSS of 15 mg/L and a maximum of 300 kg/d). In general, well-designed plants can tolerate normal variations in influent quality without any deterioration in effluent quality. While it is difficult to generalize, table 4-2 shows typical effluent limits for primary, secondary, and tertiary plants.

Well-designed and -operated plants will, in many instances, achieve higher effluent qualities. Also, as discussed in section 4.4, secondary plants designed for nitrification (nitrogen conversion) and phosphorus removal will achieve effluent qualities for these two contaminants more in line with the limits typical for tertiary plants.

One other important treatment concept is the mixing zone at the point of discharge where the effluent stream enters the receiving water. A mixing zone can be defined as a passive form of treatment by dilution. The MOE definition highlights the difficulties in dealing with the subject, especially in cases where by most measures a lake or river could be considered pristine: a mixing zone is "an area of water contiguous to a point source … where the water quality does not comply with one or more of the provincial water quality objectives." Terms and conditions are established on a case-by-case basis. The MOE states that a mixing zone is "under

Table 4-2 Typical Effluent Quality for Different Levels of Treatment (mg/L)

Parameter	Level of treatment		
	Primary	Secondary	Tertiary
Total suspended solids (TSS)	110	15	5
5-day biochemical oxygen demand (BOD_5)	70	15	10
Total Kjeldahl Nitrogen (TKN)	25	20	5
Total phosphorus (TP)	5	3.5	0.3

no circumstances to be used as an alternative to reasonable and practical treatment. It must be designed to be as small as possible."[49] The language implies a level of uncertainty as to what will constitute an acceptable level of treatment. In situations where a 10:1 dilution ratio is readily achievable, good outfall engineering design coupled with an assessment of its effect on localized aquatic fauna is usually sufficient to gain approval. Where the operator cannot ensure such ratios, complex modelling of assimilative capacity may be required, together with agreement by MOE staff that good engineering practice is being adopted in satisfying the requirement that the mixing zone be minimized to the greatest possible degree.

4.3 Primary Treatment

Primary treatment, typically limited to the use of separators, represents the most basic level of treatment acceptable for municipal plants in Ontario. It is unlikely that a certificate of approval would be issued by the MOE today for a new primary plant. Although several primary plants exist throughout the province, most of them face regulatory pressure to optimize their performance and progressively move toward secondary treatment.

Figure 4-2 illustrates a typical primary process train.

In all cases the unit process can be configured as either passive or active; the design decision will depend to some degree on the size of the treatment plant. *Passive* implies a manual batch approach to solids removal and *active* implies mechanical means – normally automated.

Screening removes rags and larger floatables. The key design parameter is bar spacing, for which the clear openings have been progressively reduced in the past two decades from 25 mm to 12 mm. For some emerging tertiary technologies, bar spacing of less than 6 mm has been advocated. The trade-off as spacing is reduced is an increase in the volume of organics removed, along with their potential for odour generation.

Grit removal is designed primarily to remove larger settleable inorganics to reduce abrasive wear on mechanical systems downstream. Grit enters the sewer system mainly through infiltration at pipe joints and access covers. Finely ground materials from kitchen waste disposal units also contribute grit. Many of Ontario's older

[49] Ontario, Ministry of Environment and Energy, 1994, sec. 3.4.

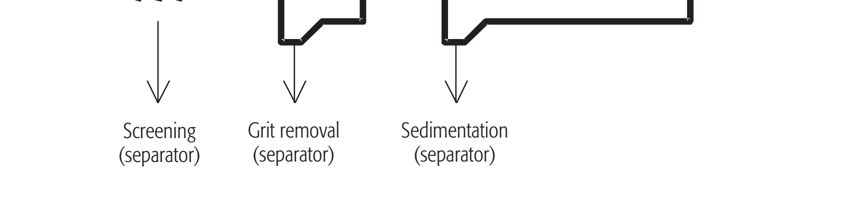
sewer systems are designed for combined wastewater and surface runoff during wet weather. Sanding of roads during winter compounds the problem of grit.

Primary sedimentation removes solids and organics. For large plants in particular, removal of approximately 65% and 35% for TSS and BOD, respectively, reduces energy requirements significantly in downstream secondary aerobic processes. In cases where influent wastewater contamination is low due to infiltration, arguments can be made for primary treatment alone based on removals of this magnitude. This suggests, however, that in-sewer dilution is being used as a unit process, a situation longer acceptable in Ontario for new plants; it is regulated by placing mass loading limits together with allowable contaminant concentrations in certificates of approval.

Enhanced, or coagulant-assisted, primary treatment (classified as physical-chemical treatment) is used to achieve higher removal efficiencies of approximately 85% and 65% for TSS and BOD, respectively. Chemical reactions produce settleable chemical solids that agglomerate to form larger particles, which in turn attract contaminant solids and settle to the floor of the primary sedimentation tank. This tank therefore operates as both separator and reactor. Metal salts, typically aluminum sulphate or ferric chloride, are the most common chemicals used. Coagulant addition is generally an interim step toward secondary treatment for existing plants and for phosphorus removal in new plants. Figure 4-3 shows a typical enhanced or coagulant-assisted primary process train.

Solids removed during primary treatment require further treatment before ultimate disposal. Although primary unit processes 'wash' the solids to some degree, degradable organics responsible for generating odours tend to be removed together with non-degradable separated solids. Their treatment and ultimate disposal is discussed in section 4.7.

Figure 4-2 Primary Treatment



4.4 Secondary Treatment

4.4.1 General Process Classifications

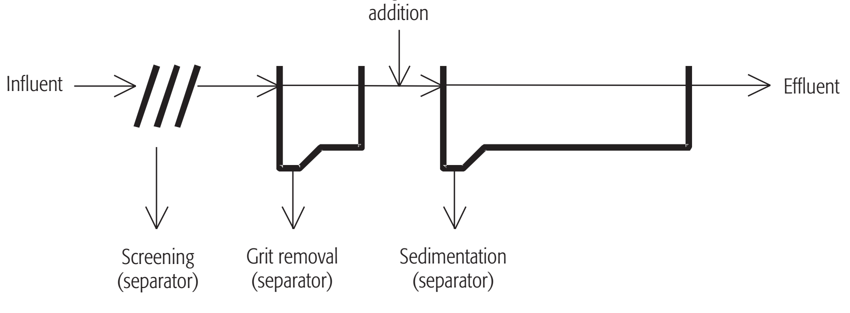
Secondary treatment typically involves separators and reactors that can be either active or passive. Visually, secondary plants can be readily classified as lagoon-based or mechanical, although the distinction is not necessarily precise or exclusive. However, the fact that a plant is lagoon-based or mechanical does not necessarily mean it is actually a secondary plant. Secondary treatment can be further divided into aerobic and anaerobic processes. This classification defines the type of organism developed in the reactor: organisms that thrive in the presence of oxygen (aerobic) or a lack of oxygen (anaerobic).

A further classification can be made in the reactor portion of secondary plants. The biomass (the organisms that are contained within the reactor) can be either suspended by mixing or supported by attachment to an inert medium. Green slime attached to stones in a riverbed is a natural example of a supported biomass. Reactors can also be configured as a hybrid in which supported-growth structures are mounted in a suspended-growth tank.

4.4.2 Anaerobic Reactors

Septic tanks are an example of anaerobic secondary treatment. On a larger scale, anaerobic plants are more commonly used for higher-strength industrial organic waste streams. Compared with mechanical aerobic processes, their energy requirements are small. The off-gas from an anaerobic reactor is predominantly methane, which can be used to offset energy requirements. Anaerobic processes have limited ability, however, to achieve effluent qualities equal to those of aerobic

Figure 4-3 Enhanced Primary Treatment



processes and, as such, are more commonly associated with pre-treatment to reduce TSS and BOD before discharge to a sewer system or conventional aerobic plant.

Anaerobic treatment can be configured as a suspended- or supported-growth facility. Figure 4-4 shows a typical suspended growth process train that includes reactor mixing to suspend the biomass.

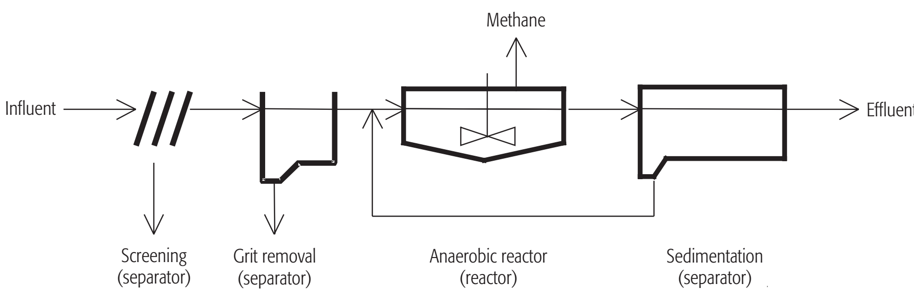
4.4.3 Waste Stabilization Lagoons

In Ontario the vast majority of municipal secondary plants can be classified as aerobic, either mechanical or lagoon-based. Mechanical plants can be suspended-growth, fixed-film, or hybrid. Lagoons fall more into the aerobic-suspended-growth category, though the definition is imprecise. Lagoons predominate in smaller communities where land is available and relatively inexpensive.

Although lagoons are classified as secondary treatment facilities, effluent qualities are unlikely to match those of mechanical plants, typically TSS of 30 mg/L versus 15 mg/L and BOD of 25 mg/L versus 15 mg/L. The generally passive approach to solids removal, a characteristic of lagoons, can ultimately erode performance. For these reasons the MOE has progressively applied higher effluent standards for new plants in the province, effectively excluding the use of conventional lagoons. Using the approval process, the MOE has also made existing lagoon upgrades a prerequisite for growth-related sewer system expansion.

Despite the trend in Ontario, lagoons remain a technically sound form of treatment in many jurisdictions. Although numerous terms are used to describe lagoon-based treatment, there are fundamentally two types of lagoons: aerobic and facultative.

Figure 4-4 Anaerobic Treatment



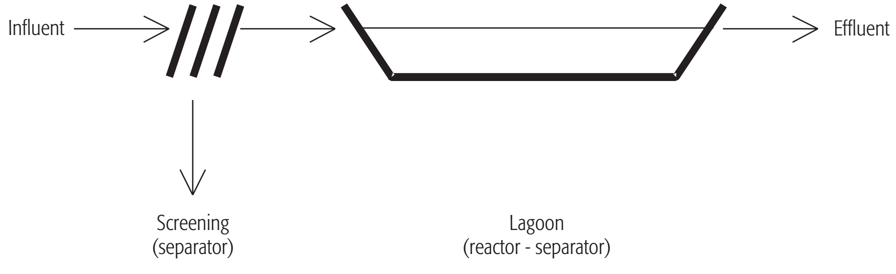
Aerobic lagoons, or oxidation ponds, are shallow, typically less than 1.8 m deep, and rely on oxygen transfer between air and the water surface, as well as photosynthetic oxygen generation by algae, to promote the growth of aerobic bacteria that degrade or metabolize influent organics.

Facultative lagoons are deeper, comprising an upper aerobic zone and a lower anaerobic zone. Waste stabilization is accomplished by a combination of aerobic and anaerobic bacteria and by facultative bacteria that thrive under both aerobic and anaerobic conditions. Settleable solids are stored in the lower anaerobic zone, where they are anaerobically reduced to inert solids.

Lagoons can be configured in many ways. Multiple cells – used to control hydraulic retention and provide effluent polishing – also provide flexibility for maintenance. From a treatment perspective, however, the process train is very simple (see figure 4-5).

Lagoons can also be designed as active treatment facilities. Aerated lagoons use mechanical systems to supply oxygen rather than rely on air-water interface transfers and photosynthesis. The advantages are that the distribution of the aerobic biomass can be controlled and the surface area of the lagoons reduced due to the increase in oxygen transfer efficiency. The lagoons are deeper, typically 3 m or more, and can still be categorized as facultative as long as the aeration system does not disturb the lower zone where solids are stored and anaerobically reduced. Passive polishing lagoons are required to achieve a reasonable quality of secondary effluent. Figure 4-6 shows a typical process train.

Figure 4-5 Aerobic or Facultative Lagoon



4.4.4 Activated Sludge

The activated sludge process is the most common form of secondary treatment in Ontario. Developed in the early 1900s, the process remains both a viable option today and one of the basic building blocks for tertiary plants and emerging technologies.

The process involves an aerated and mixed reactor, or aeration tank, followed by a sedimentation tank, or clarifier. Sludge from the clarifier is returned to the inlet of the aeration tank to maintain the aerobic biomass at a concentration designed to promote the growth of an optimal microbial population of heterotrophic and autotrophic organisms, organisms that require organic and inorganic compounds, respectively, for metabolic synthesis. An optimal biomass is one in which the particles agglomerate such that they readily settle in the secondary sedimentation tank or clarifier. A typical activated sludge process train is shown in figure 4-7.

Activated sludge plants are aerobic and almost exclusively active, or mechanical. They afford tighter process control and are more compact than lagoon-based treatment facilities. Many of the older plants in Ontario are designed only for carbonaceous oxidation or BOD removal. In practical terms this means that

Figure 4-6 Aerated Lagoon

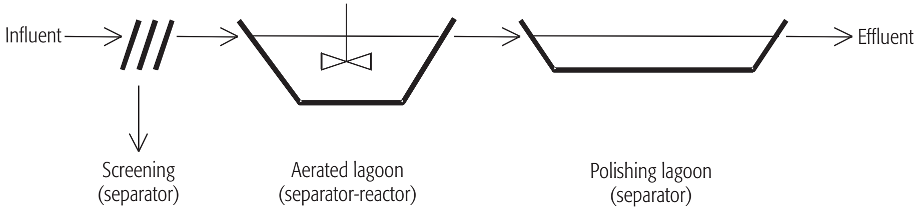
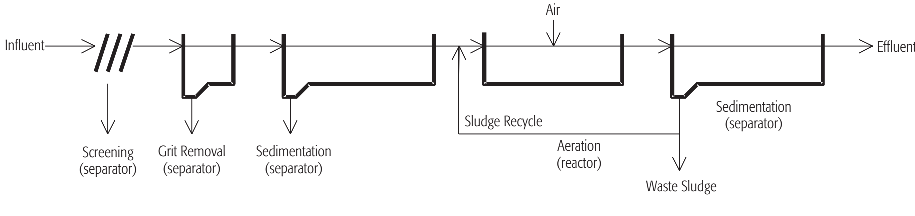


Figure 4-7 Activated Sludge



the air supply system is sized on the basis of 1.0 to 1.5 kg of oxygen for each kilogram of influent BOD fed to the aeration tank. Other related design parameters include the volume of the aeration tank, its corresponding hydraulic retention time, sludge recycle rate, average solids retention time before wasting (SRT), the concentration of the suspended biomass, and the ratio of the oxidizable fraction in the aeration tank influent to the biomass or mixed liquor concentration (referred to as the food-to-micro-organism (F:M) ratio).

Different names describe activated sludge plants depending on their configuration and design parameters. Conventional activated sludge describes the majority of the larger plants in Ontario, and extended aeration describes most of the smaller plants. The most obvious distinction between the two, especially for municipal plants, is that extended aeration rarely involves primary sedimentation. Although there is no precise delineation between conventional and extended aeration, table 4-3 indicates a range of commonly applied design parameters.

Other types of activated sludge plant are defined by differences in both design parameters and configuration:

- high-rate activated sludge (categorized by shorter hydraulic retention times and a greater need for tight process control)
- contact stabilization (again categorized by short hydraulic retention times)
- oxidation ditch (essentially an extended aeration plant in which mixed liquor is pumped around an oval-shaped tank by mechanical aerators located at one or more points around the circuit)

Table 4-3 Conventional Activated Sludge and Extended Aeration Design Parameters

Design parameter		Conventional activated sludge	Extended aeration
Plant rating (m^3/d)	Q	>5,000	<10,000
Hydraulic retention (h)	HRT	4–8	18–36
Oxygen applied (kg O_2/kg BOD)		1.0	1.5
Food-to-micro-organism ratio	F:M	0.2–0.4	0.05–0.15
Mixed-liquor concentration (mg/L)	MLSS	1,500–3,000	4,000–10,000
Sludge age (d)	SRT	5–15	20–30

- sequencing batch reactor (typically a two-cell tank in which each cell is alternately aerated, allowed to settle, and decanted)

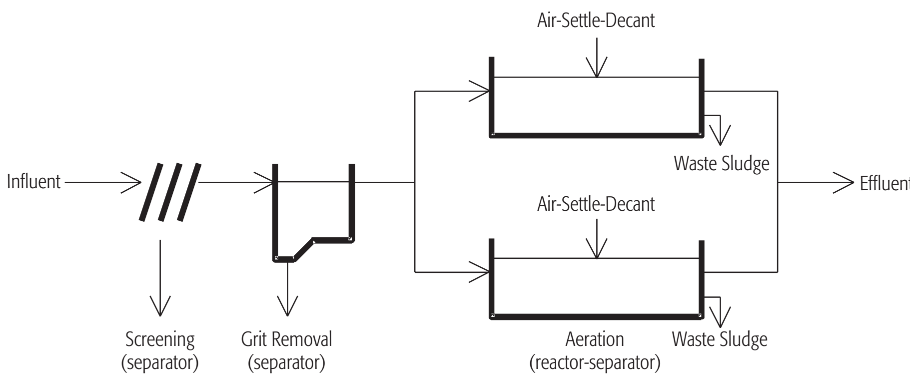
In Ontario, sequencing batch reactors, also referred to as cyclic activated sludge plants, are gaining wider acceptance because of their simplicity, increased mechanical and control reliability, the elimination of secondary clarifiers, and their ability to produce high quality effluents. A typical configuration is shown in figure 4-8.

