UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

CIVIL ACTION NUMBER 98-10267

UNITED STATES OF AMERICA
v.

MASSACHUSETTS WATER RESOURCES AUTHORITY,
and METROPOLITAN DISTRICT COMMISSION

MEMORANDUM AND ORDER ON A MOTION BY
THE UNITED STATES FOR AN ORDER OF INJUNCTIVE RELIEF

May 5, 2000

STEARNS, D.J.

On February 12, 1998, the United States, on behalf of the federal Environmental Protection Agency ("EPA"), brought this enforcement action against the Massachusetts Water Resources Authority ("MWRA") and the Metropolitan District Commission ("MDC")[1], alleging violations of the Safe Drinking Water Act ("SDWA"), 42 U.S.C. §§ 300f, et seq., and EPA's Surface Water Treatment Rule ("SWTR"), 40 C.F.R. Part 141. The United States seeks injunctive relief in the form of an order requiring the MWRA to build a filtration plant to treat the water that it draws from the Wachusett Reservoir to supply the metropolitan Boston area.

[1]The United States has named the MDC as a party because of its control of the Wachusett Reservoir and portions of the adjacent watershed. The United States maintains that the MDC is a necessary party within the meaning of Fed.R.Civ.P. 19 because without it "complete relief cannot be accorded." The Complaint does not allege that the MDC is in violation of any federal or state statute or regulation. On April 11, 2000, the MDC filed a "post-trial" motion to dismiss maintaining that "the evidence adduced at trial negates any notion that its presence [in this lawsuit] is either necessary or indispensable for the resolution of the single issue before this court." MDC's Memorandum, at 1 n.1.

The MWRA initially maintained that because the Massachusetts Department of Environmental Protection ("DEP"), the primary agency responsible for enforcement of the SWTR, had determined that it was in compliance with the SWTR's filtration avoidance criteria, it could not be compelled by the EPA to filter its water. The MWRA proposed instead to treat its water with ozone, which coupled with aggressive watershed protection and an accelerated program to replace aging pipes, the MWRA believed to be a more cost-efficient alternative to filtration. The MWRA conceded that subsequent to the DEP's determination (and after the filing of its initial brief), it fell, albeit narrowly, out of compliance with the fecal coliform avoidance criterion (one of the eleven filtration avoidance criteria specified by the SWTR). The EPA immediately renewed its request for a filtration order, arguing that the SWTR admits only a filtration remedy for a compliance violation, no matter what its magnitude. The MWRA took the position that because the SDWA, § 42 U.S.C. § 300g-3(b), authorizes a district court to enforce compliance with the SWTR by entering "such judgment as protection of public health may require," the court's power to fashion a remedy for a compliance violation is more flexible than the enforcement mandate conferred by Congress on the EPA.

In a written opinion, the court agreed with the MWRA that "the SDWA does not deprive a court of discretion in fashioning remedies for a violation of the SWTR." See United States v. MWRA, 48 F. Supp.2d 65, 72 (D. Mass. 1999). After the Court of Appeals rejected the EPA's petition for interlocutory review of the court's determination,twenty-four days of evidentiary hearings were held to consider the EPA's request for injunctive relief. Twenty-three witnesses, mostly experts, testified and 524 exhibits were entered in evidence. Final arguments were held on April 14, 2000. The court agreed to the parties'

request that it expedite its decision for release on May 5, 2000, so that there would be no delay in the construction of the planned new treatment facility.

This self-imposed deadline has aspects both good and bad. On the positive side, this opinion is much shorter than it would otherwise have been. There is, however, a lingering fear, that in reviewing the mass of testimony and exhibits offered during the trial, I may have missed something truly important. As a prophylaxis, I have used the very thorough suggested findings submitted by the parties as a cross-check on my evaluation of the evidence. I have read the transcripts of the witness testimony and, to the extent humanly possibly in so short a time, the tens of thousand pages of trial exhibits.

What follows is not a conventional finding of facts. I have not selected one version of a contested fact over another based on any assignment of the burden of proof. Burdens of proof, while they work well in resolving most legal disputes, do not easily lend themselves to the resolution of scientific controversies. Science, by and large, rejects binary decision making in favor of a more nuanced quest for understanding. While a scientist might testify that a supposed fact has been proven to be false, the same scientist, when asked about conflicting data, will say only that an asserted fact has not been disproven or "falsified," and could therefore "possibly" be true. In this decision, I relate those facts, including those that are in dispute, that fall within what I consider to be a reasonable range of possibility, indicating where appropriate the facts that I believe were shown to enjoy the greater empirical support or reflected the thinking of witnesses whom I found especially credible.

I will incorporate the rulings of law made in United States v. MWRA, supra. No subsequent decision of a higher court has caused me to doubt their essential correctness.[2]

> While there is no doubt that Congress, in enacting a statute, "may intervene and guide or control the exercise of the courts' discretion," its decision to do so is not to be "lightly assume[d]," especially in the absence of a clear legislative command. Weinberger v. Romero-Barcelo, 456 U.S. 305, 313 (1982). "Unless a statute in so many words, or by a necessary and inescapable inference, restricts the court's jurisdiction in equity, the full scope of that jurisdiction is to be recognized and applied. 'The great principles of equity, securing complete justice, should not be yielded to light inferences or doubtful construction.'" Id., quoting from Porter v. Warner Holding Co., 328 U.S. 395, 398 (1946).
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> The most explicit Congressional statement clarifying the intent of § 300g-3(b) [providing for judicial review of regulatory orders of the EPA Administrator] appears in the House Conference Committee Report on the 1974 enactment of the SDWA. The Conference Report states that:
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> > [t]he Committee intends that courts which are considering remedies in enforcement actions under this section are not to apply traditional balancing principles used by equity courts. Rather they are directed to give utmost weight to the Committee's paramount objective of providing maximum feasible protection of the public health.
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> H.R.Conf. Rep. No. 93-1185, at 23 (1974).
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> In emphasizing its overriding goal of protecting the public health, Congress did not, however, say that a court was to limit itself to mechanical enforcement of EPA compliance orders. Had it been Congress's intent to strip the courts of their equitable powers, one would think that it would have drafted § 300g-3(b) to say so, for example, by imposing the same narrow mandate on the courts that it imposed on the EPA in § 300g-1(b)(7)(C)(i). Instead Congress used language descriptive of the traditional powers of a court of chancery. Why Congress might not have wanted to eliminate judicial discretion in ordering compliance with the SDWA is not difficult to imagine. Technology evolves more rapidly than typically does legislation, and there is an inherent danger in attempting to legislate today's science

[2]One case possibly lends additional support to my original rulings. In a somewhat different context, the Supreme Court recently observed that "a federal judge sitting as chancellor is not mechanicallyobligated to grant an injunction for every violation of [an environmental] law." Friends of the Earth v. Laidlaw Environmental Services (TOC), Inc., ___ U.S. ___, 120 S.Ct. 693, 710 (2000), quoting Romero-Barcelo, supra, at 313.

> as the foreordained solution for tomorrow's problems. Congress may also have been concerned that an overly rigid application of the filtration mandate by the EPA might result in a wasteful expenditure of finite public funds to correct ***de minimis*** problems, or even exacerbate problems that the legislators had not foreseen. Cf. United States v. City of San Diego, 1994 WL 521216, at 8 (S.D.Cal. 1994); 33 U.S.C. § 1311(j)(5). In sum, while the issue is by no means open and shut, I agree with the MWRA that the SDWA does not deprive a court of discretion in fashioning remedies for a violation of the SWTR.

48 F. Supp. 2d at 71-72.

The opinion will proceed as follows. I begin with a brief history of Boston's water supply, followed by a discourse on the pathogenic threats that influence contemporary thinking about the safety of the nation's drinking water. I then describe the legal and regulatory framework intended by Congress and the EPA to insure the health of public water supplies. I follow with a discussion of the MWRA distribution system and the watersheds from which it draws its water. Finally, I assess the current quality of MWRA water and the differing approaches of the MWRA and the EPA to the issue of preserving its safety.

I. HISTORICAL BACKGROUND

Colonial Boston drew its water from underground wells and rain-fed cisterns. Ex. 291, at 3-2. By the end of the eighteenth century, consumption began to outstrip the increasingly contaminated supply of natural water. Fern L. Nesson, Great Waters: A History of Boston's Water Supply 112 (1983) ("Nesson"). In 1796, a privately chartered company, the Aqueduct Corporation, sought to profit from the demand for clean water by building a network of gravity-fed, underground wooden pipes connecting Boston to Jamaica Pond. The company's efforts, however, did little to slake a rapacious public thirst. Ex. 291, at 3-1.

Public officials ineffectually debated Boston's water problem for several decades without achieving a consensus. In 1845, a frustrated Boston Water Committee turned to John Jervis, the engineer who built New York City's Croton aqueducts, for advice.[3] Ex. 291, at 3-1. Jervis recommended that an aqueduct be built to carry water from Long Pond (Lake Cochituate) in Natick to a holding reservoir in Brookline. The City Council endorsed Jervis' proposal, and in 1846, the General Court passed the Boston Water Act. The Act established a three-member Cochituate Water Board, and authorized the issuance of $3,000,000 in public bonds. In 1848, the Cochituate water system, capable of delivering 18 million gallons daily of fresh water, was opened.[4]

As indoor plumbing became more commonplace, the demand for water increased accordingly. In 1851, the Cochituate Water Board purchased the Aqueduct

[3]Jervis was at the time acclaimed as "America's foremost water supply engineer." Nesson, at 4.

[4]According to Nesson, the work of the Cochituate Water Board was so irreproachable that in 1851 the City Council gave it sole responsibility for operating the municipal water system, thus beginning Boston's tradition of relying on nonpoliticalwater managers. Nesson, at 7-8.

Corporation and connected the Jamaica Pond waterworks to the Cochituate system. In 1865, the Board began construction of a 731 million gallon reservoir at Chestnut Hill to serve a population now in excess of 175,000. Ex. 316, Att. 3, at 114. In 1878, the Board added six small reservoirs fed by the Sudbury River to the system. Ex. 291, at 3-1.