4.4.5 Activated Sludge with Chemical Phosphorus Removal and Nitrification

Conventional activated sludge plants designed for BOD and TSS removal can often be readily modified or operated in such a manner as to remove phosphorus (TP) and nitrogen (TKN). Phosphorus removal has been a requirement for most plants discharging to the Great Lakes and other inland waters for the past several decades, following recognition of the effect of phosphorus on surface water quality. The simplest solution was to add a coagulant (such as ferric chloride or aluminum sulphate) to precipitate particulate phosphorus.

Ammonia nitrogen (NH_3-N), the fraction that is toxic to aquatic life if untreated, makes up approximately 60% of total nitrogen in wastewater. It is unlikely that any new certificate of approval would be issued in Ontario today without a requirement for nitrification (conversion of ammonia nitrogen to nitrate, NO_3^-). However, many existing plants do not nitrify, especially some of the larger plants discharging into the Great Lakes where a larger mixing zone

Figure 4-8 Sequencing Batch Reactor



(i.e., dilution zone) can be defined because of the volume of the lakes relative to the volume of effluent being discharged.

Ammonium nitrogen can be oxidized to nitrate by the biological action of the autotrophic bacteria *Nitrosomonas* and *Nitrobacter.* In lightly loaded treatment plants or plants with long hydraulic retention times in aeration, nitrification can occur as long as the aeration system can first satisfy all carbonaceous oxygen demands and has sufficient capacity left over to deliver a further 4.2 kg of oxygen for every kilogram of ammonia oxidized. The kinetics of nitrification are particularly sensitive to temperature. A loss of nitrifying bacteria from the biomass in cold weather can shut down the process completely, with serious consequences in terms of effluent toxicity. This potential for on/off performance necessitates careful control of the biomass concentration and its population of nitrifiers.

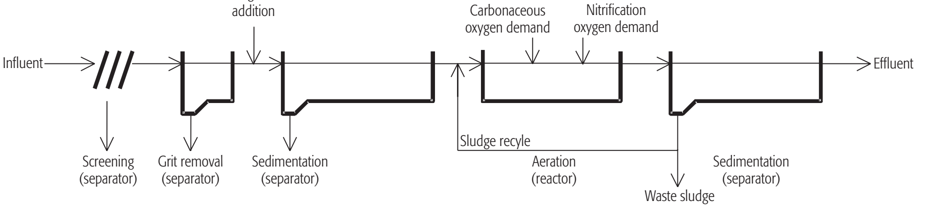
An activated sludge plant configured for chemical phosphorus removal and biological nitrification is shown in figure 4-9.

4.4.6 Fixed-Film Processes

Secondary fixed-film, attached-growth, or supported-growth biological processes are mechanical plants. An important characteristic is that they require very little energy to operate compared to suspended-growth systems. There are two basic types: trickling filters and rotating biological contactors.

Early trickling filters used beds of gravel contained in circular tanks. The trend today is to use plastic media designed to support the biological growth and maximize surface area; taller mechanically ventilated towers minimize the plant footprint and

Figure 4-9 Activated Sludge with Chemical Phosphorus Removal and Nitrification



increase oxygen transfer efficiency. Influent is sprayed evenly over the media by a series of fixed nozzles in the case of packed towers or by hydraulically rotated distribution arms in the case of conventional circular filter beds. Trickling filter plants usually include primary and secondary sedimentation and pumped recycle to maintain treatment efficiency and to keep the biomass wet and active during periods of low flow. Figure 4-10 depicts a typical trickling filter configuration.

The most common type of rotating biological contactor (RBC) comprises a set of circular closely spaced high-density-plastic plates mounted on a horizontal shaft, usually less than 10 m in length, driven by a low-power electric motor. The diameter of the rotating plates varies according to plant capacity but is limited to approximately 3–4 m by the mechanical properties of the material and its ability to support biological growth without deformation. The shaft is mounted across the reactor so that the plates are partially immersed in the flow. As the plates rotate at speeds of 1–2 rpm, the attached biomass carries a film of wastewater into the air, where it absorbs oxygen, thus enabling oxidation. Waste sludge is continually sloughed off and settles out in a final clarifier. A typical RBC process train is shown in figure 4-11.

Trickling filters are not widely used in Ontario because they are not well suited to the cold climate and are generally unable to achieve effluent qualities equal to those from suspended-growth plants. RBCs are more common but generally associated with small plants (less than 5,000 m^3/d). True scale-up

Figure 4-10 Trickling Filter

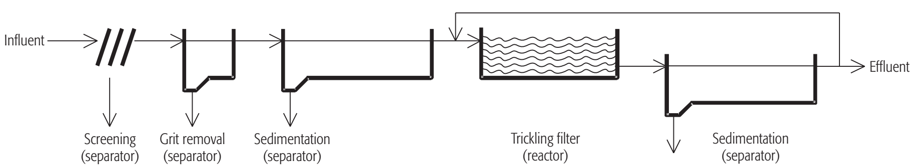
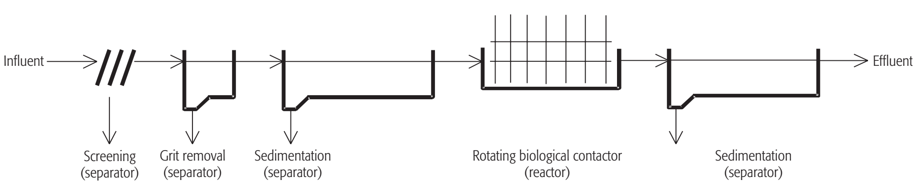


Figure 4-11 Rotating Biological Contactor



is not possible because of the mechanical limitations on plate diameter and shaft length. Larger plants must therefore be configured as multiple units. Ultimately, capital cost and footprint size become factors that tend to favour suspended-growth plants, despite their energy requirements. Fixed-film processes can also be configured for phosphorus removal and nitrification, the latter being achieved in RBCs by adding shafts in successive stages, or in trickling filters by adding bed area in stages.

4.4.7 Hybrid Processes

Hybrid or dual-process facilities combining suspended growth and fixed film are not common; they are more often associated with plant retrofits to improve performance or increase capacity. In general terms, fixed film is considered better able to resist hydraulic shock or organic loadings, while suspended growth is associated with high quality effluent. A hybrid combines these advantages, including the low energy requirements of fixed film.

The many different configurations have their own operational advantages and disadvantages. Names attached to these configurations include activated biofilter (ABF), trickling filter solids contact (TF/SC), roughing filter activated sludge (RF/AS), biofilter activated sludge (BF/AS), and trickling filter activated sludge (TF/AS).

In the context of current practice in Ontario or emerging technology, none of these processes has any particular relevance or significance requiring its detailed description and evaluation.

4.5 Tertiary Treatment

4.5.1 General Process Classifications

No discrete process or configuration classification separates secondary treatment from tertiary. In general, however, the addition of a further solids separation stage (e.g., filtration) to a conventional secondary plant is usually sufficient to earn a 'tertiary' designation.

In Ontario any new plant designed for discharge to a dry or perennial stream will almost certainly require filtration or its equivalent to satisfy the MOE's approval procedures. A dry or perennial stream is defined by the 7Q20 rule (referring to the minimum flow recorded or predicted over a 7-day period in the past 20 years). In cases where 7Q20 equals zero or where effluent dilution ratios fall below 10:1 during the same period, the MOE will require tertiary treatment by placing stringent limits on effluent BOD, suspended solids, phosphorus, and ammonia nitrogen.

Currently, tertiary plants treating normal domestic wastewater are considered best available technology economically achievable (BATEA). Any further level of treatment might only be considered for closed-loop watersheds in which plant effluent becomes the primary source of raw water for the production of drinking water. This is not an issue in Ontario, with its abundance of surface water.

Tertiary treatment has not been imposed by regulatory agencies on the major large plants discharging to the Great Lakes, including those serving Toronto. The plants must, however, reduce phosphorus through "enhanced secondary" treatment, though not necessarily to tertiary limits. Any new plants will likely be required to reduce ammonia to non-toxic levels, although there is no perceived need currently to impose nitrification globally on existing plants discharging to large bodies of surface water.

The Great Lakes, however, have many environmentally degraded areas with a need for improved treatment performance. Remedial Action Plans (RAPs) have been formulated for 17 areas in Canadian waters through the U.S.–Canada Great Lakes Water Quality Agreement (GLWQA), first signed in 1972. RAPs take an ecosystem approach in which all sources of pollution are considered. The net result is that treatment plants are subject to strict limits on mass loadings of pollutants, including phosphorus and nitrogen. These limits can exceed the capabilities of BATEA. The current approach is to plan expansions and retrofits with such limits set as goals rather than as regulatory criteria.

4.5.2 Tertiary Filtration

Effluent filtration through granular media is the most common form of tertiary treatment applied in Ontario. The process is designed to remove suspended solids and particulate BOD in the effluent from a secondary plant. The medium typically consists of a bed of graded silica sand 150–300 mm deep, with an average effective particle size of 0.4–0.8 mm. In some cases the sand is overlain by a lighter 300–600-mm-deep layer of anthracite (hard coal) with a larger effective particle size of 0.8–2.0 mm to provide deeper solids penetration.

The removal mechanisms at work are (1) particle straining, in which the size of the solids is larger than the pores and (2) physical-chemical, in which a combination of chemical bonds and electrical destabilization or neutralization processes allows smaller particles to attach themselves lightly to the granular media. As particles accumulate in the media, the filter tends to plug to a point where it must be backwashed by reversing the flow of treated effluent. Backwashing expands or fluidizes the bed and removes the lighter solids. Because of the relative densities of sand and anthracite in the case of dual-media filters, the sand settles first after backwashing, thus rebuilding a clear delineation between the upper anthracite and lower sand layers.

Particle straining alone is rarely considered sufficient to meet tertiary effluent criteria. In cases of discharge to 'dry' or heavily loaded streams, the MOE is progressively applying more stringent requirements for phosphorus in particular such that chemical addition in the form of either aluminum sulphate or ferric chloride is necessary. In practice, chemically assisted filtration should achieve significantly better effluent qualities than the typical values given in table 4-2 for tertiary treatment. Design objectives for tertiary filtration include reducing TSS to <5 mg/L (5 mg/L for tertiary treatment), BOD to <5 mg/L (10 mg/L), and phosphorus as PO_4 to <0.1 mg/L (0.3 mg/L).

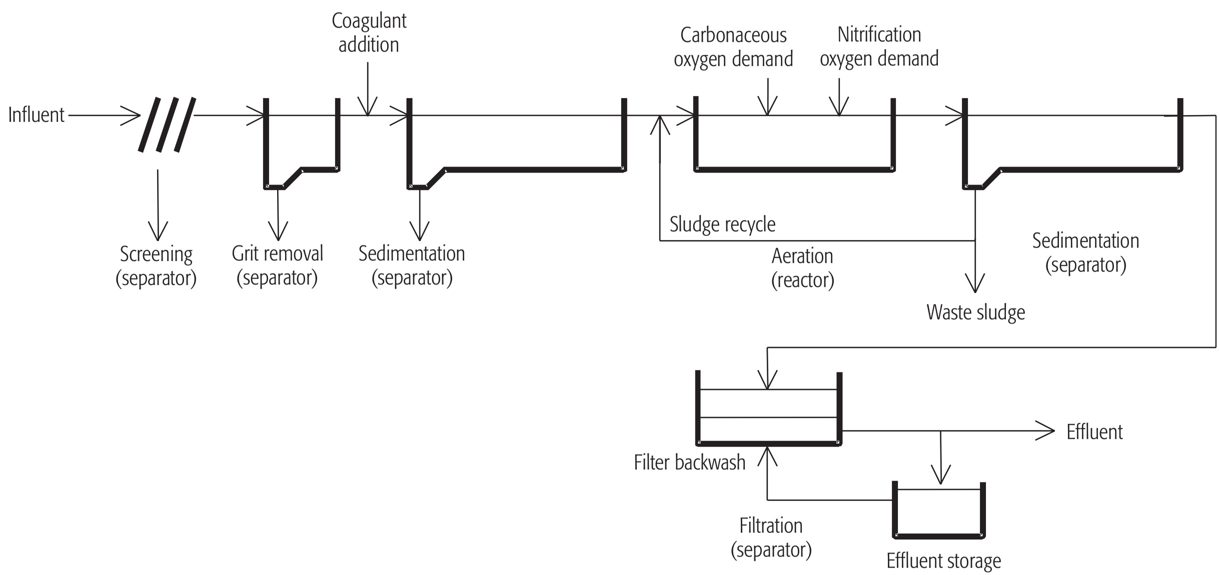
Tertiary filtration does not specifically target ammonia-nitrogen, but in most cases nitrification would be regulated together with solids, BOD, and phosphorus. A typical activated sludge plant configured for tertiary treatment is shown in figure 4-12.

4.5.3 Other Tertiary Treatment Processes

Several other tertiary processes are applicable to wastewater treatment, but they are rarely used for normal domestic wastewater. They include

- adsorption using activated carbon for high efficiency removals of dissolved organics,
- chemical treatment for removing metals in addition to phosphorus, and
- air stripping for removing volatile organics in addition to those removed by normal aeration processes.

Figure 4-12 Tertiary Activated Sludge



4.6 Disinfection

4.6.1 Disinfection Practices

Effluent disinfection cannot be classified in terms of level of treatment. The need for disinfection relates primarily to the recreational use of surface water. The MOE establishes criteria on a case-by-case basis. Continuous disinfection is required where there is a reasonable probability of the effluent mixing zone infringing on the zones of influence of neighbouring raw-water intakes. Good engineering practice is used to evaluate these interactions but there is an inherent lack of precision because of the influence of weather and lake and river currents. As a result, the MOE applies engineering judgement in defining whether disinfection should be seasonal or continuous.

Two organisms, fecal coliform bacteria and *E. coli,* can be quantitatively related to the presence of sewage or fecal matter and therefore to the risk of disease from pathogens. Current disinfection practices are unable to achieve the total elimination of these indicator organisms. As a result, MOE regulates their density in the mixing zone or point of discharge on the basis of best available technology and on a case-by-case basis. An acceptance of some degree of risk of disease to humans rests on the basis that the recreational use of water implies external contact rather than ingestion.

MOE objectives state that a potential health hazard exists if fecal coliform densities in water used for recreation exceed 100 bacterial colonies per 100 mL, as determined by standard analytical methods. By comparison, drinking water standards require a zero bacterial count. Total coliforms are another indicator organism but are not exclusively related to domestic sewage; water is considered impaired if their density exceeds 1,000 per 100 mL.

Recognizing that it is difficult to monitor disinfection performance at the boundaries of the mixing zone, regulatory criteria are typically set higher than these limits (e.g., *E. coli* and fecal coliforms less than 200 per 100 mL, allowing for dilution).

Bacterial contamination is also a function of surface runoff or drainage; hence the requirement for stormwater quantity and quality control facilities for new housing developments and paved areas such as highways and roads. That subject is beyond the scope of this document, but it should be noted that in the early 1990s the MOE imposed effluent criteria on a drainage discharge to the Rideau River near Ottawa that required disinfection in addition to sedimentation (i.e., the addition of a reactor to the conventional separation approach used for surface runoff treatment). This represented a major step toward redefining best available technology related to drainage. The practice has yet to be adopted across the province, however, because of cost and the difficulty in measuring economic benefit.

4.6.2 Chlorination

Chlorine is the most common disinfectant used for drinking water and for wastewater. Its effectiveness varies considerably depending on effluent quality. Because of the inability of chlorine and most oxidants to penetrate larger particulates, regulatory criteria of 100–200 fecal coliforms and *E. coli* per 100 mL could not be achieved readily without a minimum of secondary treatment. Biochemical reactions between oxidizable matter and chlorine are described under the subject of drinking water and will not be reviewed in detail here.[50]

Chlorine can be generated on-site, but economics normally favour its supply as a pressurized gas (Cl_2) for large plants and liquid sodium hypochlorite (NaOCl) for smaller facilities. By comparison with drinking water, dosage rates for wastewater vary widely and cannot be controlled to the same level of accuracy. The effectiveness of chlorination is a function of concentration and detention time. Typically, chlorine contact tanks are provided at the end of secondary or tertiary treatment, sized for a minimum of 30 minutes' contact time at average plant flow.

Ideally, the dosage rate is set to leave zero residual chlorine at the end of the contact tank because free chlorine is toxic to fish. Some plants use automated process control systems to control residual, but there is increasing pressure through the regulatory approval process to achieve much higher levels of success and accuracy. Existing plants invariably rely on the mixing zone to achieve dilution ratios in which fish are able to thrive.

All new plants required to disinfect would also be subject to a requirement that the final effluent be non-toxic. In this case, the certificate of approval would define the need for de-chlorination, which is usually achieved by injecting gaseous sulphur dioxide (SO_2) at the end of chlorination (see figure 4-13).

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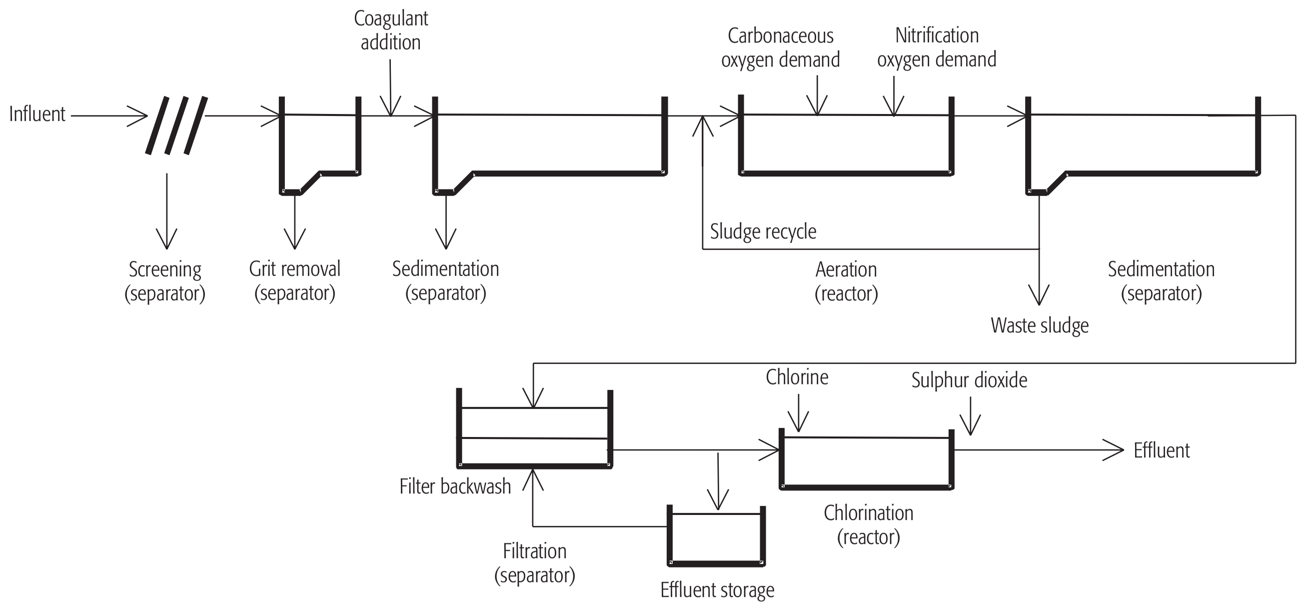
[50] Doyle et al., 2002, *Production and Distribution of Drinking Water* (Toronto: Ministry of the Attorney General), Walkerton Inquiry Commissioned Paper 8, Walkerton Inquiry CD-ROM, <www.walkertoninquiry.com>.

Figure 4-13 Tertiary Activated Sludge with Chlorination-Dechlorination



4.6.3 Ultraviolet (UV) Disinfection

During the past decade in Ontario, disinfection by ultraviolet (UV) radiation has gained wide acceptance. It is reasonable to suggest that UV has become the disinfection method of choice rather than an alternative to chlorine. UV radiation, or light with a wavelength of 254 nm, alters the DNA in micro-organisms, which in turn prevents them from propagating. There have been rapid advances in UV technology, but the process remains essentially the same. Electrically powered mercury arc lamps are immersed in the effluent at a spacing close enough to ensure that micro-organisms receive a large enough dosage, measured as a product of intensity and time and reported in $\mu W \cdot s/cm^2$.

UV systems consume much more power than chlorination, but they have many advantages, including

- very short retention times of one minute or less, compared to 30 minutes for chlorine (hence compact size),
- non-toxic effluent,
- no residual by-products such as trihalomethanes,
- no need to transport, store, and handle hazardous chemicals,
- no need for emergency ventilation and scrubbing systems as necessary for chlorine,
- simple and accurate process control, and
- low and simple maintenance.

UV has its comparative disadvantages, but none seems likely to reverse the trend away from chlorine, especially as regulatory authorities place more emphasis on ensuring a non-toxic effluent.

4.6.4 Other Disinfection Methods

Among other methods of disinfection, none has gained wide acceptance in Ontario, or elsewhere around the world. Ozone is a strong oxidant and is perhaps most commonly used after chlorine and UV. Other oxidants include bromine and iodine, which are sometimes used for swimming pools because they cause less eye irritation and degrade more slowly than chlorine. They also operate with a residual concentration that can be readily and automatically controlled by in-line instrumentation.

4.7 Biosolids Treatment

4.7.1 Objectives and General Classifications

Biosolids (sludge) are removed from the process train in primary and secondary sedimentation. Treating and disposing these solids are in many ways more complex operational problems than that of achieving a high effluent quality. The objectives of biosolids treatment can be summarized as stabilization (the reduction of pathogens and odours) and volume reduction.

Primary sludge is inherently less stable and more likely to produce offensive odours than secondary waste activated sludge, which is partially stabilized, or digested, as a result of its age, or solids retention time (SRT). In Ontario, sludge stabilization typically involves digestion in which micro-organisms – separated from influent organics and nutrients – feed on their own cell structures until rendered almost inert. Anaerobic digestion is carried out in the absence of oxygen and produces methane gas, which is often used as an energy source for plant operations. Aerobic digestion, also referred to as endogenous respiration, occurs naturally in lightly loaded aeration tanks or in extended aeration plants where the food-to-micro-organism (F:M) ratio is low. Off-line aerobic digestors are used to take this process to its conclusion.

Volume reductions of approximately 50% can be obtained through digestion. But a digested sludge drawn off at a concentration of 3% to 4% still presents a problem for off-site disposal unless it is further dewatered. To put it in perspective, a typical activated sludge plant rated at 100,000 m^3/d will generate as much as 500 m^3 of sludge at this concentration each day – enough to fill approximately 30 tanker trucks. Thickening to 6% or 8% will have the immediate benefit of halving the number of tanker trucks. Dewatering to 30% to 35%, which is about the limit of technology in common use today, produces a sludge cake equivalent to two or three truckloads. The selection of disposal method and degree of volume reduction are usually driven by economics.

Options for final disposal of biosolids include agricultural land application, composting, landfill, incineration, and pelletization for ultimate use as a fertilizer.

4.7.2 Regulation and Guidelines for Land Disposal

The disposal of biosolids on agricultural land is regulated under the *Ontario Water Resources Act,* the *Environmental Protection Act,* Ontario Regulation 347 (which establishes standards for waste disposal and utilization sites), and the *Environmental Assessment Act.* To assist in the evaluation of specific proposals for land disposal and submission of applications for approval, the Ministry of Environment and Ministry of Agriculture, Food and Rural Affairs published in March 1996 a supplement to Regulation 347, *Guidelines for the Utilization of Biosolids and other Wastes on Agricultural Land.*[51]

The guidelines place limits on concentrations of metals and other substances detrimental to agricultural land-use. They also protect groundwater and surface water through limits on bio-solids application rates and their proximity to water sources.

4.8 Emerging Technologies

4.8.1 What Defines an Emerging Technology?

It is reasonable to state that, although the level of understanding has grown, the science of wastewater treatment has not changed significantly in the past century. The activated sludge process developed in the 1920s is still in use today and has not been replaced. Change has occurred, however, in how the process is implemented, configured, and controlled. Change has also occurred in the regulatory and design objectives with effluent qualities becoming increasingly stringent.

In Ontario over the past two decades there has been a gradual shift from secondary carbonaceous activated sludge plants to tertiary plants with phosphorus removal, nitrification, and effluent filtration. For the most part, however, the larger plants in the province, including those serving Toronto,

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[51] Ontario, Ministry of the Environment and Ministry of Agriculture, Food and Rural Affairs, 1998. This electronic revision of the original 1996 document includes regulatory amendments to October 1997.

Hamilton, Durham Region, and Ottawa, are still configured as conventional secondary plants with the addition of chemical phosphorus removal.

Equipment manufacturers tend to lead the way with technology improvements, but change continues at a relatively slow pace because of the understandable reluctance of municipalities to seek change when BATEA already exists as defined through the MOE's approval process. However, several candidates for emerging technology may have a bearing on the future of the industry.

4.8.2 Membrane Filtration

Membrane filtration is gaining wide acceptance in the treatment of drinking water as a state-of-the-art process that is both cost effective and produces exceptionally high quality water compared to that obtained from conventional chemically assisted sand filtration. Membranes are now being considered for wastewater treatment but have yet to earn the same degree of acceptance. As a concept, however, membranes must be considered an emerging technology with the potential for dramatic improvements in effluent quality and overall reductions in cost. It remains to be seen whether initial operational concerns can be overcome to the point of wide and general acceptance.

Membranes manufactured in Ontario comprise thin, hollow, flexible strands of an inert polymeric compound approximately 2 mm in diameter. The pores through the membrane walls are in the order of 0.09–0.2 μm (microns) in diameter. The membrane strands are strung vertically between PVC permeate (filtrate) pipe headers top and bottom and assembled in modules each with a total surface or filtration area of 45 m^2. Typically, eight modules are connected to a common header to form a cassette, and six to eight cassettes are mounted in a steel frame and immersed directly in the aeration tank of an activated sludge plant. The permeate lines are connected to the suction side of a centrifugal pump, drawing clarified liquid through the membrane pores and leaving the mixed-liquor solids, or biomass, in the aeration tank.

The potential advantages of membranes are significant:

- They eliminate secondary clarifiers, which invariably are the limiting process in terms of plant rating and performance.

- They eliminate tertiary filtration.

- Aeration tanks can operate at a mixed-liquor suspended solids (MLSS) concentration of approximately 15,000 mg/L, compared to 2,000–5,000 mg/L for conventional plants. Simplistically, this reduces the aeration tank footprint and volume by a factor of 3 or 4, which is a dramatic difference made even more so when the elimination of clarifiers and filters is taken into account.

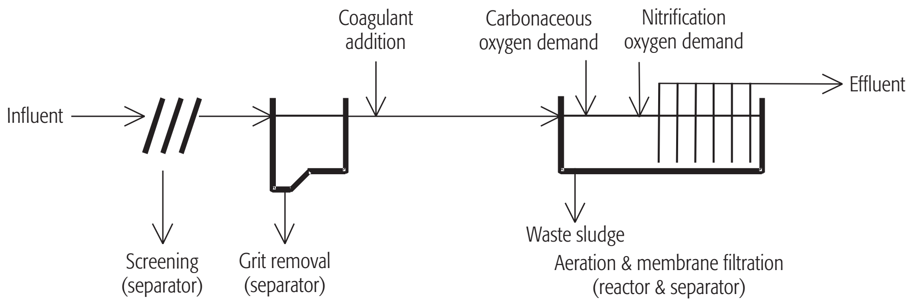
- Rather than reduce the size of the aeration tank, the high MLSS concentration can be used to increase solids retention time, promote nitrification, and reduce the volume of solids or sludge removed from the reactor requiring further treatment.

- Membrane pore sizes are small enough to strain out bacteria physically, effectively eliminating the need for disinfection.

- Effluent suspended solids are consistently maintained at <5 mg/L to non-detectable, regardless of the quality of the flocculated mixed-liquor solids, a factor crucial to the operation of conventional secondary clarifiers.

There are some disadvantages to the use of membranes in wastewater, and the economics of membrane fouling and replacement have not been fully understood. Regardless, the potential benefits are so wide-ranging and dramatic that the incentive is there to resolve or accept some of their limitations. Figure 4-14 illustrates the significance of membrane filtration in terms of its simplicity and size (compare with figure 4-13 for a conventional activated sludge plant with tertiary filtration and disinfection).

Figure 4-14 Membrane Activated Sludge



4.8.3 Ultraviolet (UV) Disinfection as Emerging Technology

UV disinfection, described in section 4.6.3, can perhaps be considered a technology that has already passed acceptance and is already in widespread use. It continues to undergo development, however, and manufacturers are continuing to seek ways to extend lamp life, reduce the number of lamps, reduce power consumption, and reduce maintenance.

It is appropriate, therefore, to categorize UV as an emerging technology because of its importance in terms of simplifying and improving disinfection practices. Producing a non-toxic effluent is now a simple matter of demonstrating that UV is an economical alternative to chlorine, which involves implementing control systems that first must add toxic compounds only to have them subsequently rendered non-toxic prior to discharge.

4.8.4 Sequencing Batch Reactors

The sequencing batch reactor (SBR), or cyclic activated sludge plant, is also an emerging trend in Ontario. The concept is as old as the activated sludge process itself, with early versions configured as 'fill and draw,' or batch, plants. Its re-emergence can be linked to the development of robust programmable control systems in which relatively long sequential control strategies can be programmed to handle potential equipment failures or rapid changes in hydraulic conditions.

As interest in SBRs has grown over the past two decades, they have progressively shed their 'small-plant' (less than 5,000 m^3/d) classification. There are now some examples around the world of SBRs in the large-plant category with ratings in the order of 200,000 m^3/d. In Ontario during the same period there have been very few opportunities for consideration of SBRs for large plants. It is of interest to note, however, that SBRs have gained wide acceptance for 'design-build' projects in Ontario, in which consortia comprising designers and contractors are allowed to define plant configuration. This suggests that SBRs are less costly than conventional extended aeration.

Like membrane plants, SBRs eliminate constant-flow secondary clarifiers and achieve solids separation in a perfectly quiescent environment as influent and air supply is directed to the neighbouring aeration reactor. Solids carryover and fluctuations in secondary clarifier rise rate are no longer of concern. Although SBRs are not considered tertiary plants, their performance in terms of solids and BOD removal is typically better than that achieved by conventional extended aeration plants.

Aeration equipment and reactor volumes for SBRs are essentially the same as for extended aeration. The difference is the use of decanter mechanisms to draw off settled final effluent at the end of each cycle. Cycles typically are of either four or six hours duration, of which the first half is devoted to aeration followed by quiescent settling and decanting.

In summary, the advantages of SBRs include

- lower capital cost,
- better effluent quality than conventional secondary plants,
- inherent equalization storage for peak hydraulic loadings,
- elimination of secondary clarifiers, which are frequently cited as the main area of concern in conventional plants in terms of capacity limitations and effluent quality,
- ease of operation, and
- ease of maintenance.

4.8.5 Biological Phosphorus Removal

Biological phosphorus removal (BPR) is one aspect of the more generic process description "biological nutrient removal" (BNR) that refers to both phosphorus and ammonia nitrogen removals. BPR was developed in response to the cost of coagulant chemicals and the increased volume of sludge generated through their use.

BPR is a relatively complex biochemical subject. In practical terms, however, it involves the addition of anaerobic and anoxic (low oxygen concentration) reactors ahead of aeration and the recycling of aerated mixed liquor to develop a biomass population that takes up phosphorus in what is, essentially, a secondary plant. It is also usually combined with nitrification and controlled de-nitrification, which is the conversion of nitrates (NO_3^-) formed during nitrification to nitrogen gas (N_2).

BPR is not a new concept, but it has not been widely used in Ontario because of the availability and relatively low cost of coagulant chemicals. Although it is now more commonly considered in process option evaluations for new or expanded plants, BPR falls short of the increasingly more stringent limits placed on effluent phosphorus to the point where chemicals must still be used.

5 United States of America

5.1 Introduction

The United States has had laws and regulations to govern the introduction of pollutants into the water environment since at least 1948, when the first version of the *Federal Water Pollution Control Act* (now know as the *Clean Water Act*) was enacted. Since then, a complex framework of laws and regulations has developed to minimize the discharge of pollutants into the environment and to rehabilitate previously damaged waterways. This chapter outlines the key components of the American legal and regulatory system related to wastewater and ambient waters, and then provides a comparison with the Canadian system.

5.2 U.S. Regulatory Framework

5.2.1 Legal Authority – Federal versus State

The authority to enact federal legislation is granted to the U.S. Congress by Article I, Section 1, of the U.S. Constitution. Article I, Section 8, then indicates the wide range of areas in which Congress may and should enact legislation. The list is not all-inclusive and, not surprisingly (it was written in 1787), does not include any reference to environmental issues or wastewater. However, the final paragraph of Section 8 grants Congress the authority "to make all laws which shall be necessary and proper for carrying into execution the foregoing powers and all other powers vested by this Constitution in the government of the United States, or in any department or officer thereof."

The Constitution then clearly separates legislative authority from executive authority. The president, elected separately from Congress, is identified as the chief executive officer in Article II, Section 1. Later, at the end of Article II, Section 3, the Constitution states that the president "shall take care that the laws be faithfully executed …" In short, Congress enacts federal laws and the president executes them.

The Constitution does not indicate what laws the individual states can enact, although in Article I, Section 10, it clearly states what individual states cannot do. In this legal vacuum, states pass laws in order to govern their citizens. When there is no conflict with federal law or the Constitution (including the Bill of Rights and all subsequent amendments that did not exist in 1787), the state law stands. However, according to Article VI, "[t]his Constitution and the laws of the United States which shall be made in pursuance thereof … shall be the supreme law of the land …" Therefore, if a conflict arises between state law and federal law, the issue must be settled in court. Over the past 210 years numerous legal cases have added both clarification and confusion.

With respect to environmental protection, the situation is relatively clear. Once the federal government began passing substantive legislation on environmental issues (described in section 5.3), federal laws and the resulting regulations took precedence over state laws and regulations. However, in many cases the federal government pushes the detailed work (but not necessarily the needed money) down to the state level. The federal government then ensures that the federal laws and regulations are appropriately enforced (in the case of water quality standards and permitting, for example, as will be described in section 5.4). Although friction between the federal government and states remains, environmental protection proceeds. Furthermore, states and local governments are allowed to set standards more stringent than those of the federal government, an option that California, for example, often exercises.

5.2.2 Laws and Regulations

The general process for enacting federal laws is described in the U.S. Constitution and, as practised today, can be summarized as follows. A member of either the House of Representatives or the Senate introduces a bill to be considered (note: bills for raising revenue can be introduced only in the House of Representatives). Often, a similar bill will be introduced in the other house of Congress at the same time. Following discussion, evaluation, and revision, a vote may be called on the introduced bill. Typically, one draft of a bill is first approved in one house, then further revised for approval in the other house. Finally, a single version of the bill is approved by both houses of Congress and is sent to the president for approval. The president may veto a bill, in which case it goes back to Congress. When the president signs a bill it becomes law and is called an act. The act then goes back to the House of Representatives, which standardizes the text before the act is published in the *United States Code*. All federal laws are contained in the 50 titles of the *United States Code*. On the Internet, the Cornell University Law Library site is a convenient access point.[52]

Most laws do not include the details necessary to be useful. Instead, the laws usually clearly state which department or agency of the executive branch (under the president's control) should execute the law. The next step (after translating the legalese of the law into English) is often the development of regulations that provide necessary details. For example, the *Federal Water Pollution Control Act* states: "Except as in compliance with this section and sections … of this title, the discharge of any pollutant by any person shall be unlawful."[53] The U.S. Environmental Protection Agency (EPA) is left with the job of defining, through regulations, what a pollutant is, determining the concentration in ambient waters that causes effects, and developing the rules for obtaining a discharge permit.