By the 1890's, Boston and its burgeoning suburbs were again experiencing severe water shortages. In 1893, the Legislature ordered the State Board of Public Health to explore the feasability of a permanent solution. In 1895, Frederic Pike Stearns,[5] the Board's chief engineer, saw such a solution in the pristine watersheds to the west of Boston.[6] He recommended that the south branch of the Nashua River be dammed to create a 63 billion gallon reservoir in Clinton, Massachusetts (the Wachusett Reservoir).

> Stearns based his recommendations on three contemporary factors: the sparsity of settlement and industry in the Nashua watershed, the relative purity of the water (which would improve through long storage in a large reservoir), and the availability of a supply propelled by gravity rather than pumping.

Nesson, at 21. Stearns also urged that a unified water district encompassingthe greater Boston metropolitan area be created. After devising a fee-sharing formula based on real estate values and population size, the Legislature adopted Stearns' proposals, and in

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[5]While I would like to claim Frederic Stearns as a relation, he is not.

[6]In his Board of Health report, Stearns lyrically wrote:

> the chain of the metropolitan water supplies to the valley of the Nashua will settle forever the future water policy of the district; for a comparatively inexpensive conduit can be constructed through to the valley of the Ware River and beyond the Ware River lies the valley of the Swift, and, in a future so far distant that we do not venture to give a date to it, are portions of the Westfield and Deerfield rivers, capable, when united, of furnishing a supply of the best water for a municipality larger than any now found in the world.

Nesson, at 21-22.

1895 created the Metropolitan Water District.[7] Interestingly enough, the political resolve that led to the adoption of Stearns' plan was heavily influenced by a distrust of filtered drinking water.

> The virtues of avoiding filtration seemed self-evident in 1895. Filtration had worked under experimental conditions, but it was too new and involved technology that could malfunction. Disruptions in water flow and the serious consequences of polluted water supply were thought best avoided altogether.

Id., at 32.

The newly-established Metropolitan Water Board purchased 4,100 acres of land in West Boylston and Clinton as the site for the new reservoir, together with 5,600 acres of the adjacent watershed. The Wachusett Reservoir, in its day the largest man-made reservoir in the world, was completed in 1906 under Stearns' oversight. Ex. 395, at 4-2. The Wachusett Reservoir was connected by two massive aqueducts, deliberately over-engineered to accommodate future expansion, to the Sudbury system and the Chestnut Hill Reservoir. Ex. 291, at 3-2.

[7]Stearns recommended that a Metropolitan Water District include the following communities: Arlington, Belmont, Boston, Brookline, Cambridge, Chelsea, Everett, Hyde Park, Lexington, Lynn, Malden, Medford, Melrose, Milton, Nahant, Newton, Quincy, Revere, Saugus, Somerville, Stoneham, Swampscott, Wakefield, Waltham, Watertown, Winchester, Winthrop and Woburn. These communities are the core of the present-day MWRA system.

In 1922, Henry Goodnough, Stearns' successor, recommended the construction of a reservoir on the Swift River to collect its flood flows. He also proposed to channel flood water from the Ware River through a gravity-operated aqueduct to the Wachusett Reservoir. (Both of these projects had been originally conceived by Stearns in his master plan).[8] X. H. Goodnough, ***Proposed Extension of the Metropolitan Water District***, Journal of N.E. Water Works Ass'n, June 1922, at 254. In 1926, the State Board of Public Health and the rechristened Metropolitan Water and Sewerage Board embarked on the second stage of Stearns' visionary scheme. Ex. 291, at 3-2. Despite fierce opposition from the four towns that were to be flooded, the Ware River Supply Act was passed on May 29, 1926, authorizing the construction of the Wachusett-Coldbrook Tunnel. See 1926 Mass. Acts, ch. 35. The Swift River Act followed on April 26, 1927, extending the tunnel to the Swift River. See 1927 Mass. Acts, ch. 111. The Ware River aqueduct was completed in 1931, and the Swift River Reservoir in 1939 (later rebaptized as the Quabbin Reservoir). Because of its size, the Quabbin Reservoir took seven years to fill. Eighteen miles long, with a holding capacity of 412 billion gallons of water, the Quabbin remains one of the largest man-made reservoirs in the world. Ex. 291, at 3-3.[9]

[8]Goodnough also recommended abandoning the deteriorating Sudbury and Cochituate systems rather than attempt to salvage their water by filtering it. Goodnough, like Stearns, was an adamant opponent of filtration because of his concern that technological failure or human error might accidently release polluted water into the public supply. Nesson, at 43.

[9]The American Society of Civil Engineers described the fulfillment of Stearns' plan as "probably the most noteworthy series of waterworks structures in the United States; foremost not altogether in size, but in perfection of detail and the embodiment of the best practices in hydraulic engineering." Ex. 316, Att. 3, at 117.

After years of intervening neglect, the Legislature in 1985 created the MWRA.[10] MacDonald, 1:25. The enabling statute established an MWRA Advisory Board consisting of representatives of each of the cities and towns in the MWRA's service area.[11] MacDonald, 2:12. The MWRA is responsible for maintaining 130 miles of aqueducts and 265 miles of water mains. Ex. 291, at 3-15. The constituent cities and towns are in turn responsible for maintaining the 6,700 miles of service pipes within their boundaries.[12] Id. The MWRA is funded by annual charges assessed to the member communities based on water use. Id. The member communities, however, set water rates for their residents. The MDC is responsible for monitoring the quality of water entering the MWRA system, and for managing the Wachusett, Quabbin and Ware watersheds. Ex. 291, at 3-15. The MWRA reimburses the MDC for the costs of watershed protection, and services the debt incurred by the MDC's watershed land acquisition program. Estes-Smargiassi, 2:103.

II. PATHOGENS AND TESTING METHODS

[10]The impetus came from the federal court, specifically from Judge Mazzone, who had assumed judicial oversight of the Boston Harbor clean-up.

[11]The Advisory Board also includes designated members from the Massachusetts Metropolitan Planning Council and several environmental groups. Id.

[12]Approximately 2_ million people receive their water through the MWRA system. Id., 3-14.

The earliest recognized microbiological contaminants[13] of drinking water were the ***Rickettsia*** and ***Vibro cholerae*** bacteria[14] responsible for outbreaks of typhoid and cholera in the Dickensian urban conditions associated with the nascent Industrial Revolution. Because most bacteria thrive in the intestinal tract, they are often spread by fecal-oral contamination. Bacteria have relatively short lives and are highly susceptible to oxidizing disinfectants like chlorine and ozone. Some pathogenic bacteria like ***Legionella*** (associated with Legionnaire's Disease) and ***Mycobacterium avium*** (associated with opportunistic infections in immunocompromised individuals) occur naturally in the environment and breed prolifically in plumbing systems. They can also grow in water distribution systems. Rose, 12:129.

Viruses are a second microbiological contaminant that pose a threat to the public drinking water supply. The smallest of the pathogens, viruses have no independent metabolism and are only able to reproduce by parasitically invading a host cell and using its genetic material to replicate. Those that are known to cause waterborne disease in humans are the so-called enteric (intestinal) viruses associated with acute gastroenteritis. Although more resistant than bacteria, viruses are vulnerable to disinfectants.

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[13]By category these include bacteria, viruses, and protozoa. Dr. Joan Rose, the EPA's principal expert witness on the subject of microbiologicalpathogens, also testified to a number of "emerging pathogens" that EPA lists as potential environmentalconcerns. Among these are the bacteria ***Campylobacter***, ***Salmonella***, ***Escherichia coli ("E. coli")*** and ***Helicobacter pylori***, the viruses Coxsackie B and Hepatitis A, and the protozoa ***Cyclospora*** and ***Toxpolasma***. Most of these "emerging" pathogens are not associated with waterborne disease and are readily inactivated by chlorine or ozone.

[14]Pathogenic bacteria which cause illness in human beings are distinguished from the numerous benign bacteria that live in symbiosis with their human hosts.

Of the varieties of waterborne microbial organisms that pose a potential danger to the public water supply, two protozoans, ***Giardia lamblia*** and ***Cryptosporidiumparvum*** cause the greatest current concern.[15] This is because of their resistance to disinfection, prolonged life cycles, and high infectivity. ***Giardia*** was first identified as a disease-causing organism in the late nineteenth century. ***Giardia*** is an intestinal parasite and the cause of the disease giardiasis, the common symptoms of which are diarrhea and dyspepsia. Giardiasis is easily treatable. ***Giardia*** is transmitted fecally in a protective cyst that opens (excystates) when it becomes attached to the intestinal wall of an animal or human host. The shell-like structure of the ***Giardia*** cyst offers protection from disinfectants but is pervious to chlorine and ozone.

Cryptosporidium parvum was recognized as a water contaminant in the early twentieth century, but was not identified as a human pathogen until the 1980's. Daniel, 4:132; Rose, 12:119.[16] Like ***Giardia***, ***Cryptosporidium*** is common in surface water sources, including bodies of water generally thought to be pristine. In the human body, a ***Cryptosporidium parvum*** infection can lead to the disease cryptosporidiosis, which manifests itself in symptoms of chronic fatigue, gastric disturbance, nausea, weight loss diarrhea, and fever.[17] The symptoms can be fatal to persons with compromised

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[15]***Giardia*** is regulated under the SWTR. Water utilities (whether filtered or not) must achieve a 99.9 percent (3-log) inactivation of ***Giardia***. 40 C.F.R. § 141.70(a). An interim rule promulgated by the EPA in 1998 recommends that unfiltered systems devise methods to protect their watersheds from infiltration by ***Cryptosporidium***.

[16]The first recognized outbreak of cryptosporidiosis in the United States was traced to a well at Braun Station, Texas, in 1984. Clancy, 15:91; Ex. 112, at 4-3.