The development of regulations follows a strict procedure. Once an agency determines that a regulation is required (or has been specifically directed by Congress to create a regulation), the agency develops and proposes the draft regulation. This proposal is published in the *Federal Register,* which is the official document recording all actions related to regulations. The proposal specifies the time during which comments related to the proposal will be received from the public, usually about 90 days. The agency then considers all comments and revises the regulation. The revision process may be extensive, depending on the comments received, and can take a long time. At some point a final regulation is prepared and published in the *Federal Register.* Because all regulations being generated by all federal agencies are listed in the *Federal Register,* a search for recent environmental regulations should start with the EPA Web site.[54]

After being printed in the *Federal Register* as a final rule, a regulation is codified by entering it into the *Code of Federal Regulations* (CFR). The CFR consists of 50 titles (distinct from the 50 titles of the *U.S. Code*), in which every federal regulation is recorded. The CFR is revised yearly, so new regulations that have

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[52] Legal Information Institute, 2000, *U.S. Code* [online], [cited December 2000], <www4.law.cornell.edu/uscode/index.html>. "This version is generated from the most recent version made available by the US House of Representatives. For exact information about the currency of any particular title as it is published by the House, see the listing on the House server" (from the Contents and Context section of this site).
[53] *U.S. Code,* title 33, chap. 26, subchap. III, sec. 1311(a).
[54] United States, Environmental Protection Agency, 2000c, *Federal Register: Environmental Documents* [online], [cited December 2000], <www.epa.gov/fedrgstr/>.

been promulgated between revisions must be found in the *Federal Register.* Most of the environmental regulations are published in Title 40 of the CFR.[55]

5.2.3 Compliance and Enforcement

Compliance with federal laws and regulations arising from the laws is mandatory. Environmental laws and regulations are enforced primarily by the EPA Office of Enforcement and Compliance Assurance through both civil and criminal prosecution. The legal authority of the EPA to enforce environmental laws is spelled out in the law itself. For example, compliance and enforcement of the *Clean Water Act* is detailed in the *U.S. Code,* Title 33, Chapter 26, Subchapter III – Standards and Enforcement, Section 1319. Paragraph (a) states that the EPA administrator has the responsibility and authority to order compliance and if necessary bring civil action. Paragraph (b) states that the administrator may take civil action in U.S. District Court "for appropriate relief, including a permanent or temporary injunction." Paragraph (c) details the criminal penalties for violators of specific sections of the law. Criminal penalties can be and are brought against individual people. The penalties range from US$2,500 to $25,000 per day of violation and/or up to one year in prison for negligent violations. Penalties for knowing violations range from $5,000 to $50,000 per day of violation and/or up to three years in prison. Penalties for violating other laws are laid out in their respective entries.

The EPA Office of Enforcement and Compliance Assurance has, in recent years, implemented programs of compliance incentives and assistance in addition to enforcement. The incentives are voluntary measures that encourage regulated entities to "discover, report, and correct violations of the law before the federal, state, or local government identifies them for investigation or enforcement action."[56] In essence, the existence of incentives means that if regulated entities take initiative, including reporting, they may not receive penalties. Compliance assistance comes in the form of plain-language explanations of laws and regulations, on-site programs, and specific requested assistance.

Laws related to water will be specifically enforced by the Water Enforcement Division (WED) of the EPA (a division of the Office of Enforcement and

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[55] The printed version of 40 CFR is revised every July 1; the electronic Web version is more frequently revised. See the Electronic Code of Federal Regulations [cited December 2001], <www.access.gpo.gov/ecfr/>.

[56] United States, Environmental Protection Agency, Office of Enforcement and Compliance Assistance, 2000, *About OECA* [online], [cited December 2000], <www.epa.gov/oeca/abouthm.html>.

Compliance Assurance). The WED is responsible for enforcing four laws: the *Clean Water Act,* the *Safe Drinking Water Act,* the *Marine Protection, Research and Sanctuaries Act,* and the *Oil Pollution Act.* These laws have resulted in seven major enforcement programs ranging from discharges to surface waters and biosolids disposal to underground injection control.

The U.S. Congress has given the EPA considerable authority for enforcement. The expectation is that violators of environmental laws will be caught and punished, just as violators of other laws are caught and punished. Recognizing that some environmental regulations may be subject to scientific uncertainty (e.g., if the permit allows a maximum discharge concentration of 1 mg/L, is a discharge concentration of 1.01 mg/L truly unsafe?), the EPA has flexibility to work with violators. The intent of the laws is to protect the environment and human health. Nevertheless, the agency aggressively pursues enforcement. People have received large fines and prison sentences for violating environmental law, and companies have paid large sums in damages and received injunctions.

5.3 Federal Laws

5.3.1 National Environmental Policy Act

The *National Environmental Policy Act* was enacted in January 1970. Commonly called *NEPA,* this act is a broad philosophical statement that the federal government will "promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man …"[57] In addition to this broad philosophy, the act established two concrete initiatives: (1) the Council on Environmental Quality to advise the president on environmental issues and (2) the requirement for federal agencies to produce environmental impact statements for any action that could significantly affect the environment. Unlike much of the environmental legislation since enacted, *NEPA* is relatively brief and contains less substantive information than most legislation.

Contrary to common belief, *NEPA* is not the 'Environmental Protection Act.' Nor does *NEPA* makes reference to the Environmental Protection Agency – the EPA did not exist when the act was promulgated in 1970. Furthermore, *NEPA* did not establish the EPA. That occurred later in 1970, when President

[57] *U.S. Code,* title 42, chap. 55, sec. 4321.

Richard Nixon did establish the EPA in Reorganization Plan No. 3, as allowed by Title 5, Chapter 9, of the *U.S. Code*. Duties related to the environment that had been scattered among a number of different departments and agencies were officially transferred to the EPA, which would be headed by an administrator. The enactment of *NEPA* might have prodded the president to establish the EPA, but the two actions were legally separate. Because the EPA is not a department, Congress was not required to enact a law to establish it, although, as with all executive departments and agencies, Congress enacts the legislation that funds the agency.

From the standpoint of issues related to wastewater treatment, *NEPA* has little direct effect. The requirement to produce environmental impact statements has no doubt led to reduced overall impact to the water environment, but does not directly affect most discharges. Other acts address these issues much more directly.

5.3.2 Clean Water Act

The predecessor to the *Clean Water Act* was enacted in 1948. This original act was amended numerous times before 1972, when it was extensively amended, reorganized, and expanded into modern legislation officially called the *Federal Water Pollution Control Act*. The name *Clean Water Act* technically refers solely to the amendments of 1977. Further amendments were made in 1987. For simplicity, in this paper all of these laws and amendments will be lumped under the name *Clean Water Act*. They are currently found in Title 33 (Navigation and Navigable Waters), Chapter 26 (Water Pollution Prevention and Control), of the *U.S. Code*.

Chapter 26 has six subchapters, two of which are of particular interest. Subchapter III – Standards and Enforcement specifies penalties (see section 5.2.3) but also indicates that water quality standards should be developed. Although this part of the law looks very detailed, it provides little useful information for practitioners (except for potential fines and prison terms). Lists of pollutants and their maximum concentrations are to be developed by the EPA.

Subchapter IV – Permits and Licenses defines, in Section 1342, the National Pollutant Discharge Elimination System (NPDES). As will be discussed in section 5.4, NPDES is the basis for permits issued to entities that discharge treated wastewaters into U.S. surface waters. Paragraph (a) of Section 1342 specifically authorizes the EPA to issue permits. Paragraph (b) indicates that states may request permission to issue NPDES permits but that their request must be approved by the EPA and meet all requirements of the law.

The *Clean Water Act* is the most relevant U.S. law for issues related to wastewater treatment and discharge. All of the regulations discussed in section 5.4 were promulgated under the authority of this law.

5.3.3 Other Relevant Acts

Of the large number of other acts that relate to the environment, three merit specific mention in this paper. The *Resource Conservation and Recovery Act* (*RCRA*) was first enacted in 1976 and has been amended five times since.[58] *RCRA* deals with solid waste (Subchapter II, Sections 6911–17), hazardous waste (Subchapter III, Sections 6921–39), and underground storage tanks (Subchapter IX, Sections 6991a–91i), among other things. The regulations arising from this act focus on properly handling solid and hazardous wastes and proper design of storage facilities for solid wastes, hazardous wastes, and underground storage tanks. A violation of *RCRA* or its related regulations might not have an impact on the water environment, but if a violation also leads to an unauthorized discharge to water bodies, the *Clean Water Act* might also be violated.

The *Comprehensive Environmental Response, Compensation and Liability Act* (*CERCLA,* or "Superfund" as it is more commonly called) was first enacted in 1980 and has been amended three times since.[59] *CERCLA* establishes the need for a National Priorities List of contaminated sites across the United States as well as, in theory, the funding to clean up the sites. The effectiveness of *CERCLA* notwithstanding, Subchapter I, Section 9618, establishes a higher clean-up priority for facilities where the release of contaminants "has resulted in the closing of drinking water wells or has contaminated a principal drinking water supply."

The *Safe Drinking Water Act* (*SDWA*) was first enacted in 1974 and has been amended several times since.[60] *SDWA* deals specifically with drinking water issues. There is no clear legal link between the *SDWA* and the *Clean Water Act.* However, ambient water quality criteria arising from the latter do consider human health issues and refer, for selected contaminants, to the maximum

[58] *U.S. Code,* title 42, chap. 82 (Solid Waste Disposal).
[59] *U.S. Code,* title 42, chap. 103 (Comprehensive Environmental Response, Compensation and Liability).
[60] *U.S. Code,* title 42, chap. 6A (Public Health Service), subchap. XII (Safety of Public Water Systems).

contaminant levels (MCLs) established under the authority of the *SDWA*. One area of common confusion is that MCLs are not directly linked to wastewater discharge criteria. MCLs refer specifically to water used for drinking. The initialism MCL is not used in conjunction with the *Clean Water Act* regulations. Undoubtedly, some wastewater is discharged into waters that will also be used for drinking. However, using MCLs with respect to wastewater is inappropriate. Although wastewater is treated, sometimes to very high standards, there should be no implication that such water would be used for drinking without further attenuation in the environment followed by highly regulated treatment.

5.4 Federal Regulations

5.4.1 Summary

The *Code of Federal Regulations* (CFR) contains 50 titles (each of which is subdivided into chapters, subchapters, parts, subparts, and sections). Most of the regulations related to environmental issues are found in Title 40 – Protection of the Environment. Three subchapters contain the bulk of the water related regulations: Subchapter D – Water Programs (Parts 100–149), Subchapter N – Effluent Guidelines and Standards (Parts 400–471), and Subchapter O – Sewage Sludge (Parts 501 and 503). Table 5-1 summarizes the most relevant regulations for wastewater treatment and related issues.

These regulations are posted on the EPA Web site.[61] They contain very detailed material. The following subsections summarize briefly several of the more important regulations. Full details are in the regulations themselves. For brevity, regulations in subsequent sections are abbreviated (e.g., 40 CFR 122 = CFR, Title 40, Part 122). See table 5-1 for the titles of parts.

5.4.2 National Pollutant Discharge Elimination System

The key regulation describing the NPDES program is 40 CFR 122. Section 122.1(b) states: "The NPDES program requires permits for the discharge of 'pollutants' from any 'point source' into 'waters of the United States.'" In addition to facilities that treat municipal wastewater and facilities treating wastewater

[61] United States, Environmental Protection Agency, 2000a, *Code of Federal Regulations, Title 40 – Protection of Environment* [online], [cited December 2000], <www.epa.gov/epahome/cfr40toc.htm>. For the text of regulations, this site connects to the federal e-CFR Web site (see footnote 55).

from 34 specified industry categories (Appendix A to Part 122), NPDES permits are also required for concentrated animal feeding operations containing more than 1,000 cattle or equivalent (Appendix B to Part 122), concentrated aquatic animal production facilities, and stormwater discharges.

With respect to large animal feeding operations, currently only about 2,500 large and small livestock operations have enforceable permits. On December 15, 2000, the EPA proposed strict new controls that would apply to as many as 39,000 concentrated animal feeding operations.[62] In part this arises from the EPA's proposal to reduce the size of an operation requiring NPDES permits to either 300 or 500 cattle or equivalent units. Poultry, veal, and swine operations would also be required to prevent all untreated discharges. Existing exemptions would be eliminated, and spreading manure on land owned by the livestock operation would be limited.

Table 5-1 Summary of Relevant U.S. Federal Regulations for Wastewater, 40 CFR

Part	Title
122	EPA Administered Permit Programs: The National Pollutant Discharge Elimination System
123	State Program Requirements
125	Criteria and Standards for the National Pollutant Discharge Elimination System
129	Toxic Pollutant Effluent Standards
131	Water Quality Standards
132	Water Quality Guidelines for the Great Lakes System
133	Secondary Treatment Regulation
136	Guidelines Establishing Test Procedures for the Analysis of Pollutants
403	General Pretreatment Regulations for Existing and New Sources of Pollution
405	Dairy Products Processing Point Source Category*
412	Feedlots Point Source Category*
503	Standards for the Use and Disposal of Sewage Sludge

* These are examples of the specific regulations that have been prepared for industrial point-source dischargers. Non-agricultural industry makes up the bulk of these regulations (parts 400–471).

[62] United States, Environmental Protection Agency, 2000b, *EPA Proposes Strict New Controls to Reduce Water Pollution from Large Industrial Feedlot Operations* [online], (press release) [cited December 2000], <http://yosemite1.epa.gov/opa/admpress.nsf/b1ab9f485b098972852562e7004dc686/274ed4f48827bcce852569b6006bac31?OpenDocument>.

NPDES permits are issued either by the EPA directly or by the state in which a discharge will occur. A state may issue a NPDES permit only if the state has prepared a program in accordance with 40 CFR 123 and the program has been approved. As of September 1998, only 44 states had programs. A NPDES permit is valid for five years and may be renewed. The permit will specify the concentrations and loadings of contaminants that may be discharged, as well as the monitoring and reporting requirements.

The procedural requirements for requesting a permit are in 40 CFR 122. The detailed technical information required to set specific limits for individual permits is contained in Parts 125, 129, 133, and 136, as well as in Subchapter N, Parts 400–460, which contain detailed limits for industrial dischargers. 40 CFR 503 (Standards for the Use or Disposal of Sewage Sludge) may also come into effect, because an NPDES-permitted municipal wastewater treatment facility will generate sludge requiring disposal.

Obtaining an NPDES permit is a time-consuming and costly process. The EPA provides excellent resources on the Internet. A good starting point is the NPDES page at the Office of Wastewater Management site, which includes links to the required application forms as well as to appropriate regulatory contacts (state and federal).[63]

Although many states have been authorized by the EPA to issue NPDES permits, NPDES remains a national program. Therefore, the EPA maintains a Web site that allows the user to view the permit requirements, compliance status, recent measurement results, and other relevant information for any NPDES-permitted facility.[64]

5.4.3 Water Quality Standards

Three regulations listed in table 5-1 include the word ‘standards’ in their titles. Neither 40 CFR 125 nor 40 CFR 129 is particularly useful for the issue of water quality. 40 CFR 131 (Water Quality Standards) spells out the requirement for ambient water quality standards and provides the procedure by which they

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[63] United States, Environmental Protection Agency, Office of Water, Office of Wastewater Management, 2000, *National Pollutant Discharge Elimination System Permit Program* [online], [cited December 2000], <http://cfpub1.epa.gov/npdes/>.

[64] United States, Environmental Protection Agency, 2000d, *Water Discharge Permits Query Form* [online], [cited December 2000], <www.epa.gov/enviro/html/pcs/pcs_query_java.html>.

should be established. The issuance of an NPDES permit can occur only after the discharge to be permitted is compared to the water quality standards.

According to Section 131.2 of 40 CFR 131,

> [a] water quality standard defines the water quality goals of a water body … by designating the use or uses to be made of the water and by setting criteria necessary to protect the uses. … Such standards serve … as the regulatory basis for the establishment of water-quality-based treatment controls and strategies beyond the technology-based levels of treatment required by [the *Clean Water Act*].

The *Clean Water Act* assigns the states the responsibility to establish water quality standards. Specifically, as stated in section 131.4(a) of 40 CFR 131, "states may develop water quality standards more stringent than required by this regulation." In other words, states are free to adopt whatever standards they want, as long as they are at least as stringent as those recommended by the EPA.

To ensure that states properly exercise their authority, the EPA reviews and approves or disapproves state water quality standards as per section 131.5 of 40 CFR 131. In particular, the EPA checks that designated water uses are appropriate, that water quality criteria are consistent with the designated use, and that appropriate legal procedures are in place and have been followed. If the EPA disapproves the state standards, the state must follow standards promulgated by the federal agency.

The establishment of state water quality standards is a massive effort. Every water body and source in the state must be evaluated and a use assigned. Possible uses are "for public water supplies, protection and propagation of fish, shellfish and wildlife, recreation in and on the water, agricultural, industrial, and other purposes including navigation."[65] Downstream waters must also be considered.

Once the use is designated, water quality criteria (the allowable concentrations of contaminants in the ambient waters) must be specified. The state must establish numerical criteria when possible, narrative criteria when numerical criteria cannot be established. The water quality criteria must protect the designated use. Additionally, the numerical criteria must be based on the EPA-

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[65] 40 CFR 131, sec. 131.10(a).

recommended criteria, the EPA-recommended criteria modified for site-specific conditions, or "other scientifically defensible methods."[66]

Finally, the state must adopt an antidegradation policy. This specifically means that if a certain water body has higher quality than is needed to support wildlife and recreation, that quality cannot be reduced without proof that important economic or social development in the area requires such degradation. Even so, the quality cannot be degraded below that required for the designated use. If the water constitutes "an outstanding national resource, such as waters of national and state parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected."[67] For these latter waters, degradation is not allowed under any conditions.