[17]Sixty-seven cases of cryptosporidiosis were reported in Massachusetts in 1998, six of which were recorded in Suffolk County. The figures are most likely understated because of underdiagnosis and underreporting. Rutherford, 8:63-65. None of these cases were traced to contaminated drinking water. The City of Worcester, which draws its water from the Worcester/Quinapoxet Basin, a drainage area separate from the

immune systems, particularly those suffering from AIDS, cancer patients, and the very young or old. There is no effective treatment or cure for cryptosporidiosis, Rose, 12:121, although in healthy individuals the disease is self-limiting and usually runs its course in 7 to 14 days. Fecal-oral ingestion is a common form of transmission of the disease, but it may also be transmitted by direct or indirect contact with an infected person or animal.[18]

In 1993, after a mechanical malfunction in Milwaukee's water filtration plant, a ***Cryptosporidium*** release caused an outbreak of cryptosporidiosis which infected over half of the system's 800,000 consumers. At least 50, and perhaps as many as 100 immunocompromised individuals are believed to have died from the illness. Ex. 112, 4-2; Hass, 8:85. According to the Centers for Disease Control, there were ten outbreaks of cryptosporidiosis in the United States between 1984 and 1995 (none of which were associated with unfiltered water systems). Rutherford, 8:42. The Milwaukee outbreak accounted for 93 percent of the recorded cases of cryptosporidiosis, although there is a consensus among health professionals that the great majority of cases go unreported. Ex. 112, at 4-3.

Cryptosporidium (only the ***parvum*** species is infective to humans) is endemic in the animal kingdom. The ***Cryptosporidium*** oocyst excystates in the intestines of its animal host and is shed into the environment in fecal waste. The thick-walled oocyst is capable of surviving outside the host in a fully infective stage for weeks, and even longer in cold water. Rose, 12:130. The oocyst, because of the thickness of its shell, is highly

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Wachusett Reservoir basins, experienced an outbreak of crytosporidiosis in 1994, causing it to begin filtering its drinking water. The Centers for Disease Control did not, however, conclude that the outbreak originated in Worcester's water supply. Daniel, 5:5; Ex. 344, Att. B, at 6.

[18]So-called "secondary spread" is not, however, regarded as a significant mode of transmission. Hass, 8:117.

resistant to chlorine. Daniel, 4:133; 5:58. Farm animals, particularly cattle, are prolific excreters of the ***Cryptosporidium*** parasite, a concern in the Wachusett watershed because of several local dairy farms.[19] Humans and mammalian wildlife are also sources, as are birds, although avian ***Cryptosporidium*** is not infective of humans.

The dose-response relationship of the ***Cryptosporidium parvum*** oocyst is largely a matter of conjecture, although it appears to vary depending on the strain involved and the relative health and resistance of the exposed subject. An often-cited study involving human volunteers was conducted at the University of Texas at Houston. Rutherford, 8:38. The study, which focused on the Iowa strain of ***Cryptosporidium parvum***, estimated the ID_{50} of ***Cryptosporidium*** to be 132, that is, that the average person would contract cryptosporidiosis after ingesting 132 oocysts.[20] Id., at 8:39.

Because fecal deposits are the most common means by which pathogens are introduced into public water supplies, science for nearly a century has used fecal coliform counts as a predictor of pathogenic risk. Rose, 12:123. (Fecal coliform itself is not a risk to human health, nor are all bacteria that respond positively to the thermal test for fecal coliform necessarily fecal in origin).[21] While fecal coliform is a reasonably good indicator of gross bacterial contamination, scientists have come to understand that there is no

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[19]One study estimates that an infected calf is capable of shedding as many as 10 billion oocysts in a single bowel movement. Ex. 131, 2-4.

[20]According to Dr. George Rutherford, of the U.C. San Francisco School of Medicine, subsequent studies have identified ID_{50} rates for ***Cryptosporidium*** ranging from 9 to 1042 oocysts depending on the strain tested. Rutherford, 8:39. The ID_{50} of 9 is associated with the Texas A&M University (TAMU) strain, considered by many microbiologists to be the most potent strain yet identified. There is, however, conflicting evidence suggesting no appreciable difference in the ID_{50}s of the Iowa and TAMU strains. Hass, 9:9; Ex. 422.

[21]Generic fecal coliform should not, for example, be confused with ***E. coli***, a subset of the larger genus that is fecal in origin.

statistical correlation between fecal coliform counts and the presence or concentration of ***Cryptosporidium*** and ***Giardia*** in water. Rose, 13:72.

Attempts to develop a precise method of monitoring for the presence of ***Cryptosporidium*** have been largely unsuccessful. While laboratory testing methods for fecal coliform are very reliable, the ***Cryptosporidium*** oocyst, some 5 to 10 microns in diameter, can only be detected by sophisticated microscopic analysis. The testing method sanctioned by the EPA throughout the 1990's depended on a separation technique and the use of a fluorescent stain to identify the oocyst. Clancy, 15:95. The immunoflourescence assay, however, has proven to be a poor oocyst detector, because the stain tends to identify with other types of biological matter, causing false positives. The separation technique, which involves the reduction of the water sample by filtration, centrifugation, and flotation, if done improperly, can also lead to false negatives. Id., at 15:110-111.

The reliability of ***Cryptosporidium*** oocyst screening was called into serious question by a 1997 EPA study supervised by Dr. Jennifer Clancy. Ex. 445. Independent laboratories participating in a performance evaluation succeeded in recovering only 23 percent of the oocysts in spiked samples,[22] with numerous reports of false negatives and false positives. In response to the Clancy study, the EPA implemented a number of changes intended to give greater rigor to the testing protocol, although with disappointing results. According to Dr. Clancy, even with the new protocol, the oocyst recovery rate improved to only 35 percent.[23] Clancy, 15:115. A subsequently revised EPA protocol

[22]The recovery rate for ***Giardia*** was 44 percent. Clancy, 15:106. Dr. Clancy testified that in an earlier blind study, the recovery rate for ***Cryptosporidium*** oocysts was only 1.1 percent. Id., at 15:104.

[23]The ***Giardia*** recovery rate actually dropped to 25 percent.

(developed by Dr. Clancy) was promulgated in draft form in 1999 as Method 1622. It uses magnetic beading to concentrate the oocysts, Ex. 131, 2-7, yielding a further improved recovery rate in the range of 40 to 50 percent. Clancy, 15:119.[24]

Despite the absence of a regulatory mandate, the MWRA has monitored its water for ***Cryptosporidium*** since 1994.[25] The testing method used by the MWRA is the one sanctioned for data collection under the EPA's 1996 Information Collection Rule ("ICR"),[26] although the MWRA has used water samples 10 to 22 times larger than called for by the ICR and has tested larger portions of the samples collected. Under the ICR protocol, sampling was required on a monthly basis. From 1996 through 1998, the MWRA sampled two to four times a month, and in January of 1999, began sampling on a weekly basis. Even with the enhanced sampling method, there has never been a confirmed ***Cryptosporidium*** oocyst detected (that is, an oocyst identifiable by its internal structure) at the Cosgrove Intake or in the Wachusett Reservoir, and no presumptive oocyst since

[24]According to Dr. Michael Messner, an EPA statistician, in a more recent EPA field study involving spiked water samples taken from 70 utilities, the twenty participating laboratories recovered on average only 12 percent of the planted oocysts. The average recovery rate for ***Giardia*** cysts was 26 percent. Messner, 17:114.

[25]The presence of ***Cryptosporidium*** in the Wachusett watershed and its tributaries has long been confirmed. Estes-Smargiassi, 2:137-138.

[26]The MWRA volunteered to participate in an EPA study to evaluate the effectiveness of Method 1622, but was not selected. Estes-Smargiassi, 3:23.

1995.[27] Estes-Smargiassi, 2:138-139; Clancy, 16:58-59; Ex. 47. See also Aieta, 24:29; Ex. 519.[28]

EPA's Revised Draft Unfiltered Water System Guidance Manual, issued February 4, 1999, recommends either filtration or a minimum of 2-log ***Cryptosporidium*** inactivation when the number of oocysts in baseline samples exceeds 1 per 100/l. Ex. 398, at 4-4. According to EPA, the Draft Guidance was issued without appropriate review by senior EPA management. King, 22:91-92, 109-110. EPA has therefore concluded "that it should not finalize the Draft Guidance, at least until after evaluation of the spiking study, the full ICR data set, and completion of ongoing Federal Advisory Committee Act deliberations." EPA Proposed Finding # 162.[29]

III. STATUTORY AND REGULATORY FRAMEWORK

The SDWA, enacted in 1974, charges the EPA with overall responsibility for insuring the safety of the nation's public water supply. Congress directed the EPA to promulgate Maximum Contaminant Levels ("MCLs") specifying the upper bound of

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[27]Two presumptive oocysts were detected in samples taken from the Hultman Aqueduct in 1996. The EPA points to a June 1996 outbreak of cryptosporidiosis among guests at the Bay Tower Room in Boston as suggesting that ***Cryptosporidium*** is resident in the MWRA distribution system. See EPA Proposed Finding # 288. The evidence offered at trial (as well as the absence of any subsequent outbreak) points to unsanitary kitchen conditions, and not tap water, as the cause.

[28]As Dr. Clancy explained, only the presence of sporozoites provides reliable confirmation of a viable oocyst. Clancy, 16:11. Objects that exhibit external features consistent with an oocyst are classified as suspected or presumptive.

[29]It is difficult for me to conceive how a filtration avoidance criterion based on ***Cryptosporidium*** could be formulated without identifying some objective triggering threshold. The 1 per 100/l standard may be the wrong one, given the acknowledged deficiencies in present sampling techniques, but if the best sampling techniques available produce zero results, a case for filtering MWRA water predicated on the mere possibility of ***Cryptosporidium*** contamination is very weak. It is possible that the EPA is moving to the position that the threat of ***Cryptosporidium*** alone requires the filtration of all drinking water. If that is so, it will require an amendment to the SDWA to enforce.

contaminants permissible in finished water, or, if that was not feasible for economic or technological reasons, to mandate treatment techniques to insure the public health. 42 U.S.C. §§ 300f(1)(C); 300g-1(a); 300g-1(b)(7)(A).

In 1986, frustrated by an apparent lack of rule-making progress, Congress amended the SDWA to require the EPA to mandate disinfection for all public water systems. 42 U.S.C. § 300g-1(b)(8). The 1986 amendments entailed a Congressional judgment that filtration is a superior technology for treating contaminated water supplies.[30] Congress directed the EPA to specify criteria for requiring filtration as a treatment technique after considering "the quality of source waters, protection afforded by watershed management, treatment practices (such as disinfection and length of water storage) and other factors relevant to protection of health." 42 U.S.C. § 300(g)-1(b)(7)(C)(i). Congress, in other words, stopped short of ordering filtration as an all-encompassing preventive.

While the 1986 amendments strengthened EPA's oversight of the regulatory process, the amendments preserved the role of the states in enforcing the SDWA. States whose drinking water regulations are determined by the EPA to be at least as strict as those mandated by federal regulations have "primary enforcement responsibility" for the

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[30]The Senate Report accompanying the amendments stated:

> [t]he problem of viral and bacterial contamination of drinking water supplies is addressed in the [SDWA] by the requirement that EPA issue criteria specifying those systems which must filter their surface water supplies and promulgate regulations requiring disinfection of all public water systems. . . . Filtration and disinfection techniques have been widely proven to be effective in removing bacterial and some viral contaminants from water. The [SDWA] requires the Administratorto promulgate treatment technique regulations for filtration and disinfection to assure that all public water systems are providing basic health protection to their customers.

S. Rep. No. 99-56, at 2, 7 (1986).

safety of public water systems within their jurisdiction, including the decision whether to order filtration. 42 U.S.C. § 300g-2(a); 42 U.S.C. § 300g-1(b)(7)(c)(ii). The DEP was granted enforcement responsibility by EPA in 1993.[31]

In response to the Congressional prodding, on June 29, 1989, the EPA promulgated the SWTR, which applies to all public water systems using surface water or ground water sources affected by surface water. See 40 C.F.R. § 141.70 et seq. The EPA concluded that it was not feasible to establish MCLs for ***Giardia lamblia***, viruses, heterotrophic bacteria, and ***Legionella***, the contaminants that had been identified as presenting the most significant risks to the public health. Consequently, the SWTR mandated that both filtered and unfiltered systems achieve:

> (1) at least 99.9 percent (3-log) removal and/or inactivation of ***Giardia lamblia*** cysts between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer; and
>
> (2) [a]t least 99.99 percent (4-log) removal and/or inactivation of viruses between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer.

40 C.F.R. § 141.70(a). The stated goal of the SWTR is to reduce the risk of illness from waterborne pathogens to one occurrence yearly among every 10,000 consumers of public water. Ex. 115, SWTR, 54 Fed. Reg. at 27490; Ex. 114, IESWTR, 62 Fed. Reg. at 59489.[32]

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[31]The EPA has the power to rescind a state's enforcement authority if it determines that the state no longer meets the requirements imposed by Subpart B of Part 142 of the Code of Federal Regulations (National Primary Drinking Water Regulations Implementation). 40 C.F.R. § 142.17(a)(2). The EPA has taken no steps to rescind its delegation of enforcement authority to the DEP.

[32]Dr. Michael Messner, an EPA statistician, testified that the one in 10,000 risk factor "is not . . . an EPA standard of any sort." Messner, 17:127. The statement is puzzling, because the 1 in 10,000 standard is explicitly referenced in the original SWTR and in its enhanced version. In fact, the EPA's witness Dr. Rose acknowledged that "1

The SWTR was intended to be "self-implementing," in the sense that the SDWA required nonconforming water systems to begin filtration within 30 months of the SWTR's promulgation (that is, by June 29, 1993), unless within 18 months (by December 30, 1991), the system could demonstrate that it met the filtration avoidance criteria. (These are set out at 40 C.F.R. § 141.71(a) and (b)). Public water systems that met the avoidance criteria but later fell out of compliance were given eighteen months from the date of noncompliance to begin filtration. 40 C.F.R. § 141.73. Although the deadlines are couched in categorical terms,[33] an internal guidance issued by the EPA in 1992 gave state enforcement agencies discretion to defer a final filtration determination if it appeared that a water system through intermediate measures could bring itself into compliance.

The SWTR established eleven avoidance criteria, all of which a water system must meet to be exempt from the filtration requirement. Two of the criteria concern the quality of a system's source water. (1): In relevant part, no more than 10 percent of samples taken prior to the first point of disinfection may contain fecal coliform concentrations in excess of 20 colony forming units ("cfu") per 100 ml during any six

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in 10,000 " is the risk factor that she uses in her own work "because it was mentioned" in the SWTR. Rose, 13:61.

[33]The introductory paragraph of 40 C.F.R. § 141.73 states:

> [a] public water system that uses a surface water source . . . and does not meet all of the criteria in § 141.71(a) and (b) for avoiding filtration, must provide treatment consisting of both disinfection, as specified in § 141.72(b), and filtration treatment which complies with the requirements of paragraph (a), (b), (c), (d), or (e) of this section by June 29, 1993, or within 18 months of the failure to meet any one of the criteria for avoiding filtration in § 141.71(a) and (b), whichever is later. Failure to meet any requirement of this section after the date specified in this introductory paragraph is a treatment technique violation.

month period. 40 C.F.R. § 141.71(a)(1). Sampling must be done by EPA-approved methods. 40 C.F.R. § 141.74(a). (2): Turbidity[34] cannot exceed 5 nephelometric turbidity units ("NTU") in samples taken prior to the first point of disinfection (with an exception for unusual and unpredictable events). 40 C.F.R. § 141.71(a).

Four criteria establish minimum levels of disinfection. (1): The system must meet the 3-log (99.9 percent) requirement for inactivation of ***Giardia lamblia*** cysts in at least 11 out of any preceding 12 months, and the 4-log (99.99 percent) inactivation requirement for viruses every day but one during any given month. 40 C.F.R. § 141.71(b)(1)(i). (Log removal is measured as a function of contact time ("CT"), a value obtained by multiplying the amount of residual disinfectant by the time it is in contact with treated water. 40 C.F.R. § 141.72(a)(1)). (2): The system must either be redundant in design or provide for the automatic shut-off of flow if the concentration of residual disinfectant falls below 0.2 mg/l. 40 C.F.R. § 141.71(b)(1)(ii). (3): The system must not permit the residual disinfectant concentration in water entering the distribution system to fall below 0.2 mg/l for more than four continuous hours. 40 C.F.R. § 141.71(b)(1)(iii). (4): The residual disinfectant concentration must not be undectable in 5 percent of the samples taken during any month for two consecutive months. 40 C.F.R. § 141.71(b)(1)(iv).

Five criteria involve watershed protection and systems operations. (1): The system must have a comprehensive watershed control program that meets mandated

[34]Turbidity is measured by the amount of light scattered by suspended matter in water. Suspended matter, depending on its density, can interfere with the disinfection process.

standards designed to minimize the infiltration of the source water by ***Giardia lamblia*** and viruses. 40 C.F.R. § 141.71(b)(2). (2): The system must be inspected annually by the state enforcement authority to insure the efficacy of the watershed control program and disinfection procedures. 40 C.F.R. § 141.71(b)(3). (3): The system must not have been identified as responsible for an outbreak of waterborne disease, or if it has, it must have implemented corrective measures adequate to prevent a recurrence. 40 C.F.R. § 141.71(b)(4). (4): The system must be in compliance with the MCL for total coliform concentrations in the distribution system. No more than 5 percent of samples in any eleven of twelve months may exceed the total coliform standard of 100 cfu per 100 ml. 40 C.F.R. § 141.71(b)(5). (5): The system must meet the MCL for disinfection by-products ("DBPs") in the distribution system (currently 0.10 mg trihalomethanes per liter or 100 parts per billion ("ppb")). 40 C.F.R. § 141.71(b)(6).

In 1996, Congress amended the SDWA a second time, by directing the EPA to promulgate an Interim ("IESWTR") and Final Enhanced Surface Water Treatment Rule addressing the threat of ***Cryptosporidium*** and DBPs to the safety of drinking water supplies.[35] 42 U.S.C. § 300g-1(b)(2)(C). The 1996 amendments loosened the filtration avoidance criteria for water systems "having uninhabited, undeveloped watersheds in consolidated ownership, and having control over, access to, and activities in, those watersheds" where a state determines that alternative treatment methods will achieve a greater removal of pathogens from drinking water than will filtration. 42 U.S.C. § 300g-1(b)(7)(C)(v). The amendments also directed the EPA Administrator to use a cost-benefit

[35]"The primary goal of the IESWTR is to improve public health by increasing the level of protection from exposure to ***Cryptosporidium*** and other pathogens in drinking water supplies." Ex. 112, ES-1. The SWTR did not control for ***Cryptosporidium*** nor did it fully recognize the potential health risks posed by DBPs.

analysis in assessing the health risk reduction benefits expected from any new national primary drinking water regulation that includes an MCL or proposed treatment technique. 42 U.S.C. § 300g-1(b)(3)(C)(i)&(ii). Cost-benefit analysis may not, however, be used to establish MCLs for DBPs "or to establish a maximum contamination level or treatment technique requirement for the control of cryptosporidium." 42 U.S.C. § 300g-1(b)(6)(C). Apart from these modifications, the 1996 amendments left the essential structure of the SDWA intact.

The IESWTR was published on December 16, 1998, and will take effect on December 17, 2001. Consistent with the 1996 amendments, the IESWTR focuses on ***Cryptosporidium***. For filtered systems, the IESWTR requires a 2-log (99 percent) reduction of ***Cryptosporidium*** oocysts. It also requires unfiltered systems to extend the existing ***Giardia lamblia*** watershed controls to cover ***Cryptosporidium***. Unfiltered systems are not, however, required to monitor their treated water for ***Cryptosporidium***.

Much of the empirical data on which the IESWTR is based was gathered by EPA under the ICR assaying the prevalence of ***Cryptosporidium*** in source water. See 61 Fed. Reg. 24354 (1996). Water systems serving in excess of 100,000 consumers were required to test monthly for 18 months for the presence of ***Cryptosporidium*** and to submit water samples for independent analysis by EPA-approved laboratories.[36]

[36]The EPA acknowledged the deficiencies in the testing methods devised to measure ***Cryptosporidium*** but expressed confidence "that data produced by approved laboratories will enable the Agency to develop a reliable occurrence data base." Id., at 24356.