The EPA publishes National Recommended Water Quality Criteria for use by the states. These recommended criteria are provided for guidance only – they are not directly enforceable. That they will be carefully considered by states is ensured, however, by the requirement of 40 CFR 131 that state water quality standards, including criteria, be approved by the EPA. Additionally, section 131.36 of 40 CFR 131 (Toxics criteria for those states not complying with *Clean Water Act* Section 303(c)(2)(B)) specifically sets out the criteria for 126 priority pollutants. These criteria are legally binding in states that do not have approved criteria for these pollutants in their water quality standards. On the Internet, a convenient access point for a summary of these priority pollutants is the Electronic Code of Federal Regulations.[68]

5.4.4 Residual Solids Disposal

Although sewage sludges are considered solids, the regulation of their disposal falls under 40 CFR 503 (promulgated primarily under the authority of the *Clean Water Act*). Three disposal options are considered: land application, surface disposal, and incineration. The first two options are clearly related to the *Clean Water Act;* runoff over land to which sewage sludge has been applied can contaminate waters. Incineration is included in 40 CFR 503 for completeness, so that producers of sewage sludge can find the relevant regulations in one location.

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[66] 40 CFR 131, sec. 131.11(b)(1)(iii).
[67] 40 CFR 131, sec. 131.12(a)(3).
[68] 40 CFR-Chapter I-Part 131, [online], [cited December 2000], <www.access.gpo.gov/nara/cfr/cfrhtml_00/Title_40/40cfr131_00.html>.

Sewage solids to be disposed of on land are regulated on the basis of contaminant concentrations and cumulative loading to the receiving lands. Table 5-2 summarizes the requirements for nine metals.

The limits are designed so that the maximum cumulative loading allowed onto land would result from the application to one hectare of land of 1,000,000 kg of solids containing the average monthly concentration. The maximum cumulative loading is also equal to 20 years of application at the maximum annual loading rate, which would be achieved by applying to one hectare of land per year 50,000 kg of solids containing the average monthly concentration.

Sewage solids must also meet pathogen and vector-attraction reduction standards. Two classes are allowed: (1) Sewage solids meeting Class A pathogen requirements may be land applied without site restrictions and may be applied to a lawn or home garden, or sold or given away in a bag or other container for application to land. Solids that meet Class A pathogen requirements may also be applied to agricultural land, forests, sites that might have public contact, and reclamation sites. (2) Sewage solids that only meet Class B pathogen requirements may not be applied to a lawn or home garden but may be applied

Table 5-2 Maximum Concentrations and Cumulative Loadings for Metals

Pollutant	Ceiling concentration (mg/kg) [a]	Monthly average concentration (mg/kg) [a]	Cumulative loading rates (kg/ha) [b]	Annual loading rates (kg/ha per year)
Arsenic	75	41	41	2.0
Cadmium	85	39	39	1.9
Copper	4,300	1,500	1,500	75
Lead	840	300	300	15
Mercury	57	17	17	0.85
Molybdenum	75	NA	NA	NA
Nickel	420	420	420	21
Selenium	100	100	100	5.0
Zinc	7,500	2,800	2,800	140

Source: 40 CFR 503, <http://access.gpo.gov.nara/cfr/cfrhtml_00/Title_40/40cfr503_00.html.>
NA = not applicable
[a] mg contaminant per kg total solids (dry mass basis).
[b] kg contaminant per hectare.

to agricultural land, forests, sites that might have public contact, and reclamation sites, but only in conjunction with site restrictions.

The detailed pathogen requirements and site restrictions for Classes A and B are presented in 40 CFR 503, starting in Section 503.32, but they are not readily summarized. For example, there are six alternatives allowed for Class A, with the specific bacterial, virus, and helminth ova concentrations depending to some extent on the solids concentration and pH of the sewage solids. Additionally, Appendix B of 40 CFR 503 details five technical Processes to Significantly Reduce Pathogens and seven technical Processes to Further Reduce Pathogens that can be used to meet the different alternatives for achieving Class A.

In addition to details about concentrations of contaminants and loading, 40 CFR 503 specifies the required frequency of monitoring as a function of the total amount of sludge applied per year (more frequent monitoring as total application increases). The regulations also specify the requirements for record keeping, which is the responsibility of the person who prepares the sludge for disposal. Records must be retained for five years and must include a certification statement in which the person preparing the records states that the requirements have been met and that he or she is aware that significant penalties for false certification exist, "including the possibility of fine and imprisonment."[69]

Permits required to dispose of sewage sludge may be issued directly by the EPA or by a state that has been approved to issue them. As of September 1998, only three states had received federal approval to issue sludge disposal permits. More approvals may have been issued since then.

5.4.5 Pretreatment

Besides regulating the direct discharge to receiving waters and the disposal of sludge, the EPA regulates the indirect disposal of materials (say from industrial dischargers that do not want to obtain NPDES permits) to municipal wastewater treatment facilities or publicly owned treatment works (POTWs). The purpose is

> (a) to prevent the introduction of pollutants into POTWs which will interfere with the operation of a POTW, including interference

[69] 40 CFR 503.17(a)(ii).

> with its use or disposal of municipal sludge; (b) to prevent the introduction of pollutants into POTWs which will pass through the treatment works or otherwise be incompatible with such works; and (c) [t]o improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.[70]

The legal need for pretreatment regulations arises as follows. NPDES permits are issued to POTWs and are legally binding. POTWs receive wastewater from a large variety of sources and will enter into agreements with industrial dischargers to treat their wastewater. While such pretreatment agreements are legally binding, in the absence of pretreatment regulations the industry is protected even if it breaches the agreement and discharges something that will cause the POTW to exceed its NPDES discharge permit. As the NPDES permit holder, the POTW is charged. The pretreatment regulations therefore provide the POTW with the means to enforce pretreatment agreements and to allow recovery from the industry whose discharge actually caused the POTW to violate its permit. The burden is on the POTW to ensure that pretreatment agreements are properly executed in accordance with 40 CFR 403; once executed, such agreements provide the POTW with legal protection.

5.5 Guidance Manuals

The laws and regulations governing wastewater in the United States are detailed, complicated, and extensive. To help dischargers meet their legal obligations, the EPA has prepared guidance manuals for virtually every issue. These manuals attempt to guide dischargers through the legal maze. They range from step-by-step approaches for preparing permit requests to more general information describing the intention of a specific regulation. The guidance manuals do not carry the force of law, as do the acts and their associated regulations. Additionally, because guidance manuals can be prepared only after laws and regulations are amended or updated, the manuals might not always reflect current legal requirements.

5.6 Contrast of U.S. and Canadian Approaches

Although the objectives of the U.S. and Canadian approaches for dealing with wastewater and discharges to the environment are philosophically the same – to

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[70] 40 CFR 403.2.

protect the environment and water resources – they are fundamentally different at a legal level. Legally, the U.S. approach is clearly structured. Federal legislation supersedes state legislation unless the state legislation is more stringent. Regulations promulgated to execute laws have the force of law and are mandatory unless specifically stated otherwise. Permits issued in accordance with regulations, and that meet legal standards, are also legally binding. Violators of permits, standards, regulations, and laws will be punished in accordance with the law.

The U.S. approach follows logically from the U.S. Constitution, which specifically lays out the necessary framework. As an agency of the executive branch of the government, the EPA is legally required to promulgate and enforce regulations required to fulfill the laws passed by Congress. In contrast to Canadian agencies responsible for environmental issues, the EPA has much more legal authority. It is also legally separate from the legislative branch of the government and is headed by a non-elected appointee of the president. The EPA administrator is thus not directly subjected to public whim, which is readily and frequently reflected in the actions of politicians.

Undoubtedly, the U.S. system appears to be less consensual than the Canadian system. U.S. agencies have much legal authority. There are equally powerful counterbalancing forces, however. The budgets of agencies can be approved only by Congress, regulations must be presented for public review prior to promulgation, and regulations are subject to challenge through the court system and can be overthrown if shown to be unconstitutional.

At a practical level, the U.S. system provides much more extensive regulation of wastewater and environmental discharges. Thousands of pages of laws and regulations exist to deal with these issues. This more aggressive approach is probably necessary, however, in a country that has almost 10 times the population of Canada but less land mass and water. While the fundamentally different legal systems of the countries appear to give rise to the differences in approaching wastewater and environmental discharges, the real reason is probably much simpler. Because it has less water for diluting pollutants than Canada does, the United States needs firmer controls to protect water ecosystems and human health. If Canada had the same pressures on its water resources as the United States, more aggressive and effective approaches to wastewater would probably be implemented.

The command-and-control approach of the United States with respect to environmental issues might be appealing to some and less appealing to others.

From the standpoint of punishing polluters and violators, a desirable goal to some, the U.S. system is more effective than the Canadian system. From the standpoint of protecting the environment, the U.S. system occasionally collapses under the weight of its own regulations. One thing should be clear, however. Because the Canadian government is legally much different from the U.S. government, direct importation of the U.S. approach is not possible. While ideas underlying the U.S. approach might be useful, implementation of these ideas in Canada must proceed within the Canadian legal context.

6 European Union

6.1 Structure of EU Regulations

The European Commission holds responsibility for initiating and implementing new European legislation. The Commission, the civil service arm of the EU government, comprises 24 directorates, each of which is responsible for specific areas of EU policy. The Environment Directorate General, which administers water policy, includes this mission statement:

- To maintain and improve the quality of life through a high level of protection of our natural resources, effective risk assessment and management and the timely implementation of Community legislation.

- To foster resource-efficiency in production, consumption and waste disposal measures.

- To integrate environmental concerns into other EU policy areas.

- To promote growth in the EU that takes account of the economic, social and environmental needs both of the citizens and of future generations.

- To address the global challenges facing us notably combating climate change and the international conservation of bio-diversity.

- To ensure that all policies and measures in the above areas are based on a multi-sectoral approach, involve all stakeholders in the process and are communicated in an effective way.[71]

The path to new legislation begins with a proposal from the commission to the Council of Ministers and the European Parliament. For a proposal to become law it must receive approval from both decision-making bodies. This may take several revisions, as each can request modifications to the original proposal. If the council and parliament cannot find agreement, a Conciliation Committee, comprising representatives from both, is charged with finding an acceptable compromise. If the committee fails, the proposal is not adopted into law.

Once a proposal gains joint approval it is passed as an EU directive and published in the *Official Journal of the European Communities*; it becomes law and a deadline is set for the member states to adopt its provisions into their national legislation. The directives implemented by the Environmental Directorate represent the minimum standards that member states of the EU must adopt into their own regulations.

The Environmental Directorate, through its directives, has adopted a policy of integrated water quality management. This unified approach integrates legislation designed to protect consumers with legislation designed to protect and manage source waters. Consumers are protected through The Bathing Water and Drinking Water directives, which deal with water for consumption. Water-source management focuses on two areas: protection of raw-water quality, and control of emissions to surface and groundwater. The new Water Framework Directive, enacted in October 2000, consolidates a series of previous directives passed to ensure good water quality and good habitat for fish life, in addition to ensuring high-quality source water for abstraction. A series of emission control directives limit discharge of wastes and potentially harmful substances to European surface or groundwater. Figure 6-1 illustrates the EU integrated water quality management approach.

In accordance with the objective of this paper to examine wastewater treatment in jurisdictions outside Canada, this chapter explores how EU regulations influence wastewater treatment objectives in the member states. It also examines standards for treated wastewater quality.

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[71] European Union, Environment Directorate General, 2000, *Environment DG Mission* [online], [cited December 2000], <http://europa.eu.int/comm/dgs/environment/mission_en.htm>.

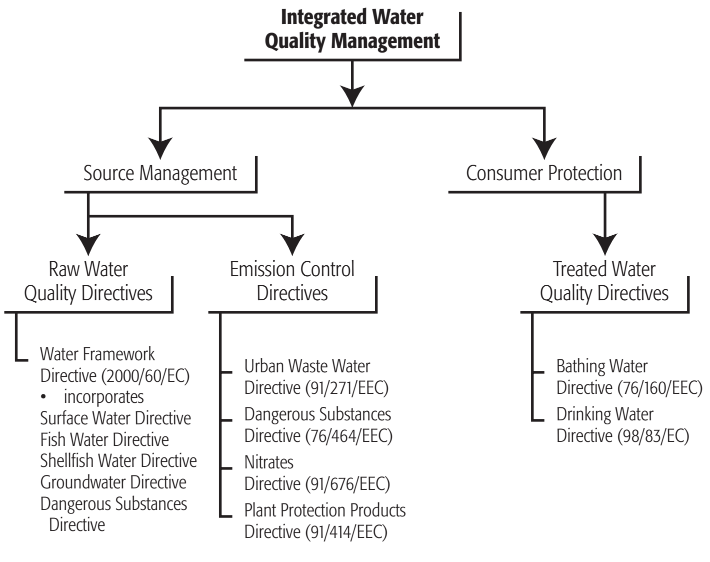
6.2 The Urban Waste Water Treatment Directive

The European Union established the “Council Directive of 21 May 1991 concerning urban wastewater treatment” and the standards to be met. This directive forms the basis for protection of receiving waters in the European Union and on which all member states must set their own standards. Member states may, however, adopt stricter national standards.

The existing EU wastewater treatment and emission control legislation consists principally of the Urban Waste Water Treatment Directive (91/271/EEC) and its amendments.[72] Other water-quality-objective-oriented directives are noted in figure 6-1. Additional directives regulate specific contaminants such as mercury, cadmium, and other listed contaminants.

The Urban Waste Water Treatment Directive (UWWTD) regulates collection, treatment, and discharge of urban wastewater, as well as treatment and discharge of wastewater from certain industrial sectors. The central objective of the directive, laid out in Article 1, is to protect the environment from the adverse

Figure 6-1 EU Integrated Water Quality Management Approach



[72] European Union, 1991, *Urban Waste Water Treatment* [online], directive 91/271/EEC [cited December 2000], <http://europa.eu.int/water/water-urbanwaste/directiv.html>.

effects of wastewater discharges. In addition, the UWWTD is an integral part of the new Water Framework Directive, without any changes to the deadlines set under the 1991 directive.[73]

In general, the UWWTD is non-prescriptive in formulating specific technical rules for the requirements set out. But it is detailed in that it prescribes the general approach that must be followed in providing for wastewater treatment in the European Community, and it prescribes effluent goals, together with the minimum acceptable treatment.

The UWWTD requires that member states complete collection systems for urban wastewater based on population size and specific implementation dates. It also requires that member states implement biological treatment systems, or an equivalent treatment, based on population and implementation dates.

6.2.1 Standards and Obligations

Table 6-1 shows the EU and UK requirements (which are almost identical) for discharges from urban wastewater treatment plants. In general, the requirements are similar to typical Ontario limits for the parameters shown, although Ontario has site-specific cases for which limits are more stringent than the EU standards. In addition, phosphorous is generally limited to a maximum of 1 mg/L on a monthly basis in Ontario and total nitrogen is controlled only in limited cases here. Chemical oxygen demand (COD) is not usually a controlled parameter in Ontario.

The basic EU requirements do not appear to include a general requirement for disinfection, although the Bathing Water Directive has requirements to prevent bacterial contamination. Disinfection appears to be site specific in that it is implemented in key areas – Inverness, Scotland, for example, with a limit of 2,000 fecal coliforms per 100 mL after UV disinfection.[74] In Ontario it is common to have seasonal or year-round disinfection controls.

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[73] European Union, 2000, *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing A Framework for Community Action in the Field of Water Policy* [online], document 300L0060 [cited April 2001], <http://europa.eu.int/eur-lex/en/lif/dat/2000/en_300L0060.html>.

[74] Personal communication with Evangelina Belia of Hydromantis Inc., Hamilton, Ontario (January 2001).

The Urban Waste Water Treatment Directive consists of 20 articles of definitions and conditions. In particular, the directive stipulates that "sensitive areas" require more stringent treatment, including nitrogen and phosphorus controls as shown in table 6-1. Discharges to coastal waters or estuaries may not require the degree of treatment shown in the table. At a minimum, plants in these areas must provide primary treatment, as long as studies demonstrate that the discharges will not adversely affect the environment. Treatment alternatives for small communities with less than 2,000 population equivalent are broader than secondary treatment using biological treatment.[75]

Table 6-1 Requirements for Discharges from Urban Waste Water Treatment Plants in the EU and in the UK

	United Kingdom		European Union	
	Concentration (mg/L)	Minimum reduction (%)	Concentration (mg/L)	Minimum reduction (%)
BOD_5 – inhibited from nitrification	25	70–90	25	70–90
COD	125	75	125	75
Total phosphorus				
(10^4–10^5 p.e.*)	2	80	2	80
>10^5 p.e.)	1	80	1	80
Total nitrogen				
(10^4–10^5 p.e.)	15	70–80	15	70–80
(>10^5 p.e.)	10	70–80	10	70–80
TSS**	-		35	90
(>10^4 p.e.)	-		35	90
(2,000–10^4 p.e.)	-		60	70

Sources: United Kingdom, 1994a, *The Urban Waste Water Treatment* (England and Wales) Regulations 1994 [online], Statutory Instrument no. 2841 [cited December 2000], <www.hmso.gov.uk/si/si1994/Uksi_19942841_en_1.htm>; European Union, 1991.
* p.e. = population equivalent.
** Values given for European Union are optional.

[75] Population equivalent (p.e.) is a term used in wastewater monitoring and treatment. It refers to the amount of oxygen-demanding substances whose oxygen consumption during biodegradation equals the average oxygen demand of the waste water produced by one person. For practical calculations, one unit equals a BOD_5 of 60 g of oxygen per 24 hours.