IV. JUDICIAL ENFORCEMENT

The EPA Administrator is authorized to seek enforcement of the SDWA's requirements in the district court if a state, after being given notice of a violation in a regulated water system, does not within 30 days commence an appropriate enforcement action. 42 U.S.C. §§ 300g-3(a)(1)(B); 300g-3(b). The district court

> may enter, in an action brought under this subsection, such judgment as protection of public health may require, taking into consideration the time necessary to comply and the availability of alternative water supplies; and, if the court determines that there has been a violation of the regulation or schedule or other requirements with respect to which the action was brought, the court may, taking into account the seriousness of the violation, the population at risk, and other appropriate factors, impose on the violator a civil penalty of [sic] not to exceed $25,000 for each day in which such violation occurs.

42 U.S.C. § 300g-3(b).

V. THE DISTRIBUTION SYSTEM

Quabbin water enters the Wachusett Reservoir at its western end near the mouth of the Quinapoxet River. The amount of water withdrawn from the Quabbin Reservoir varies seasonally depending on demand, which is highest in the dry months of May to December. Ex. 16; Estes-Smargiassi, 2:63. At any given time, roughly half the water in the Wachusett Reservoir is contributed by the Quabbin. Ex. 395, at 1-5 (Table 1-1). Most of the remaining water is collected from the Wachusett watershed. Ex. 127, at 2-7.

At the eastern end of the Reservoir, water flows into the Cosgrove Tunnel at the Cosgrove Intake. The tunnel is 8 miles long, 14 feet in diameter, and has a carrying capacity of up to 600 million gallons of water a day. Estes-Smargiassi, 2:66. At the terminus of the Cosgrove Tunnel, at Shaft C in Marlborough, the water enters the Hultman Aqueduct. At Framingham, the Hultman Aqueduct branches in two directions. The smaller branch, the Weston Aqueduct, empties into the Weston Reservoir.[37] The main branch of the Hultman Aqueduct flows beneath the Norumbega Reservoir in Weston.[38] A portion of the water is drawn into the Norumbega Reservoir (which supplies backup water during periods of peak demand). The remainder flows through various connecting tunnels to consumers.[39]

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[37]The Weston Aqueduct and the Weston Reservoir were taken out of regular service in 1996 and are now used only in water emergencies. A 20 million gallon covered storage facility will replace the Weston facilities in October of 2003 when the MetroWest Water Tunnel is completed. Ex. 390, at 2-9; Estes-Smargiassi, 2:129.

[38]Of the system's five open reservoirs, three, the Weston, Spot Pond, and Fells, have already been decommissioned. MacDonald, 1:51. The MWRA also intends to replace the Blue Hills Reservoir with a covered facility. Estes-Smargiassi, at 3:38-39; Ex. 5; Ex. 8.

[39]The Towns of Marlborough, Southborough, Framingham and Weston receive their water from the Hultman Aqueduct. Northborough draws its water directly from the Wachusett Reservoir.

The MWRA treats its drinking water with three general techniques: primary disinfection, corrosion control, and residual disinfection. Primary disinfection is the use of chemicals, primarily chlorine, to kill microorganisms in water. Estes-Smargiassi, 2:125-126. Corrosion control involves the adjustment of the chemistry of water to reduce the leaching of metals (such as lead) from pipe casings. Id., at 127. Residual disinfection maintains low doses of disinfectant in the water to prevent recontamination as the water moves through the distribution system. Id., at 128.

Prior to June of 1996, MWRA water received primary and residual treatment at Weston. The water was adjusted for pH and fluoridized at Shaft 4 in Southborough. In September of 1997, the primary disinfection point was moved to the Cosgrove Intake and the disinfectant changed from chloramine to more powerful free chlorine. The corrosion control point was moved to Marlborough and the chemical mix was changed to regulate alkalinity as well as pH. Residual disinfection treatment was also modified in August of 1997 by injecting ammonia into the water at a point downstream of the Norumbega station to generate a more durable chloramine residual. Id., at 127-128.

Most of the 265 miles of mainline pipes in the MWRA system were installed in the 1800's and early 1900's and only intermittently replaced or refurbished.[40] Estes-Smargiassi, 2:74; Ex. 127, at 2-12 to 2-13. Some eighty percent of the present-day pipes are unlined cast iron or steel. Most are corroded and "prone to leaks . . . [and] water quality problems" caused by intrusion (outside contaminants seeping into the pipe and the water supply). Id., at 3-10; Daniel, 5:74-76. Many of the pipes are severely

[40]While the average pipe in the MWRA system is 83 years old, some are more than 150 years old. See Second Decl. of Kevin Reilly ¶ 9, Ex. 127, at 3-9; Ex. 291, at 1-1. Water pipes are ordinarily expected to have a service life of approximately 100 years. Id., at 7-1.

tuberculated (incrusted with metal deposits) to the point that the flow of water is virtually occluded.[41] Ex. 17; Ex. 18 and Ex. 19.

The 6,700 miles of pipe owned by the MWRA's constituent cities and towns have suffered from even greater neglect. Although a few communities (Brookline, for example), have done an admirable job in rehabilitating their delivery systems, nearly half the pipes supplying water to consumers are of the antiquated unlined cast iron type (in some communities the figure rises to 70 percent). Ex. 20. In the mid-1990's, the MWRA established a rehabilitation target of 2 _ percent per year for its own pipes, a goal that it has generally exceeded. In 1997, it instituted a two year pilot project, the Local Water Infrastructure Rehabilitation Assistance Program, offering $30 million in grants and interest free loans to member communities to encourage pipeline improvements.[42] Ex. 301. In 1999, the MWRA Advisory Board extended the program for ten years, with a projected annual allocation of $25 million.

The MWRA presently has four capital improvement projects under construction that will impact the distribution system. These are the 17.6 mile MetroWest Water Supply Tunnel ($728 million) which will carry water from Marlborough to Weston; the construction of covered facilities to store finished water, permitting the closure of the two remaining open reservoirs ($205 million); the construction of a new disinfection facility at Walnut Hill in Marlborough ($309 million);[43] and the ongoing rehabilitation of the water mains ($460 million). Ex. 5.

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[41]Tuberculation can also induce bacterial regrowth by diluting or blocking the disinfectant residual necessary to control it. Ex. 289, at 2; Daniel, 5:69.

[42]As of July 1999, the MWRA had distributed $29,746,687.00 under the Program to 42 communities. Ex. 309.

[43]The $309 million figure is for ozonation only.

VI. THE WATERSHEDS[44]

There are three contiguous watersheds within the MWRA system, the Quabbin, the Ware, and the Wachusett, collectively covering some 400 square miles of land inhabited by some 44,000 humans and 3,600 farm animals. Estes-Smargiassi, 2:54; Reilly, 21:7-8; Ex. 131, at 4-2.

Wachusett Watershed

The Wachusett is the most developed of the three watersheds. Its 117 square miles of surface area contain all or parts of twelve towns[45] with watershed populations ranging from single numbers into the thousands. Ex. 204. The largest population centers are concentrated in the southern portion of the watershed (primarily in the Towns of West Boylston and Holden). Population density in the watershed as a whole is 290 persons per square mile. The present-day human population numbers approximately 34,000.[46] The watershed contains 118 miles of roads and 17.5 miles of railroad track. Ex. 149.

The topography of the watershed is hilly, sloping upward from the Reservoir at 395 feet above sea level, in a northwesterly direction towards the 2,006 foot peak of Mount Wachusett. Estes-Smargiassi, 2:59. Approximately 75 percent of the watershed is forested or covered by wetlands. Twenty-six percent of the land area is owned outright

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[44]"A 'watershed' is that area of land on which rain or snow falling travels across the ground or through the ground into streams filling the reservoir." Estes-Smargiassi, 2:53.

[45]The communities are the towns of Boylston, Clinton, Holden, Hubbardston, Leominster, Paxton, Princeton, Rutland, Sterling, West Boylston, Westminster, and the City of Worcester. Ex. 147, at 38.

[46]Census figures for the six largest towns, while perhaps not reflective of the watershed as a whole, suggest an annual population growth rate of approximately 1% over the last decade. Ex. 462.

by the MDC, while an equivalent amount is owned by other government agencies and conservation groups. Eight percent of the land is used for agricultural pursuits, 9 percent is settled urban or residential, and 1 percent is dedicated to industrial and commercial uses.

The Nashua, Quinapoxet and Stillwater Rivers contribute roughly 40 percent of the water collected by the Reservoir.[47] Estes-Smargiassi, 2:62; Ex. 147, at 38; Ex. 395, at 2-33. A very small contribution is made by Malagasco Brook, which empties into the Reservoir at South Bay, and by the Boylston, French and Hasting Cove Brooks, which enter the Reservoir on the southeast shore. Nearly half of the Wachusett water arrives from the Quabbin watershed. Id. The balance comes from run-off and direct precipitation. Id.

Over ninety percent of Wachusett water enters at the Thomas Basin, a narrow, elongated appendage to the northwest of the main body of the Reservoir. Ex. 13. The mouth at the southern end of the Thomas Basin is artificially constricted by the Route 12 causeway. "The constriction at the Route 12 bridge narrows the reservoir from approximately 1,000 feet to 50 feet, and makes Thomas Basin an effective detention and sedimentation basin helping to maintain the high quality of water in the main body of the reservoir."[48] Ex. 395, at ES-5. See also Ex. 13. The average time taken for water entering the Thomas Basin to migrate to the Cosgrove Intake is six months. Ex. 129. Water

[47]The Waushacum Brook is located in the Stillwater River Basin. Ex. 31. The West Boylston, Gates, and Scarlett Brooks lie in the Quinapoxet River Basin.

[48]Eighty-five percent of the sediment in the inflow settles out in the Thomas Basin. Estes-Smargiassi, 2:62-63.

released from the Reservoir at the Wachusett Dam is drained by the Nashua and Merrimac Rivers into the Atlantic Ocean.[49] Estes-Smargiassi, 2:54.

The watershed is an important wildlife habitat and a major recreational area.[50] The MDC permits hiking, cycling, seasonal shore fishing and cross-country skiing on much of the land under its control. Canoeing is permitted on West Waushacum Pond and on the upper reaches of the Quinapoxet and Stillwater Rivers. Seasonal hunting is also allowed in some areas. Recreational uses of MDC land are regulated by a Public Access Plan promulgated in 1996. See Ex. 147.[51]

The Massachusetts Department of Environmental Management ("DEM") owns 2,052 acres of the watershed, including portions of the Leominster State Forest and the Wachusett Mountain Reservation. Id., at 131. The Massachusetts Division of Fisheries and Wildlife ("DFW") manages 580 acres. DEM and DFW allow a variety of recreational

[49]The MWRA has long-term plans to reconfigure the Wachusett Dam to permit larger releases of Wachusett water into the Nashua River, thus allowing for a greater intake of purer Quabbin water, much of which is now sloughed into the Swift River.

[50]The Watershed Protection Act, passed in 1992, restricts land uses and activity adjacent to the reservoirs and their tributaries. Within the Primary Protection Zone (400 feet from reservoir shoreline and 200 feet from the banks of tributaries) all development is prohibited. In the Secondary Protection Zone (200 to 400 feet from river and stream banks) certain activities are prohibited and development is restricted. 350 CMR 11.00. In the Wachusett watershed, 5,725 private acres of land fall within the Primary Zone, and another 6,580 acres within the Secondary Zone. Exemptions to the restrictions are permitted for certain "grandfathered" uses. According to the EPA, some 450 exemptions were granted between 1994 and 1999.

[51]The Plan establishes three zones covering the intake area (where no access is permitted), the shorelines of the Reservoir and nearby tributaries (where light recreational uses are allowed) and the headwaters area (where hunting and fishing are permitted). Although EPA criticizes the Plan (EPA Proposed Finding # 91) for allowing more recreational activity than other water suppliers permit, the then EPA Regional Administrator, John DeVillars, commended the Plan for striking an appropriate balance between public and private uses. Ex. 484, at 6.

activities.[52] Sporting clubs own 1,450 acres of open space.[53] The clubs allow hunting, trapping and target practice, and permit dogs. There are two private land trusts in the watershed, the White Oak Land ConservationSociety (122 acres) and the Princeton Land Trust (4 acres). The trusts permit hiking, hunting, snowshoeing and skiing on their land. The Massachusetts Audubon Society owns three sanctuaries totaling 1,257 acres. There are also several municipal parks, six country clubs, and several public golf courses. The Trout Brook Reservation (660 acres) and Town Forest (124 acres) permit horseback riding, dogs, hunting, fishing and camping. Id., at 134 -135.

The watershed contains twelve "significant" farms (with 10 or more cows), although six of these are located in the Worcester/Quinapoxet Basin. Ex. 35; Estes-Smargiassi, 2:122. There are also numerous "hobby" farms that stable horses and other animals. Id. In total, the farms in the watershed house some 2,250 domestic animals (principally dairy cows, horses and pigs).

The Quabbin and Ware Watersheds

The Quabbin, the most westerly of the three watersheds, covers an area of 187 square miles, and is 93 percent forested. Id., at 55. More than half of the land surface is owned by the MDC. Ex. 207. Approximately 3,000 persons live within the watershed (a population density of 16 persons per square mile). Less than 3 percent of the land area is dedicated to agricultural use, involving fewer than 450 farm animals. Ex. 131, at 3. The Quabbin Reservoir is a pristine water source, with very low turbidity, and extremely

[52]DEM and DFW allow many activities that are prohibited by the MDC, such as trapping, motorized boating, horseback riding, snowmobiling, snow-shoeing and ice-fishing. Id., at 131-132.

[53]The Bartlett Pond Sports Club owns 500 acres in Leominster. The Eightpoint Sports Club (60 acres), Worcester Fox & Coon Club (81 acres), the Nimrod Sports Club (449 acres), and the Norco Sports Club (361 acres) are located in Princeton. Id., at 134.

low levels of contaminants. There is no dispute that the Quabbin amply meets the filtration avoidance criteria. Ex. 127, at 2-3; Ex. 390, at 2-3, n. 1.

The Ware River watershed, to the east of the Quabbin, contains 97 square miles of surface area, 85 percent of which consists of forests and wetlands. The population density is 77 inhabitants per square mile. More than one-third of the land area is owned by the MDC, while one-half of the remaining watershed is protected open space. Ex. 207. Very little water is presently diverted from the Ware watershed into the Wachusett Reservoir. There have been no diversions during the past five years. Estes-Smargiassi, 2:56-57.

MDC Management Practices Within the Watershed

The MDC, through its Division of Watershed Management, ("DWM") is mandated by statute "to assure pure water for future generations." M.G.L. c. 92, § 105. The DWM and the MWRA collaborated on the development of the 1991 Watershed Protection Plan ("WPP"). The WPP identified livestock, unsewered septic systems, wildlife (principally birds, beaver and muskrat), human recreation, urban run-off, and transportation spills, as the major potential threats to the watershed's integrity. The WPP was updated in 1995 and again in 1998. It has six principal components: (1) staffing and management goals and objectives;[54] (2) a bird control program; (3) land acquisition; (4) implementation of the Watershed Protection Act; (5) the elimination of unsewered septic systems; and (6) mitigation of the threat posed by farm animal excretions and farm operations.[55] Ex. 395, at 3-5 to 3-15; Estes-Smargiassi, 2:103-104. Some of the more significant initiatives taken pursuant to the WPP are described below.

The Land Acquisition Program

The 1992 Watershed Protection Act ("WPA") established a $135 million fund to purchase development rights to environmentally sensitive property in the Wachusett and Quabbin watersheds.[56] The goal established by the MDC was to raise its total watershed holdings to 25 percent of the land area, giving priority to purchases that would

[54]The MDC presently has some 165 staff, including wildlife biologists, environmental engineers, and park rangers, involved in watershed protection. The MDC also employs outside consultants to conduct specialized watershed studies. The WPP has an annual budget of $11.5 million.

[55]There are presently some 280 farms in the watershed, although many are so-called "hobby" farms. The MDC has acquired several of the largest farms through its land acquisition program and has implemented a program of Best Management Practices. See Ex. 131.

[56]Although ***ad hoc*** legislative appropriations in the 1980's permitted the MDC to expand its watershed holdings, the WPA provided the first permanent funding.

mitigate development and farming activity in close proximity to the Reservoir or its tributaries. See M.G.L. c. 92, § 107(A), inserting act § 6. In designing the program,

> [t]he MDC and MWRA developed a prioritization mechanism to establish what are the most important parcels of land to be purchased. . . . The MDC and MWRA staff, planners, natural - - environmental scientists and natural resource folks and others, ranked a series of factors as to how important they were to water quality. They included things such as steep slopes, the type of development which could be built on land, the proximity to tributaries and a number of other issues, including aquifer which allowed us to say that this piece of land is more important than another piece. And then we have, in fact, ranked every parcel in the watershed. . . .[W]e're concentrating on purchases in the portion of the watershed which is more directly tributary to the reservoir.

Estes-Smargiassi, 2:109-111.[57] See also, Ex. 395, at 4-7. Since 1985, the MDC has purchased approximately17,000 acres within the two principal watersheds. With respect to the Wachusett watershed, the MDC has surpassed its goal of 25 percent ownership. Ex. 395, at 3-14.[58] The MDC expects to purchase 5,000 additional acres from private owners over the next five years, principally in the Wachusett watershed. Estes-Smargiassi, 2:37.

Sewering

The WPA identified leaking septic systems within the watershed as "the most significant potential source of pathogens and other pollutants of concern". Ex. 395, at 6-29. This concern is exacerbated by sandy soil conditions that do a poor job of filtering wastewater. Walker, 16:103. In 1930, the MDC built sewers to evacuate wastewater from Holden and Rutland for treatment outside of the watershed. In 1991, however, the watershed still had 6,558 unsewered septic systems. Ex. 139, at 3-5. In 1995, the MDC

[57]The MDC, for example, recently purchased the 155 acre Giobellina Farm, permitting the removal of 30 cows from the watershed. The farmland is being returned to its natural state. Id., at 112.

[58]In 1985, the MDC owned only 8 percent of the Wachusett watershed. Ex. 33.

inaugurated a Wastewater Facilities Plan to provide sewer connections for septic systems in and around Holden and West Boylston that had been identified as a source of fecal coliform polluting Gates Brook and the West Boylston Brook.[59] Ex. 41; Ex. 395, at ES-20. When the Plan is completed in 2004, more than 40 percent of the septic systems in the watershed will be connected to the Upper Blackstone treatment plant in Worcester. Estes-Smargiassi, 2:120; Ex. 395, at 6-31.[60]

Bird Harassment Program

In 1991, the MWRA concluded that roosting gulls and other birds were the probable source of seasonally high fecal coliform concentrations detected in water samples taken at the Cosgrove Intake.[61] Estes-Smargiassi, 2:106.; Ex. 218, at 1. In 1992, the MDC instituted a campaign of harassment to discourage birds from roosting near the Intake. Scannel, 9:76-77. In 1993, the MDC intensified the harassment program in the late fall and winter when the bird population reaches its peak. Id., at 78-79. The MDC scatters the birds with noise makers, pyrotechnical devices, propane cannons, and distress tapes, and (most effectively) by launching boats in areas favored by the birds.

[59]In a 1996 letter to the MWRA, EPA Regional Administrator John DeVillars stressed that "the construction of the sewer lines in West Boylston and Holden continues to be the single most critical watershed protection measure [to be undertaken]." Ex. 484, at 2.

[60]The 75 miles of sewer pipe being installed is expected to cost $80 million. The project is funded by the Commonwealth of Massachusetts, the participating communities, and by the MWRA. Title V, which imposes strict penalties on homeowners with deficient or failing septic systems, is expected to encourage homeowners to connect their septic systems to the new sewer lines. EPA witnesses acknowledged that improved sewering will have a positive impact on the watershed. Reilly, 20:134-135,139; Walker, 17:24.