The *Handbook for Implementation of EU Environmental Legislation* describes the interrelationship of the UWWTD with other legislation.[76] Other key legislation includes

- the Environmental Impact Assessment Directive,
- the Access to Environmental Information Directive,
- the Reporting Directive, and
- the Sewage Sludge Directive.

Member states are responsible for implementing the provisions of the UWWTD, which places specific obligations on the member states, including

- planning,
- regulation,
- monitoring, and
- information and reporting.

The directive requires member states to ensure that treatment plants are designed, constructed, operated, and maintained to meet specified performance requirements by specific target dates. Articles 5.6 and 5.7 require that the identification of sensitive areas needing tertiary treatment (reduction of nitrogen and phosphorus) be reviewed at intervals of not more than four years and made to comply within seven years if identified as sensitive. Article 15 requires that "competent authorities" monitor discharges from urban wastewater treatment plants and that the information be provided to the Commission within six months of receipt of request. The directive also requires that member states publish situation reports every two years on the disposition of urban wastewaters.

Pre-treatment of industrial wastewaters may be required to meet certain limits as defined in Annex I (C) of the directive. The Integrated Pollution Prevention and Control Directive targets pollution from large industries.[77] It is noteworthy that some member states have adopted it directly into their national standards.

Monitoring requirements depend on plant size or population equivalent (see table 6-2).

[76] European Union, European Commission, 2000, *Handbook for Implementation of EU Environmental Legislation* [online], [cited December 2000], <http://europa.eu.int/comm/environment/enlarg/handbook/handbook.htm>.
[77] European Union, 1996, *Council Directive 96/61/EC of 24 September 1996 Concerning Integrated Pollution Prevention and Control* [online], document 396L0061 [cited December 2000], <http://europa.eu.int/eur-lex/en/lif/dat/1996/en_396L0061.html>.

6.3 Member State Legislation and Standards

6.3.1 France

In general, France follows the EU Urban Waste Water Treatment Directive. The French regulation sets the minimum requirements for wastewater treatment in Articles L. 372-1-1 and L. 372-3 of the code des communes (Ministère de l'Environnement) in Decree No. 94-469 of June 3, 1994.

Table 6-3 shows the national standards for wastewater treatment in France.[78] In general the limits are similar to the EU standards. France has established 'not-to-exceed' effluent standards.

6.3.2 Germany

Although Germany has a comprehensive collection of regulations for water and wastewater treatment and disposal, the Federal Water Act is the guideline legislation.[79] Under the act any discharge of wastewater requires permission or a licence. Wastewater may then be discharged into a body of water only if its pollutant content meets recognized technical standards.

Table 6-2 Minimum Monitoring Requirements

Population Equivalent	Number of samples*
2,000–9,999	12 samples during the first year; 4 in subsequent years if it can be shown that the water in the first year complies with the directive; if one sample fails, 12 samples must be taken in the following year
10,000–49,999	12
>50,000	24

Source: European Union, 1991, annex I (D).
• Flow-proportional or time-based 24-hour samples; specific sample conformance criteria are established in annex I of the directive.

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78 Personal communication with Jean-Claude Bourdelot, deputy technical director for sewage, Degremont Inc. (December 2000).
79 Germany, 2000, *Federal Water Act (Wasserhaushaltsgesetz, WHG) – Excerpts* [online] (translation), in the version published on 12 November 1996 (Federal Law Gazette I, p. 1965), most recently amended by an act of 3 May 2000 (Federal Law Gazette I, p. 632) [cited December 2000], <www.iuscomp.org/gla/statutes/WHG.htm>.

The German water laws are a collective term for the federal and state regulations concerning water conservation and management. In federal law they include the acts regulating water management (Water Management Act, the Waste Water Charges Act, and the Washing and Cleansing Agents Act). At the state level the Water Management Act and the Wastewater Charges Act were passed as legislation to implement the federal framework laws.

The Waste Water Charges Act allows authorities to apply levies on discharges to receiving waters that do not meet required standards.[80] Revenues from levies must be used by the states to improve water quality. Levies are based on the volumes discharged, the mass of oxidizable substances (measured as chemical oxygen demand, COD), certain heavy metals and organic halides, and the toxicity of the wastewater to fish. The wastewater charge is an incentive to reduce pollutant loading through preventive measures, namely pre-treatment,

Table 6-3 France – Requirements for Discharges from Urban Waste Water Treatment Plants

Parameter	Loading (kg/d)	Concentration (mg/L)	Minimum reduction (%)	Not to exceed (mg/L)
BOD_5		25	–	50
	120 to 600		70	
	>600		80	
COD		125	75	250
Total phosphorus – sensitive area (10^4–10^5 p.e.)		2	80	
(>10^5 p.e.)		1	80	
Total nitrogen – sensitive area (10^4–10^5 p.e.)		15	70	
(>10^5 p.e.)		10	70	
TSS		35	90	85

Source: J.-C. Bourdelot, Degremont Inc. (2000).
Notes: Population equivalent (p.e.) based on 60 g BOD per person per day; minimum sampling standards mandated with allowable non-conformance samples.

[80] Germany, 1998, *Waste Water Charges Act (Abwasserabgabengesetz, AbwAG) – Excerpts* [online] (translation), in the version published on 3 November 1994 (Federal Law Gazette I, p. 3370), most recently amended by an act of 25 August 1998 (Federal Law Gazette I, p. 2455) [cited December 2000], <www.iuscomp.org/gla/statutes/AbwAG.htm>.

introduction of less-wastewater-intensive production processes, or wastewater-free production methods. Levies have risen annually since 1981. If wastewater production and strength are reduced by preventive measures to a level corresponding to the minimum requirements laid down in the Federal Water Act, or to stricter requirements imposed in the discharge licence, the levies are reduced accordingly.

Table 6-4 shows the German national effluent standards. They are similar to the EU standards, except that, as plant capacity increases, treatment performance must improve to maintain the same mass loading for most parameters on the receiving water. The German standards include ammonium concentration (NH_4-N) as an effluent requirement, in addition to total nitrogen.

6.3.3 United Kingdom (England and Wales) and Scotland

Wastewater treatment is legislated in the United Kingdom under Statutory Instrument 1994 no. 2841 – The Urban Waste Water Treatment (England and

Table 6-4 Germany – National Municipal Effluent Criteria

	Plant size by		Effluent				
	BOD_5 (kg/d)	**Population equivalent** (thousands)	**COD** (mg/L)	**BOD_5** (mg/L)	**NH_4-N** (mg/L)	**TP** (mg/L)	**N_{total}** (mg/L)
1	<60	<1	150	40	-	-	-
2	60–299	1–5	110	25	-	-	-
3	300–1,199	5–20	90	20	10	-	18 [c]
4	1,200–5,999	20–100	90	20	10	2	18 [c]
5	>6,000	>100	75	15	10	1	18 [c]

Source: German Waste Water Charges Act (Abwasserabgabengesetz, AbwAG) (1998), annex to Art. 3, by personal communication from P. Meiler.

N_{total} = NH_3-N + NO_2-N + NO_3-N; applies for biological plant liquid effluent temperatures of 12°C and greater; a time period restriction of May 1 to October 31 could be applied. If N_{total} reduction during treatment is at least 70%, a concentration of 25 mg/L can be approved (instead of the 18 mg/L shown).

Note: In the case of lagoons with HRT >24 hours where the sample contains algae, the COD value is reduced by 15 mg/L and the BOD_5 value by 5 mg/L.

Wales) Regulations. In general, it conforms to the EU UWWTD. Scotland is similarly regulated.[81]

The UK wastewater treatment standards (see table 6-1) are similar to the EU standards, except that suspended solids discharged from wastewater treatment plants are not part of the UK criteria. The United Kingdom provides for more stringent treatment, including nitrogen and phosphorous control, in environmentally sensitive areas that are subject to eutrophication. Formal criteria are established for identification of sensitive areas. Most Ontario wastewater treatment plants, by comparison, have had phosphorous effluent limits for many years.

In the past the United Kingdom allowed reduced treatment criteria (primary treatment) for areas of "high natural dispersion," such as estuaries and coastal areas. However, the government has now moved to a more cautionary approach in these areas and will require secondary treatment for significant coastal discharges.

Other related regulations include Statutory Instrument 1991 no. 1597 – The Bathing Waters (Classification) Regulations, Statutory Instrument 1997 no. 1331 – The Surface Waters (Fishlife) (Classification) Regulations, and Statutory Instrument 1997 No. 1332 – The Surface Waters (Shellfish) (Classification) Regulations. The Bathing Waters Regulations include mandatory criteria for coliform bacteria standards; however, no specific criteria for bacterial contamination have been identified in readily available literature for wastewater discharges. The Surface Waters (Fishlife) Regulations state that more stringent treatment conditions may be included for ammonia removal.

[81] P. Wright, 1992, "The impact of the EC urban waste water treatment directive." *J. IWEM,* vol. 6, p. 675; United Kingdom, 1994b, *The Urban Waste Water Treatment (Scotland) Regulations 1994* [online], Statutory Instrument no. 2842 (s. 144) [cited December 2000], <www.hmso.gov.uk/si/si1994/Uksi_19942842_en_1.htm>.

7 Case Study

7.1 Introduction

In preceding chapters we examine the guidelines, standards, and regulations that apply to wastewater both in Canada and in other jurisdictions. This examination leads to several significant questions: How do regulations influence wastewater treatment? Do different regulatory approaches result in a significantly different quality of effluent? What are the critical influences on production of good and safe effluent?

Many of the factors that influence drinking water production have a similar influence on the treatment of wastewater. Using the case study approach, information was gathered on one of Ontario's major wastewater treatment facilities, the Ashbridges Bay Treatment Plant in Toronto, through a comprehensive questionnaire circulated to the plant management staff.

7.2 Questionnaire

The questionnaire focused on several areas: treatment capacity, staffing and certification, management and best practices, unit processes, plant performance, effluent quality, and cost. The results were then examined to highlight how these factors enable the plant to achieve its fundamental goal of effluent compliance.

Unless otherwise identified, information in this chapter is generated from questionnaire responses.

See appendix 1 for a copy of the questionnaire.

7.3 Wastewater Treatment – Ashbridges Bay Treatment Plant, Toronto

7.3.1 Role of Technology

General Description

The Ashbridges Bay wastewater treatment plant is located at the south end of Leslie Street on the shoreline of Lake Ontario in the City of Toronto. It is the largest of four plants serving the city. In 1999 the plant, serving a population of one million, treated an average of approximately 700 million litres of water per day (ML/d).

The peak flow to the plant in the past year was 2,979 ML/d, equivalent to a peaking factor of approximately 4.2 (peak flow divided by daily average flow) and attributable to rainfall, as portions of the city still use combined sewers. This flow exceeds the 1,636 ML/d peak hydraulic rating of the plant by 82%. In 1999 there were 15 bypass events in which chlorination was the only form of treatment. Bypass flow totalled 2,792 ML in 1999.

Ashbridges Bay is a conventional activated sludge plant (with chemical phosphorus removal) comprising screening, primary sedimentation, aeration, secondary clarification, and chlorine disinfection (see figure 7-1). Treated effluent is returned to Lake Ontario via a submerged outfall.

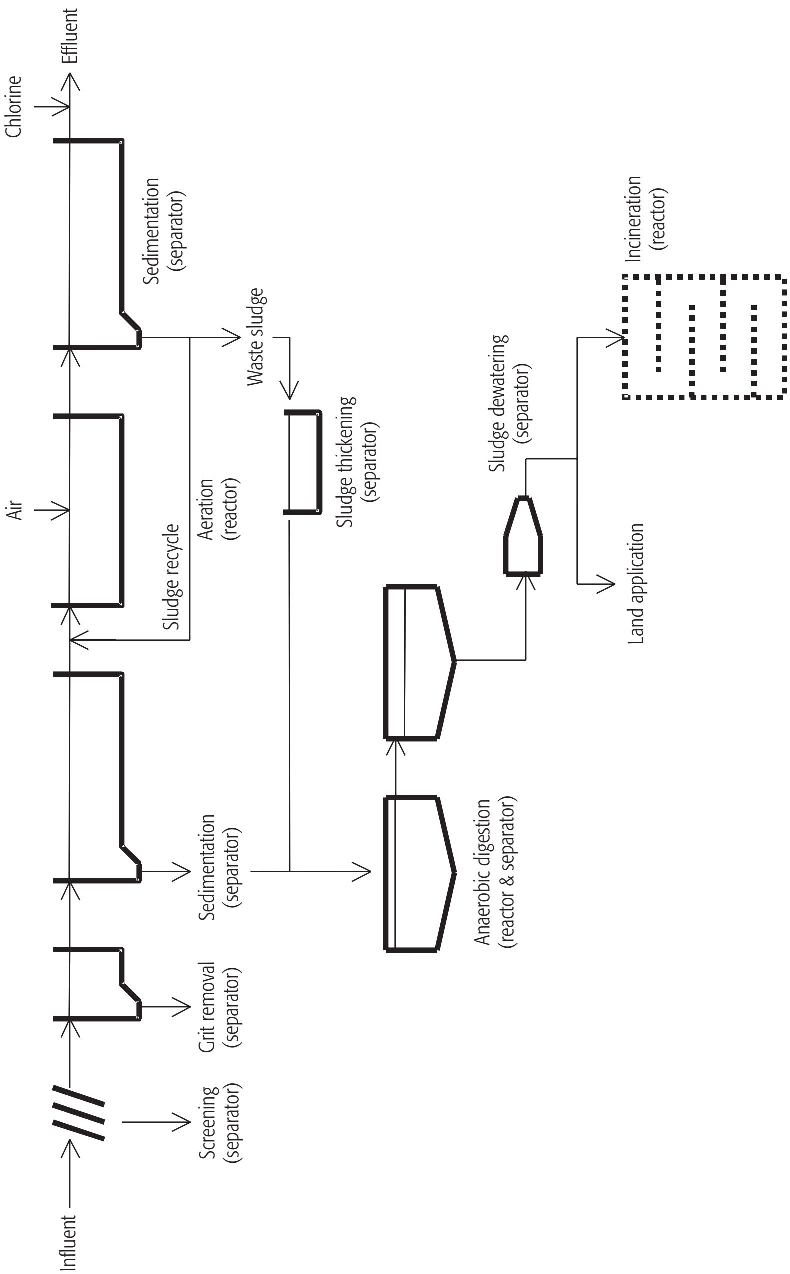
Effluent Criteria and Influent and Effluent Quality

Effluent criteria for the Ashbridges Bay plant are based on the capabilities of a conventional secondary plant. The key point to note is that there is no current requirement for nitrification to effect ammonia removals. Limits for phosphorus have been in place for many years. There are no seasonal differences in any of the parameters.

Influent quality is typical for municipal wastewater, though it is reasonable to suggest that some of the extreme values for suspended solids in particular can be attributed to combined sewer flows during rainfall events. Monitoring of influent parameters is continuous in that flow-proportional samplers are used to collect samples, which are analyzed using batch laboratory techniques.

Effluent quality is considered excellent and significantly better than that normally achievable by a highly loaded conventional activated sludge plant. To some degree this will be a function of the inherent capabilities of the plant, but it is more likely attributable to the actions of the operators and how they respond to changing conditions. At Ashbridges Bay most key actions are not automated because of the complexity and delicacy of the control actions required. Table 7-1 shows water quality parameter values at the Ashbridges Bay plant for 1999.

Figure 7-1 Ashbridges Bay Treatment Plant



Preliminary and Primary Treatment

Screens with relatively small clear openings of 13 mm to remove rags and other floatables are followed by aerated grit channels. Solids removal rates are typical for Ontario plants. The process area is contained and equipped with chemical and ozone oxidation systems for odour control.

Primary sedimentation tanks achieve TSS and BOD removals of 31% and 33%, respectively. Removal efficiencies for TSS in particular are relatively low, but this can be attributed to recycle streams returned to the head of the tanks. Ferrous sulphate is added before the primary tanks for phosphorus removal. The tanks are also covered; off-gases are treated by ozonation and charcoal filters.

Final effluent qualities could not be achieved without the contribution of preliminary and primary treatment, but the facilities lack any remarkable features that might separate Ashbridges Bay from any other typical activated sludge plant. The city's attention to off-gas containment and treatment however, is an important feature of the plant because of its proximity to residential neighbourhoods. Typically, primary tanks are not covered, as they are not normally considered sources of odour, despite the depletion of oxygen.

Aeration

Aeration is carried out in a series of eleven tanks with a four-hour hydraulic retention at average flows, thus earning the classification "high-rate activated

Table 7-1 Water Quality Parameter Values for Ashbridges Bay, 1999

Parameters	Allowable effluent concentration	Influent			Effluent
	max	min	avg	max	avg
Suspended solids – TSS (mg/L)	25	170	306	800	6
Oxygen demand – $CBOD_5$ (mg/L)	25	91	193	353	4
Phosphorus – TP (mg/L)	1.0	3	7	15	0.7
Total nitrogen – TKN (mg/L)		22	39	66	15.2
Ammonia nitrogen – NH_3-N (mg/L)		6		23	11.8
E. coli (count per 100 mL)	200				10

sludge." The plug flow tanks are aerated using coarse bubble diffusers, which are relatively inefficient by most current standards for a plant of this size. Average sludge age, or solids retention time in aeration, is two days – only half the time recommended by the MOE. However, this relatively short time does not adversely affect effluent quality.

To optimize performance during peak hydraulic flows, the tanks can be operated in a step-feed mode, in which inflow is introduced at several points in the aeration tanks, to minimize the loss or washout of biomass from aeration. The operators decide whether to go to step-feed and control the process manually. This feature is an example of good practice for plants subject to high peak flows.

Automatic dissolved oxygen (DO) control of aeration power input is a technology-driven option intended to optimize plant performance and minimize power costs. The concept is not used at Ashbridges Bay, suggesting that complexity and the cost of implementation outweigh the potential benefits.