[61]MDC biologists identified Herring, Ring-billed and Great Black-Back gulls, Canada geese, and Double-Crested Cormorants roosting in "safe" areas of the reservoir as the likely culprits. Ex. 395, at 6-3. This supposition was borne out by later studies. See, e.g., Ex. 129, at 9-7 to 9-8.

Id., at 81. The MDC has also deployed aquatic nets and has erected scaring devices on islands and along the shoreline. Id., at 83; Ex. 218, at 4. In 1994, the MDC acquired two small Model 600 hovercraft to permit boats to be launched in winter when the Reservoir begins to ice over. Scannel, 9:84. In 1994, after experiencing a number of days when choppy conditions or ice made it impossible to launch the smaller hovercraft, the MDC purchased a more powerful all-weather Model 800 and built a de-icing dock. Id., at 92-94.

VII. WACHUSETT/MWRA WATER QUALITY

Despite deficiencies in the various methods used to test for the presence of contaminants, the filtration avoidance criteria of the SWTR provide a useful benchmark for measuring water quality. Of the two source water criteria, turbidity has not affected the quality of Wachusett water. Samples taken at the Cosgrove Intake have never exceeded the SWTR limit of 5 NTU, nor since 1991 have they exceeded the more stringent Massachusetts standard of 1 NTU, even during intense storm events. Aieta 11:42-43; Ex. 53. Algae are a potential threat to disinfection that are often associated with turbidity.[62] However, algae levels in the Wachusett Reservoir are extremely low, as would be expected from the low turbidity. Edzwald, 14:59, 106-107; Hiltebrand, 23:93-94.[63]

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[62]While the MWRA states in its Proposed Finding # 241(d)(ii)(1) that the United States produced no scientific support for this proposition, that is only technically true. The MWRA's own expert, Dr. Aieta, testified that algae can shield pathogens from disinfection. Aieta, 11:36-37. He also testified that algae concentrations would indicate filtration only if the aggregate turbidity level exceeded 5 NTU. Id.

[63]While the EPA states in its Proposed Finding # 254 that turbidity is not a good indicator of the presence or absence of ***Giardia*** and ***Cryptosporidium***, its statistical expert, Dr. Messner, disagreed, although he characterized the relationship as "weak." Messner, 17:110. The EPA's Proposed Finding # 254 relies on the testimony of Ephraim King, a lawyer who heads the Standards and Risk Management Branch of EPA's Office of Groundwater and Drinking Water. The testimony was clearly beyond Mr. King's competence. King, 22:61-63.

Fecal coliform is another matter. As the MWRA admits in its Proposed Finding # 189(a)(iii), the inability to satisfy the fecal coliform standard in 1991 was a principal reason why its Board of Directors voted not to seek a filtration waiver. The term "fecal coliform," as previously noted, is somewhat misleading, as it is a generic description encompassing all coliform bacteria that respond positively to thermal testing. For the most part, the presence of fecal coliform in water is a poor marker for fecal contamination.[64] The specific indicator for the presence of fecal matter, the bacterium ***E. coli***, is in fact a small subset of the total fecal coliform population. Edberg, 7:27. Nor is fecal coliform a reliable indicator of the presence of ***Giardia*** or ***Cryptosporidium*** in water. Id., at 7:28.

The source water avoidance criterion for fecal coliform requires that no more than 10 percent of samples taken prior to the first point of disinfection contain fecal coliform concentrations in excess of 20 cfu per 100 ml during any six continuous months. In 1991, 1992 and 1993, water samples taken at the Cosgrove Intake often exceeded the 10 percent limit, particularly during the winter months. (Fecal coliform levels are generally higher in winter because coliform bacteria survive longer in cold water. Rose, 12: 130). The sharp drop in levels of fecal coliform recorded at the Intake after the full implementation of the gull harassment program in 1993 strongly supports the MWRA's determination that roosting gulls[65] were the principal coliform source. That determination

[64] According to Dr. Stephen Edberg, a Yale University Professor of Medicine and the Director of Clinical Microbiology at Yale/New Haven Hospital, the World Health Organization discourages the use of generic fecal coliform testing to gauge colonic contamination. Edberg, 7:26, 91.

[65] Gulls are carriers of ***E. coli***, ***Cryptosporidium*** and viruses, although the avian strains of the latter two contaminants are not infective of humans. Birds do not carry ***Giardia***. Edberg, 7: 41-42.

is further corroboratedby the temporary spikes in fecal coliform levels that were observed on occasions when the harassment program was disrupted by severe winter weather.[66]

[66]For example, on January 4, 1999, the MWRA recorded one of its highest levels of fecal coliform concentration (113 cfu) in five years of sampling. Because of freezing rain, high winds, and intense cold, the MDC had been unable to launch boats to perform gull harassment duties on the four previous days. Walker, 17:56-59.

The EPA presented evidence, through the testimony of Dr. William Walker,[67] that a number of the tributaries in the Wachusett watershed do not meet the Massachusetts Class A Water Quality Standard with respect to fecal coliform concentrations. Walker, 16:109, 111; Ex. 449. The exceedance is especially acute in areas with higher population densities and those impacted by agricultural activity. As Dr. Walker's analysis of MDC data showed, Justice Brook, which is the cleanest of the streams for which data was gathered, is in the least developed area of the watershed, while Gates Brook, the dirtiest, flows through the area that is most urbanized. Walker, 16:114-115. Dr. Walker hypothesized that because of the gradient and soil composition of the watershed, storm (wet weather) events could cause large concentrations of fecal coliform to leach into the western end of the Reservoir where, under the right hydraulic and wind conditions, they could be transported to the Cosgrove Intake in "less than a day." Walker, 16:134. The weak statistical association developed by Dr. Walker between antecedent rain events and fluctuations in fecal coliform counts at the Cosgrove Intake (1 percent) and the virtual absence of detectable ***Giardia*** or ***Cryptosporidium*** in the samples taken (Ex. 438), strongly suggest that the hypothesis is flawed. (According to Dr. Walker ***Giardia*** or ***Cryptosporidium*** have settling rates one magnitude slower than fecal coliform which would lead one to expect them to be more readily transportable ***en masse***). As the MWRA pointed out, the correlation between spikes in fecal coliform counts and the numbers of gulls roosting near the Cosgrove Intake is far stronger than any association with storm events identified by Dr. Walker's models.

[67]Dr. Walker is an environmental engineer who "[e]ssentially . . . does research and problem solving for government agencies as well as municipal water supplies." Walker, 16:76.

This litigation was triggered by the MWRA's admission that in January of 1999, it had fallen out of compliance with the fecal coliform avoidance criterion. More specifically, in December of 1998 and January of 1999, 14 samples were taken at the Cosgrove Intake in which fecal coliform concentrations exceeded 20 cfu, that is, one more than the 10 percent of samples permitted. It was this admission that caused the court on May 3, 1999, to enter partial summary judgment for the EPA. The argument is now made by the MWRA that the facts developed at trial disprove its prior admission and that (inferentially) partial summary judgment was improvidently granted.

The crux of the dispute involves the MWRA's testing method for fecal coliform. In 1989, when promulgating the avoidance criteria, EPA required that fecal coliform levels be measured by EPA-approved methods. Ex. 115, SWTR, Fed. Reg. at 27530. Among these were the MPN Method 908C and the Membrane Filter Procedure Method 909C, which while differing in format, involve incubation of a lactose-based solution at a temperature of 44.5ºC. Id., at 27531 The MWRA, on the other hand (for reasons that are unclear), chose to use instead a non-EPA-approved enhanced recovery method, which is far more sensitive than either of the approved methods. Edberg, 7:36. A split-sample study of water samples taken at the Cosgrove Inlet during the first three months of 1999, showed a site-specific 100 percent increase in average recoveries using the MWRA's enhanced method. See Ex. 401.[68] The MWRA argues that had it used "the analytical method to which the avoidance criterion was calibrated, it would not have detected or reported a violation." MWRA Proposed Finding # 206(d)(v). From a different perspective, the MWRA argues that, even if the enhanced method results are considered, the violation

[68]See also Aieta, 24:27-28; Ex. 518.

is ***de minimis***, that is, "had the results shown 1 less bacterium, on one day, the MWRA would have reported compliance." Id., at (d)(vi)(6).[69]

As to the first argument, EPA cites a Ninth Circuit decision holding that a defendant in an environmental case cannot "challenge [its] own sampling results as a means of avoiding liability." Sierra Club v. Union Oil Co. of Cal., 813 F.2d 1480, 1491-1492 (9th Cir. 1987), vacated on other grounds, 485 U.S. 931 (1988). The case stands for something less than EPA contends, emphasizing as it does the unfairness of permitting a defendant to impeach its own reported excursions by claiming sampling error, thereby "creat[ing] the perverse result of rewarding permittees for sloppy laboratory practices." Id., at 1492. Here the issue is not whether the results are bad because of sampling error, but whether they are better than they should have been because the testing method used was more accurate than what the regulations require. The short answer to this (not by any means specious) argument is that the issue was not raised (at least in a developed form) by the MWRA in its opposition to partial summary judgment.

As to the suggestion that any violation established using the enhanced recovery method is ***de minimis***, EPA makes a convoluted argument (that I do not fully follow) that the SWTR's "historical standard" for unfiltered drinking water is 10 rather than 20 cfu, and that the figure of 20 cfu was written into the SWTR as an upper 90 percent confidence

[69]At the time the relevant testimony was offered at trial, the parties agreed that over 90 percent of the samples taken at the Cosgrove Intake during the immediately preceding six months showed fewer than 20 cfu of fecal coliform and that consequently, the MWRA is in present compliance with the fecal coliform avoidance criterion. Estes-Smargiassi, 4:78; Reilly, 20: 113-114.

interval to account for variations in the results of MPN testing. Thus, "[i]f more than 10 percent of a system's source water samples exceed 20 fecal coliform [cfu] . . ., it provides a high degree of confidence that the source water frequently exceeds the historical standard of 10 [cfu]. . . ." EPA Proposed Finding # 231. Whatever one is supposed to make of this "historical standard," the fact remains that the SWTR's fecal coliform avoidance criterion is set at 20, not 10 cfu. EPA also makes the more inviting argument that if fecal coliform concentrations are disregarded, the avoidance criterion defaults to a total coliform count which is not permitted to exceed 100 cfu per 100 ml. 40 C.F.R. § 141.71(1)(a). That Wachusett water failed this standard several times between 1997 and 1999 (using results obtained by the enhanced recovery method) is not disputed by the MWRA.