As an added level of defence against odour, the aeration tanks are covered and the off-gases scrubbed using ozone. Typically, aeration tanks with their positive DO levels are not considered a source of odour

The aeration tanks are not designed for nitrification. At some time in the future, there may be a need to modify the plant and its operation to achieve nitrification in response to more stringent effluent criteria. Fundamentally, nitrification would necessitate an increase in oxygen supply, oxygen transfer efficiencies, and sludge age.

Secondary Clarification

The reported secondary clarifier overflow rate of 54 m3/m2/d exceeds the MOE guidelines by approximately 50%. Regardless, effluent levels are maintained well below both the operational objectives established by the city and the certificate of approval compliance limits. This gives some idea of the level of protection built into the MOE's design guidelines.

Disinfection

Gaseous chlorine is used for effluent disinfection and is now added continously at an average dosage rate of 2.2 mg/L, which is at the low end of the recommended dosage rates from the MOE design guidelines. There is no regulatory requirement for monitoring total coliforms. *E. coli* concentrations, however, are maintained at an average of 10/100 mL versus the 200/100 mL required by the certificate of approval.

Chlorine detention times are reported to be seven minutes at rated capacity, well below the MOE requirement of 30 minutes. It is not clear how detention time is measured, but it is reasonable to assume that, to satisfy the MOE requirement, the plant must rely on additional detention time in the outfall sewer to the lake.

Ashbridges Bay is not subject to a regulatory requirement for dechlorination to achieve a non-toxic effluent, although all new certificates of approval now have such a requirement. The city is currently working toward the installation of UV disinfection systems to address both retention time and toxicity.

Solids Handling and Disposal

Raw primary sludge and thickened waste activated sludge are stabilized in 12 anaerobic digesters fitted with the latest and most efficient form of gas-mixing equipment. Methane gas generated through the digestion process is compressed and re-injected into the covered tank to mix the sludge and maintain a constant optimal temperature throughout. Reported retention times of 10 days are lower than the MOE design guideline of 15 days, but tight regulation of residual contaminants is such that this appears not to be of concern.

Digested biosolids are currently dewatered to a concentration of 27% by weight, producing approximately 180,000 wet tonnes (49,300 t of dry solids) annually. Approximately 60% of the annual production of sludge is incinerated on site. The remaining 40% is disposed of by application to agricultural land.

Although incineration – complete with emission-gas scrubbing and heat reclamation – is deemed good practice in some jurisdictions, it has fallen out of favour in Toronto and will be replaced by the end of 2001 with a pelletization facility. Pelletized biosolids have a dry solids content of approximately 95%, which further reduces volume and makes them more readily reusable as land fertilizer.

7.3.2 Plant Operations

Management Structure

Figure 7-2 shows the current management structure of the plant. In part, the size of the facility is sufficient to warrant its own on-site maintenance and engineering support staff. The on-site plant manager reports to the corporate position of director of water pollution control. The plant manager directs both operations and maintenance staff. Laboratory staff, however, report to the director.

Operating Staff

The plant is staffed continuously from a complement of 275 people mostly assigned to operation and maintenance. A typical weekday shift schedule excluding maintenance and administration staff, is shown in table 7-2, together with a derived and approximate number of person-days required to operate the plant assuming a 40-hour week (8 hours is equivalent to 1 person-day). On average, weekday plant operations excluding maintenance and administration require 68 person-days – equivalent to approximately 10,000 m^3/d/person-day.

Ninety-six operating and supervisory staff at the Ashbridges WWTP have Ontario certification (see table 7-3). Of that number, 38% received their certification through written testing; the other 62% qualified through their years of experience.

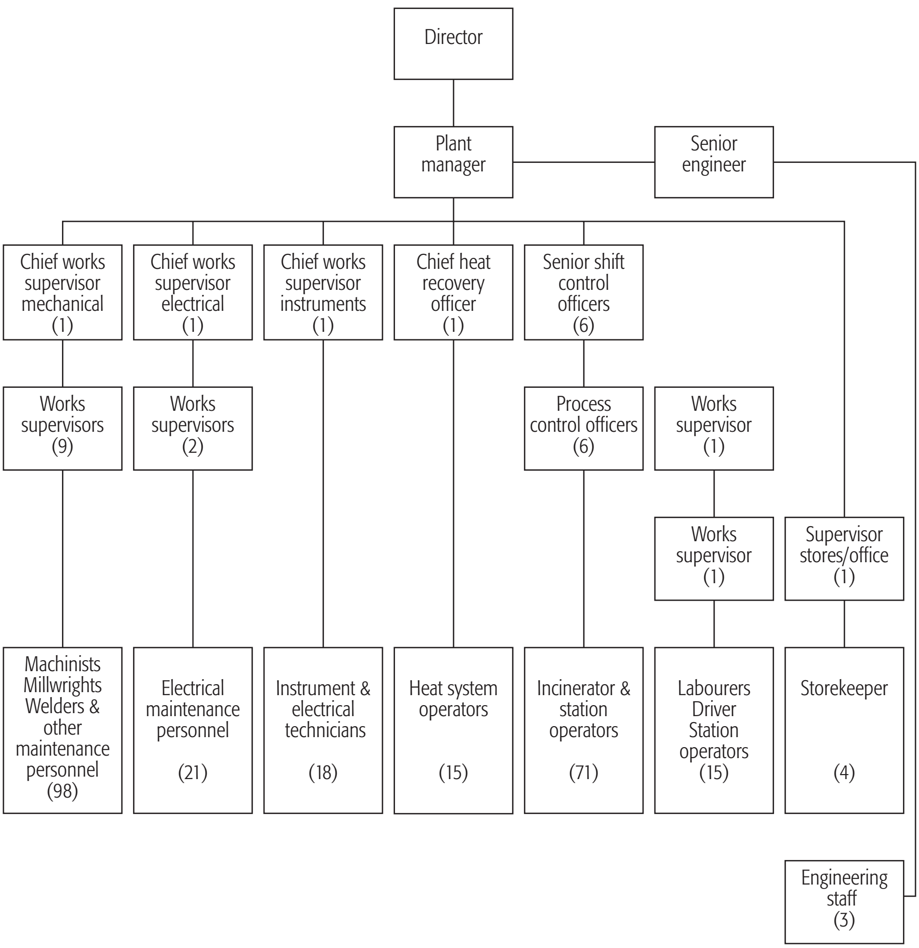
Through its Best Management Practices program the city is currently restructuring its staffing. When restaffing is complete, the picture will differ significantly: the total staff assigned primarily to Ashbridges Bay will be reduced by a third to approximately 185.

Staff training is formalized and ongoing. In 1999 plant staff spent a total of 822 person-days attending 28 in-house and external courses and speciality conferences. Specific operator training is budgeted at 13 eight-hour days per operator in the rotating day-night schedule.

Role of Technology in Plant Operations

Technology has effectively eliminated the concept of hard manual labour from normal operations. This does not necessarily apply, however, to regular or emergency maintenance procedures.

Figure 7-2 Ashbridges Bay Plant Organization



Plant automation has developed rapidly in the past two decades, and Toronto was one of the first in the industry to adopt computerization. By today's standards the early systems were primitive and offered little more than centralized monitoring and remote manual control of equipment. It is a complex subject – there are many levels and types of automation, especially those distributed throughout the plant to control localized equipment-starting and -stopping sequences.

Fundamentally, however, Ashbridges Bay is not an automated plant in the sense of overall process control. Continuous plant supervision is a necessity rather than an option. Under the best management practices program, full automation for process control is currently being studied. This should reduce the required level of direct operator intervention, but how successful it will be remains to be seen.

Table 7-2 Weekday Personnel Complement – Ashbridges Bay

Plant staff	Total	Scheduled		Estimated
		(no. staff day)	(no. staff night)	(person-days per day)
Plant manager	1	1		1
Supervisors*	28	14	2	18
Operators (12-h shifts)	80	15	15	45
Maintenance staff	150			
Laboratory staff	4	4		4
Administration	12			
Total	**275**	**34**	**17**	**68**

* 12 supervisors work 8-h day shifts; the others work 12-h shifts

Table 7-3 Operator Certification – Ashbridges Bay

Certification level	Total	Testing	Experience
I	10	1	9
II	9	4	5
III	24	4	20
IV	53	27	26
Total	**96**	**36**	**60**

Emergency Response Plans

The plant systems and equipment are equipped with all the usual electrical safety devices required by code, and alarm conditions are automatically annunciated and recorded. All process information is alarmed, but no automated process shutdown sequences are initiated by the alarms. Engineering judgment was used in deciding that alarms rather than automated shutdowns provide an adequate level of safety. The operating manual describes the procedures required to operate the plant under abnormal conditions.

There are however, specific written plans for

- evacuation in the event of a chlorine gas leak,
- reportable spills under MOE regulations, and
- odour complaints.

The concept of an emergency plant shutdown in the event of a process failure does not apply to wastewater treatment plants because there is no control over the inflow. Plant design recognizes this fact and provides for progressive reduction in treatment levels as the flow bypasses portions of the plant. For critical processes, the city has tended toward a conservative approach to equipment redundancy – one in service, one standby, one out of service for maintenance. This approach exceeds the generally accepted definition of 'firm capacity' by one additional unit.

In the case of plant bypasses resulting from wet-weather flows, the flow receives a minimum of chlorine disinfection at a dosage rate of 15 mg/L, approximately seven times higher than normal. To further protect the receiving water, the city has constructed a wet-weather detention tank at Ashbridges Bay to store a portion of extreme wet-weather flows. A similar facility currently under construction is known as the Western Beaches Storage Tunnel, which will divert the settled portion of the intercepted wet weather flows to Ashbridges Bay.

Plant Security

Visitors are welcome to the site, but they are required to sign in and sign out when they leave. Visitors must be escorted through enclosed process areas. Visitor safety is the primary reason for limits on access. The security measures also provide some protection against vandalism and theft. Safety in terms of public health is a minor concern.

Quality Management and Best Practices

No formal quality plans are used by the city in operating the plant other than those relating to the reporting requirements defined through regulation. The plant does not have ISO registration. The plant laboratory, however, is accredited, which entails standard quality management requirements.

The Best Management Practices program being implemented by the city will have far-reaching effects on the operation of Ashbridges Bay when complete. Specific programs include

- a computerized maintenance management system (CMMS) to replace the existing program,
- staff restructuring around the "total productive operations – team concept,"
- full automation through a process control system (PCS) to replace the existing computerized remote manual system,
- a laboratory information management system (LIMS), and
- millwright and EICT apprenticeship programs.

7.3.3 Cost of Treatment

Operating costs in 1999 of $38.3 million reflect direct costs to the Ashbridges Bay Plant only. The total cost for wastewater reported in the city's annual report is $169.6 million, which includes all treatment plants, the collection system, management, and debt costs. Corporate or head office costs not assigned to either treatment or collection have been simply prorated on the basis of plant or collection system specific total operating costs. Table 7-4 shows treatment costs at the plant for 1999.

Annual revenues for wastewater services are reported as $237.3 million, a net difference of $67.7 million of revenues over expenses. This positive balance is applied to the capital financing stabilization reserve fund.

8 Considerations for Ontario Wastewater

8.1 Standards

Environmental protection in Ontario, as in many jurisdictions throughout the world, is regulated by a wide range of multi-level government legislation, all of which can have direct influence on the day-to-day operations of a wastewater system. In practice, however, most interaction with government is at the provincial level. A summary of relevant legislation follows.

8.1.1 Federal Government

Canadian Environmental Protection Act

From the perspective of a wastewater operation in Ontario, this act can be viewed as umbrella legislation that deals with a broad range of environmental issues and puts specific restrictions on toxic substances.

Federal Fisheries Act

This act can have a greater provincial influence than might be expected should effluent discharges cause fish kills. It has also been the driving force behind

Table 7-4 Total and Unit Costs of Treatment – Ashbridges Bay, 1999

Category	Operating cost		Total cost [a]	
	($)	($/m^3)	($)	($/m^3)
Electrical power	7,467,091	0.03	7,467,091	0.03
Other energy sources				
Chemicals	4,586,412	0.018	4,586,412	0.018
Sampling & analysis				
Direct labour	16,512,324	0.066	16,512,324	0.066
Corporate charges			12,594,400	0.051
Contracted services	6,894,319	0.028	6,894,319	0.028
Debt repayment			2,699,300	0.011
Other [b]	2,833,556	0.011	2,833,556	0.011
Total	**38,293,702**	**0.154**	**53,587,402**	**0.215**

[a] Derived from annual report (corporate charges and debt repayment prorated).

provincial limits on ammonia nitrogen and free chlorine residuals, for example, because of their toxicity to marine life.

8.1.2 Ontario Provincial Government

Ontario Water Resources Act

The cornerstone of provincial environmental legislation, this act governs all aspects of water and wastewater activities that can otherwise impair the province's water resources. The document *Water Management: Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy,* which embodies the provincial water quality objectives (commonly known as the PWQOs), was derived from this act.

Environmental Protection Act

Under this act, certificates of approval for water and wastewater works are issued, and practical guidelines and procedures have been developed for obtaining approval:

- Guideline F-5, Levels of Treatment for Municipal and Private Sewage Treatment Works Discharging to Surface Waters[82]
- Procedure F-5-1, Determination of Treatment Requirements for Municipal and Private Sewage Treatment Works Discharging to Surface Waters[83]
- Procedure F-5-2, Relaxation of Normal Level of Treatment for Municipal and Private Sewage Works Discharging to Surface Works[84]
- Procedure F-5-3, Derivation of Sewage Treatment Works Effluent Requirements for the Incorporation of Effluent Requirements into Certificates of Approval for New or Expanded Sewage Treatment Works[85]

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[82] Ontario, Ministry of the Environment, 1994e.
[83] Ontario, Ministry of the Environment, [1994c].
[84] Ontario, Ministry of the Environment, [1994g].
[85] Ontario, Ministry of the Environment, [1994a].

- Procedure F-5-5, Determination of Treatment Requirements for Municipal and Private Combined and Partially Separated Sewer Systems[86]
- Procedure F-10, Sampling and Analysis Requirements for Municipal and Private Sewage Treatment Works (Liquid Waste Streams Only)[87]
- Procedure F-10-1, Procedures for Sampling and Analysis Requirements for Municipal and Private Sewage Treatment Works (Liquid Waste Streams Only)[88]
- Procedure F-11, Use of Farm Pollution Advisory Committee[89]

Environmental Bill of Rights

This act has changed the way in which works that may affect the environment are implemented. The public now has the right to know and influence decisions rather than simply receive notice of predetermined outcomes from well-intentioned public officials and their engineering and planning staffs.

Environmental Assessment Act

Working in conjunction with the *Environmental Bill of Rights*, this act establishes clear procedures and requirements for assuring the public that any negative environmental effects of a particular project have been mitigated to the maximum extent possible.

Building Code Act, 1992

Sometimes overlooked when dealing with large-scale projects, this is a valuable tool for regulating the construction of private wastewater disposal systems. For smaller rural communities in particular, it often forms one side of the regulatory

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[86] Ontario, Ministry of the Environment, [1994b].
[87] Ontario, Ministry of the Environment, 1994h.
[88] Ontario, Ministry of the Environment, [1994f].
[89] Ontario, Ministry of the Environment, 1994i.

dividing line in the serious environmental and financial decision as to when private systems must be replaced by a central municipal system.

8.1.3 Municipal Government

Municipal Bylaws

Most municipal bylaws were based on the MOE model bylaw. They play an important and system-specific role in controlling the use of the sewer system, especially by industries whose waste streams might impair treatment plant performance.

8.1.4 Standards in General

In general, these acts of legislation and the regulations born from them have adequate provisions for environmental protection provided they are applied rigorously. It is of interest that there are some fundamental differences between practices and regulation in Ontario and the United States, and it is an open question whether Ontario is leading or lagging by comparison. In the United States the federal level of government, represented by the Environmental Protection Agency (EPA), is perceived as the driving force behind environmental protection, even though in some cases individual state regulations may be more stringent. In Ontario, provincial legislation exerts the greatest influence over wastewater practices.

Historically, the MOE's role extended well beyond regulation and enforcement – to include project development, funding, approvals, project management, operation, operator certification, laboratory services, etc. Without a Canadian federal equivalent of the EPA, this apparent conflict of interest for the MOE compromised its enforcement of legislation. Through government policy the situation is changing, although it remains unclear just how successful the MOE will be in limiting its role to the point where it can vigorously enforce legislation without having to answer charges of conflict of interest. To be seen as having strong environmental policy and being a world leader, Ontario will have to resolve this situation.

The steps to obtaining a certificate of approval for a new discharge are well defined and centre on the definition of appropriate effluent criteria. Such definition is done on a case-by-case basis, which is not significantly different from the way in which permits are obtained in the United States. Establishing effluent criteria that can be defended scientifically is not a simple task, so case-by-case is probably the best method of dealing with the subject. The potential weakness in Ontario, however, is that criteria are established at the MOE district level, which invites inconsistency in the application of the procedures province-wide.

A simple example from the early 1990s was a requirement for UV disinfection, in addition to sedimentation, for stormwater runoff from a new development adjacent to the Rideau River in the City of Nepean. In some respects this may have propelled Ontario to world-leader class. Yet, despite any scientific argument to support the criteria applied in that case, disinfection has not become a routine requirement for separated stormwater discharges operating under similar circumstances.

Similar issues arise for discharges to inland streams, especially where assimilative capacity is limited. In these cases proponents often face the uncertainty of either an MOE directive, usually for a high level of treatment, or the need to carry out complex assimilative capacity studies well beyond what could be reasonably considered the geographical influence of the discharge. This uncertainty could be more a measure of technical complexity than arbitrary decision making, but it seems to point to the need for a province-driven registry of stressed receiving streams, and the management of their respective assimilative capacities. To some extent this sort of assessment has been done – Sixteen-Mile Creek and the Thames River are two good examples. The question arises as to whether the MOE can, or will, continue to provide adequate scientific support for such endeavours and expand the service to include all major receiving streams in the province.

Scientific definition of the effluent mixing zone also has potential for arbitrary decision making. The science of effluent plume dispersion is well documented and becomes an analytical exercise. What is less scientific is the determination of the acceptable size of the plume beyond which the discharge is deemed non-toxic to marine life. The MOE, as the regulator, must dedicate sufficient scientific resources to this subject to achieve province-wide consistency.

Sludge disposal techniques throughout the province are coming under increasing scrutiny, especially as available farmland suitable for land application decreases with urban growth. Ontario regulations differ from those in the United States to the extent that American treatment requirements and sludge quality are more clearly defined. EPA regulations define treatment requirements – together with limits for pathogens, metals, and nutrients – that place biosolids in two separate classes. One of the more important distinctions is that Class A biosolids are deemed suitable for any manner of beneficial use, allowing for their disposal or, preferably, sale for cost recovery at the treatment plant gate. This classification relieves the producer of the responsibility to demonstrate that sufficient assimilative capacity exists at the ultimate disposal site. The approach would seem to have merit for Ontario.

Waste discharges from livestock farming operations are regulated to some extent through the MOE and the Ministry of Agriculture, Farming and Rural Affairs, but to lower standards of enforcement compared to municipal or industrial wastewater. Clearly, there is a need to define when a 'farm,' with its inherent assimilative capacity for wastewater and solids disposal, becomes an 'industry' in which the livestock population exceeds the capacity of the land to accept its waste streams. This issue is linked closely to the need to define separation distances between groundwater wells and farm runoff. The EPA regulations are more definitive than those in use in Ontario.

8.2 Operations and Quality Management

8.2.1 General

Chapter 3 presents the elements and practices that constitute a best-in-class utility or define best management practice. Best practice should be a target for all wastewater utilities, but Ontario's current wastewater practices should not be discounted. Most communities are well served by at least secondary treatment achieving effluent qualities well within regulated limits. This fact, in itself, suggests that Ontario is in relatively good shape.

It is difficult to arrive at a true definition of world leader; it depends on the criteria applied. For example, which is a world leader: a facility that produces treated effluent to the quality limits of its technology, but at a cost, or a plant whose performance just meets the regulated discharge criteria but minimizes consumer cost?

For Ontario to be considered a world leader, utilities must be encouraged to adopt the former course of action, recognizing that their primary mission is to minimize environmental effects to the greatest possible extent. Such encouragement could take several forms, including a regulatory approach to best-practices programs, requirements for periodic optimization, or benchmarking studies. Best practices, however, are driven mainly by people within an organization who are continuously seeking ways to improve its operation. This type of activity is difficult to regulate, and regulation might run the risk of having the opposite effect. A more enlightened approach would be the sponsorship of technical seminars and the dissemination of best-practice achievements throughout the industry.

With respect to best-in-class utility issues and best management practices, there is no fundamental difference between drinking water and wastewater. Best-in-class utilities of both types strive for the same goal of product quality better than regulated limits.

8.2.2 Best Practices for Wastewater Facilities

To achieve the status of world leader, Ontario's utilities should subscribe to formal best-practices programs, in which continuous improvement becomes embedded in their respective operational philosophies. The subject list is extensive and should be tailored to suit the size of the operation. To a large degree the list is also a generic recipe for any successful entity (sections 3.2–3.4 for complete discussion).

Subjects for Best Management Practices:

- wastewater operations:
  - wastewater collection
  - wastewater treatment and maintenance
  - wastewater discharge system
  - water quality management
- business operations:
  - strategic planning
  - capital improvement programs
  - engineering
  - fiscal management
  - facilities management
  - information management systems
  - purchasing and inventory management
- organizational operations:
  - leadership

  - human resource management
  - continuous improvement
  - health and safety, and loss control management
  - emergency planning and response
- customer relations:
  - government relations
  - community relations
  - business relations
  - customer service

8.2.3 Accreditation

ISO (International Organization for Standardization)

Virtually any accreditation or certification related to quality standards would be regarded as a move toward best practice. Certification to ISO standards falls into this category. Standards of performance are defined by the proponent and are periodically audited by an independent agent. A wastewater utility could seek certification to either the ISO9000 (quality) or ISO14000 (environmental) series of standards. However, the key point is that neither series establishes absolute requirements for defining a quality organization. Adopting ISO standards does not in itself guarantee performance quality.

With or without ISO registration, and almost by definition, best-in-class utilities will have quality management programs in place. They will also undertake structured reviews or audits to ensure that they are satisfying their legal and policy-driven responsibilities. The question for Ontario in its desire to be viewed as a world leader, is whether certification to ISO standards should be adopted as a regulated requirement.

The success of ISO registration depends on commitment at all levels within an organization. Its success also depends on the skill of its authors in accurately defining how to manage quality. If commitment is lacking and the quality plan reflects what perhaps should be done rather than what is really done, ISO registration will not achieve its goals. Furthermore, if ISO registration becomes a regulated standard, it runs the risk of becoming a parallel bureaucratic necessity rather than a valuable operating tool.

A preferred approach might be to limit government involvement to the promotion of formal best-practices programs that, by definition, include quality management plans. Whether the plans are designed to suit individual needs or to meet ISO standards is of secondary importance.

Laboratory Accreditation

Effluent compliance monitoring depends for its success on strict adherence to standard analytical methods by laboratories charged with the responsibility. In this case, the standards are not the product of the individual laboratory, which makes accreditation a more meaningful objective.

The Standards Council of Canada (SCC) and the Canadian Association for Environmental Analytical Laboratories (CAEAL) joined forces to develop an accreditation program that complies with ISO/IEC 17025 standards. It is reasonable to require that all compliance testing be conducted by accredited and independent laboratories.

8.3 Technology

Two kinds of demand generally drive development of wastewater treatment technology. The first is the demand for levels of treatment not previously required or considered achievable. The second is the demand for improvements in the performance of existing technology, either to minimize operating cost or to achieve higher quality effluents.

The significance of the former is that the MOE can push municipalities to increasingly higher standards of compliance in the full knowledge that they are attainable based on the concept of best available technology economically achievable (BATEA). The latter opens the possibility of re-rating plants to meet increased loading without major plant expansions. Both factors push Ontario toward exceeding its well-stated water quality goals and objectives. The key is to promote innovation on both of these fronts if Ontario is to be viewed as a world leader.

In practical terms, selection of technology for any given wastewater treatment issue is driven, for the most part, by the engineering profession. In larger municipalities, in-house staff usually play a significant role in this process. Smaller communities rely more on consulting engineering firms.

As simple and straightforward as it seems, this method of selecting technology is actually a departure from the practice of ten to twenty years ago. At that time, the MOE and its predecessor, the Ontario Water Resources Commission, provided a degree of province-wide standardization through its in-house engineering resources to evaluate new technology, followed by the development of standard equipment or technology specifications available for use by anyone involved in water or wastewater projects in the province. This service, together with the certificate of approval process and government funding, gave the MOE enormous influence in the types of technology and design standards used throughout Ontario. For example, pumps not on the MOE "acceptable" list did not make it into pumping stations and treatment plants until such time as the MOE was able to complete its careful technical evaluation.

Many would argue that MOE involvement at that level had its downsides. One of the more obvious was the MOE's tendency toward conservatism and a reluctance to embrace innovative technology and ideas. At the same time, it could be argued that the engineering fraternity, which now guides decisions without MOE oversight, is no less conservative, strictly by virtue of training and professional responsibilities.

In section 4.8 several emerging technologies are presented. In the case of UV disinfection and membranes, for example, Ontario firms are viewed as world leaders. It is purely speculative to suggest that their success to date could be attributed to the declining influence of MOE. The counterargument is that MOE has been a positive influence, through regulating non-toxic standards for final effluent quality. As a result, UV disinfection became common practice in a relatively short period of time. Similarly, the imposition of tertiary effluent criteria has led to the increasing inclusion of membranes in the evaluation of technology options.

Ontario's need to be viewed as a world leader in technology may be more a question of broad economic development policy and, as such, beyond the scope of this paper. There are also many ways in which that perception of world leader can be applied. Had the MOE continued to exert its influence in technology selection, there is reason to suggest that Ontario could have been well represented beyond its borders, as a leader in technology evaluation and standardization, for example. Whether or not this would have been a worthwhile objective has been overshadowed by the need to separate the role of regulator from operator, which spawned the formation of the Ontario Clean Water Agency (OCWA). Because the OCWA now competes with the private sector for project management and operations contracts, it seems unlikely that it will take on the MOE's former role in technology leadership.

If leadership in technology is considered important and no longer a government or quasi-government responsibility, the logical choice is for the private sector to take the lead. Apart from any government-backed financial incentives that might apply, the local wastewater industry needs support and encouragement to develop technology that will be evaluated on its merits by owners and engineers on the basis of BATEA. A practical first step would be to eliminate the detailed documentation of technology (type, rating, number of units, etc.) from certificates of approval. In doing so, the MOE would separate itself from regulating how effluent compliance is achieved and thereby leave itself in a better position to enforce penalties for non-compliance.

Such a departure would be consistent with the MOE's professed role as regulator, in which effluent quality and contaminant loadings are its primary concerns. An equally important role for the MOE might be to support Ontario industry by carefully and progressively tightening effluent quality standards in response to BATEA innovation.

Appendix 1 Wastewater Treatment Survey

Treatment Facility		
Information by:		Title:
Date:		

Type of Plant	Primary Treatment	
Any other descriptive information?		

Treatment Capacity			**Specific Comments?**
Rating	m^3/d		
Peak hydraulic capacity	m^3/d		
Avg daily flow	m^3/d – past year		
Peak daily flow	m^3/d – past year		
Population served			
Bypass events	total – past year		
Avg duration	hrs		
Total volume	m^3 as	of total plant flow	
Any comments on capacity?			

Organization Structure - use following table to construct O&M org chart or attach separately

Any other comments on organization structure?

Plant Supervision - use following table to describe typical weekly shift

	Weekday 1	Weekday 1	Weekday 1	Weekday 1	Weekday 1	Weekday 1	Weekday 1	Weekday 1
Times								
Plant Manager								
No. Supervisors								
No. Operators								
No. Maintenance staff								
No. Laboratory staff								
No.								

Any other comments on plant coverage?

Staff - assigned primarily to the operation of this facility			**Specific Comments?**		
Number of staff					
Plant Manager					
Supervisors					
Operators					
Maintenance staff					
Laboratory staff					
Admin & Clerical					
Ontario Certification	Written Testing	Experience	**Other Jurisdictions**	Written Testing	Experience
Operators-in-training					
Operators Level I					
Operators Level II					
Operators Level III					
Operators Level IV					

Training – past year	Courses Attended	Staff Attendance	Total Time	**Specific Comments?**
In-house courses	No.	No.	Hours	
External courses	No.	No.	Hours	
Specialty conferences	No.	No.	Hours	
Occupational Health & Safety – past year				
Reported incidents	No.	Days lost		
Contracted Services - services contracted outside the operating authority				Contract Value

Plant Operations

Emergency Response Plans **Specific Comments?**

Do you use any automated alarm-driven sequences for plant or process shutdown designed to specifically protect water quality?

If 'Yes' - describe >

Do your operating manuals define any manually controlled alarm-driven sequences for plant or process shutdown designed to specifically protect water quality?

If 'Yes' - describe >

Describe any other emergency response procedures contained in operating manuals or posted instructions

Non-Staff Plant Access	Unrestricted	Informal	Sign in/out	Escorted	Doors Alarmed
Site	☐	☐	☐	☐	☐
Process areas	☐	☐	☐	☐	☐
Maintenance & Storage	☐	☐	☐	☐	☐
Administration	☐	☐	☐	☐	☐

Role of Technology	
Which description bests fits the plant control system?	Fully automated plant computer interface
Do you use Computerized Maintenance Management Systems (CMMS)?	Yes
Do you use Geographical Information Systems (GIS)?	Yes
Any comments on this subject?	

Quality Management	
Do you have a written Quality Management plan?	**Specific Comments?**
If 'Yes' – name >	
Subjects covered >	
Do you have designated Quality Manager(s)?	
If 'Yes' – reports to > Director	
Does your plant or water supply have ISO designation?	
If 'Yes' – designation >	
Do you have in-house laboratory services?	
If 'Yes' – is it accredited Accredited	
Do you undertake formal consumer satisfaction surveys?	
If 'Yes' – describe >	
Do you sponsor or invite community and consumer awareness and involvement programmes?	
If 'Yes' – describe >	

Best Management Practices		**Specific Comments?**
Risk Assessment		
Have you undertaken risk assessments on factors that may affect effluent quality and safety?		
Statistical definition	Describe	
How do you use historical effluent quality data?		
Systematic review to determine trends	Describe	
Benchmarking		
If 'Yes' – within last > years		
Other BMP initiatives		

Treatment Costs	Year	Per m^3	**Specific Comments?**
Electrical power			
Other energy sources			
Chemicals			
Sampling & analysis			
Direct labour			
Corporate charges			
Contracted services			
Debt repayment			
Other			
Total			

Plant Performance and Technical Data

Effluent Criteria	Compliance		Operating Objective		
	winter	summer	winter	summer	
Suspended solids – TSS					mg/L
Oxygen Demand – $CBOD_5$					mg/L
Phosphorus – TP					mg/L
Total nitrogen – TKN					mg/L
Ammonia nitrogen – NH_3-N					mg/L
E-Coli					per 100 mL
Total coliforms					per 100 mL
Any comments on effluent criteria?					

Influent Quality	Avg	Min	Max	Data from past year	
Suspended solids – TSS				mg/L	Continuous on-line
Oxygen Demand – $CBOD_5$				mg/L	Continuous on-line
Phosphorus – TP				mg/L	Continuous on-line
Total nitrogen – TKN				mg/L	Continuous on-line
Ammonia nitrogen – NH_3-N				mg/L	Continuous on-line
Temperature – ˚C				˚C	Continuous on-line
Any comments on influent quality?					

Preliminary Treatment	Comminutors	Screens	Grit Removal	**Specific Comments?**
Type	None	Manually cleaned	Aerated grit chamber	
Bar clearance		mm		
Volume solids		tonnes p.a.	tonnes p.a.	
Method of disposal		Landfill	Landfill	
Odour control		Air exchange	Air exchange	
Any comments on preliminary treatment?				

Primary Treatment	Rectangular sedimentation	
Number of tanks		
Overflow rate	m/hr at plant rating	
Hydraulic retention	hr at plant rating	
Removal efficiency – %	SS	BOD – average over past year

Sludge concentration		– average over past year		
Odour control	Air exchange			
Any comments on primary treatment?				

Chemical Feed	- use data from past year			
Chemical Phosphorus	Ferric Chloride	Continuous	Flow paced	
dosage rate – mg/L	Avg	Max	Min	litres in past year
Other?		Continuous	Flow paced	
dosage rate – mg/L	Avg	Max	Min	litres in past year
How do you set coagulant dosage rates?		Jar tests		
Any comments on chemical systems?				

Aeration	Mechanical	Complete mix
Number of tanks		
Step feed capability	No	
Hydraulic retention	hrs at plant rating	
Aeration power input		
Aeration control	Auto flow proportional	D.O. probes
Nitrification	Not designed for nitrification	
Mixed liquor solids	mg/L summer	mg/L winter
Average sludge age	days over past year	
Odour control	None	
Any comments on aeration?		

Secondary Settling	Rectangular sedimentation
Number of tanks	
Overflow rate	$L/m^2 \cdot s$ at peak plant rating
Hydraulic retention	hr at plant rating
Any comments on clarification?	

Tertiary Filtration	Not required			**Specific Comments?**
Number of filters				
Filter rate		m/hr at design rating		
Total surface area		m^2		
Layer	No.1	No.1	No.1	
Type	Sand	Sand	Sand	
Bed depth	mm	mm	mm	
Effective size	mm	mm	mm	
Any comments on filtration?				

Disinfection	Gaseous chlorine	Continuous	Flow paced	
Dosage rate	Avg	mg/L		litres in past year
Retention time		mins at rated capacity		
De-chlorination	Not required			
Any comments on disinfection?				

Effluent Quality - use data from past year

Suspended solids – TSS	Avg	mg/L		
Oxygen Demand – $CBOD_5$	Avg	mg/L		
Phosphorus – TP	Avg	mg/L		
Total nitrogen – TKN	Avg	mg/L		
Ammonia nitrogen – NH_3-N	Avg	mg/L		
E-Coli	Avg	per 100 mL		
Total coliforms	Avg	per 100 mL		
Microbiological	Grab samples	E-coli ☐	TC ☐	HPC ☐
	Sampling frequency	Daily	Daily	Daily
Any comments on effluent quality?				

Sludge Treatment	Anaerobic digestion		**Specific Comments?**
Number of tanks	primaries		secondaries
Tank volume	total m^3		total m^3
Retention time	days		days
Mixing	Mechanical W/m^3	Mechanical	W/m^3
Aeration	Mechanical	Mechanical	
Any comments on sludge treatment?			

Sludge Thickening & Dewatering		
Sludge conditioning	☐	Heat treatment
		Avg % solids
Gravity thickening	☐	
Dissolved air flotation	☐	
Rotary drum screen	☐	
Belt filter press	☐	
Plate & Frame press	☐	
Centrifuge	☐	
Other – describe	☐	

Sludge Disposal		Annual Volume
Incineration	☐	tonnes dry solids
Landfill	☐	tonnes dry solids
Land spreading	☐	tonnes dry solids
Composting	☐	tonnes dry solids
Pelletization	☐	tonnes dry solids
Other – describe	☐	tonnes dry solids
Any comments on sludge diposal?		

Any comments on any other subject that may help describe your operations?

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