Perhaps associated with the problem of fecal coliform concentrations at the Cosgrove Intake have been numerous instances in which the water reaching the MWRA's constituent communities has exceeded the Total Coliform Rule ("TCR") (no more than 5% of samples may exceed 100 cfu per 100 ml). The data are somewhat difficult to interpret because they are collected on a community-by-community rather than on an aggregate basis. But it is clear (and the MWRA does not suggest otherwise) that one or more communities (and as many as twelve in 1995-1996) have exceeded the TCR threshold on an episodic basis, although compliance has improved substantially since the mid-1990's as open storage reservoirs have been taken off-line. Estes-Smargiassi, 2:147-148; Ex. 391, at 2-8.[70]

[70]The EPA asserts that on an aggregated system-wide basis the MWRA was in violation of the TCR for the twelve months ending June 1998. EPA Proposed Findings ## 265, 266. How the EPA reached its determination of aggregate noncompliance is not explained. Exhibits 459 and 390, to which EPA refers, simply confirm instances in which individual communities were in noncompliance. They do not present aggregate figures.

In most other respects, the MWRA system and its finished water either are presently, or have historically been in compliance with the filtration avoidance criteria. The system has never been identified as the source of an outbreak of waterborne disease. It has for at least five years met the requirement that its water carry a residual disinfectant of at least 0.2 mg/l that is detectable in at least 95 percent of samples taken from the distribution system. Levels of DBPs (measured in total trihalomethanes) are well below the permissible maximum of 100 ppb despite increases in the amount of chlorine used to treat MWRA water.[71] The efficacy of the MDC's watershed protection plan, the state's inspection and reporting requirements, and the system's redundant capacity are not matters of dispute. Finally, the system provides sufficient chlorination to achieve the required 2-log inactivation of ***Giardia*** and 3-log inactivation of viruses.[72]

[71]Despite the elevation of chlorine levels in the main system, the resulting higher residual disinfectant level has made it unnecessary for constituent communities to add chlorine of their own, thereby reducing the level of DBPs in the system as a whole. Estes-Smargiassi, 2:129-131. The system also meets the new 80 ppb trihalomethane DBP standard that takes effect in November of 2001. While the EPA alludes to the potential danger of bromates (and "other as-yet uncharacterized and unknown DBPs"), it acknowledges that the bromide levels in MWRA water are "mostly low." EPA Proposed Finding # 192.

[72]The MWRA also points to a number of so-called subjective criteria that it believes reinforce the view that the quality of its water has improved over the last decade. Some of these criteria, like the low incidence of chemicals detected in the Wachusett Reservoir and improving levels of lead in the finished water, are objective. Others like improved taste and odor are matters of individual perception that are almost impossible to quantify.

VIII. THE ROAD TO LITIGATION

The EPA granted primary enforcement responsibility to the DEP on June 28, 1993. 58 Fed. Reg. 34,583 (1993).[73] The DEP's drinking water regulations, like the SWTR, require filtration if a water system fails to meet one or more of the avoidance criteria. 310 CMR 22.20A(2); 310 CMR 22.20A(4).

The Quabbin Reservoir was granted a waiver from filtration in January of 1992. However, a 1989 consultant's report persuaded the MWRA's Board of Directors that the system as a whole, because of its dependence on the Wachusett Reservoir, would be unable to qualify. Consequently, the MWRA did not seek an avoidance determination from the DEP prior to December 30, 1991 (the SWTR deadline). On January 24, 1992, the DEP ordered the MWRA to provide filtration and disinfection treatment for Wachusett Reservoir source water by June 30, 1993. The MWRA did not oppose the determination and appeared receptive, at least at a staff level, to a "multi-barrier approach to preserving drinking water quality" that included filtration as one of its components. Ex. 317, at 1. On August 26, 1993, after reviewing the results of an MWRA pilot treatment study, the DEP approved such an approach, authorizing a "process train" of dissolved air filtration ("DAF"), ozonation and filtration.

In early 1993, the DEP, the MDC, and the MWRA began negotiating an Administrative Consent Order ("ACO") to enforce the SWTR. The final version of the ACO took a "dual-track" approach. The MWRA and the MDC were to implement a Wachusett watershed protection plan as part of a larger effort to bring the system into compliance with the filtration avoidance criteria. The ACO included a "reopener" clause permitting the

[73]The DEP adopted regulations conforming to the SWTR on October 26, 1990.

MWRA to seek (by August 3, 1998),[74] a determination that filtration was no longer required. The MWRA was simultaneously ordered to begin design work for a DAF/filtration facility in the event the avoidance strategy failed.[75]

During this period, the EPA was supportive of the dual-track approach. On June 3, 1993, Jeffery Fowley, the EPA Associate Regional Counsel, wrote to the DEP and the MWRA promising that if the ACO were signed prior to July 1, 1993, the EPA would defer the taking of any federal enforcement action. Fowley cautioned, however, that "the [proposed] Consent Order requires . . . the MWRA . . . to construct filtration facilities unless it can demonstrate by August 3, 1998, and the DEP approves, that it meets all of the avoidance requirements." On June 11, 1993, the ACO was signed.[76]

Over the next three years, the EPA participated in the development of both tracks, recommending filtration options and advising the MWRA on the steps that had to be taken to satisfy the avoidance criteria. On November 14, 1996, John DeVillars, the EPA Regional Administrator, wrote a letter praising progress in implementing the watershed

[74]This date was subsequently adjusted to July 31, 1998, and then to October 31, 1998.

[75]The principal milestones set out in the ACO required the MWRA to complete the design of a new treatment plant (incorporating filtration) by April 29, 1998, to implement the full watershed protection plan by July 31, 1998, and to close the Norumbega Reservoir by December 31, 2000.

[76]On February 1, 1995, the ACO was amended to revise its reporting requirements.

protection plan, but warning that "in order to avoid filtration, more still needs to be done." Ex. 484, at 7. DeVillars emphasized the completion of the West Boylston-Holden sewerage project as the "most critical of the unfinished tasks," but with the exception of the MDC's failure to meet staffing goals, was generally approbative of its accomplishments. Id., at 2. Throughout this period the EPA gave no hint that it was dissatisfied with the deferral of the DEP's final filtration decision. On May 5, 1995, for example, DeVillars wrote to the Chair of the Wachusett Watershed Advisory Committee stating that "[t]he final answer on whether filtration is needed will be made in 1998, by the state Department of Environmental Protection, but subject to Environmental Protection Agency (EPA) review." In the November 14, 1996 letter, DeVillars noted that "August 1998 is rapidly approaching and all of these issues, and more, will need to be resolved by that time in order to avoid the necessity of constructing a filtration plant." Ex. 484, at 7.

The first sign of a shift in EPA's position came in early 1997. A January 8 letter from DeVillars to David Struhs, then the Commissioner of the DEP, expressed "extreme concern" that the MWRA would not meet "key deadlines" of the ACO involving the design and construction of the filtration plant. On May 15, 1997, the EPA warned that the ACO itself was in technical violation of the SDWA-SWTR's June 30, 1993 deadline. Ex. 381. EPA's concern intensified on September 18, 1997, when the DEP and the MWRA agreed to amend the ACO to postpone the date for completion of the full design package for the filtration plant to January 31, 2002, and to delay the construction completion date by two years to December 31, 2003.[77] By this time, EPA had tacitly taken itself out of any participation in the dual-track process. Reilly, 18:121; 20:80; 21:56.

[77]The date for the closing of the Norumbega Reservoir was also extended to December 31, 2004. The deadline for seeking a filtration redetermination (July 31, 1998) remained, however, unchanged.

On October 1, 1997, "well before the July 31, 1998 deadline specified in the . . . ACO," see EPA Proposed Finding # 304, the MWRA and the MDC jointly filed a "Request for Review and Revision of DEP Determination that Filtration is Required for Wachusett Reservoir." Ex. 390. The request proposed that the MWRA proceed with chlorination-based treatment and essentially freeze the design work on the filtration and ozonation facilities at the 60 percent level. Id., at 6-4. While in the EPA's view, the request represented a political capitulation on the part of the MWRA, the issue appears somewhat more complicated.[78] See MacDonald, 1:77; 1:96. In any event, in February of 1998, after this litigation was filed, the DEP ordered the MWRA to complete the design of the ozonation/filtration plant.

On December 9, 1997, in a letter that the MWRA characterizes as a "declaration of war," DeVillars informed the DEP and the MWRA that the EPA had asked the Department of Justice to file an enforcement action because of the December 30, 1991 failure to meet the filtration avoidance criteria. Ex. 457. According to DeVillars "[t]he MWRA did not meet these criteria in 1991, has not met them to this day, and will not meet them by next summer, either."[79] Id., at 2.

[78]EPA bases its suspicion on the following. In 1996, the MWRA staff had recommended against "chlorine-only" treatment because of the fear that higher doses of chlorine might unacceptably elevate levels of DBPs in the system. Camp, Dresser & McKee, the MWRA's principal consultant, agreed with the staff recommendation. However, Trudy Coxe, then Chairperson of the MWRA Board of Directors and Secretary of the Massachusetts Executive Office of Environmental Affairs, was a vocal advocate of a chlorine-only solution, presumably because it would lessen the pressure for future water rate increases. EPA Proposed Finding # 302; Shawcross, 15:52.

[79]It is undisputed that the MWRA did not meet the avoidance criteria as of December 30, 1991. It is also undisputed that the MWRA periodically failed to meet one or more of the avoidance criteria between January of 1992 and July of 1998, although the parties dispute at length the frequency and magnitude of the violations.

Notwithstanding the threat of litigation, on December 12, 1997, the DEP, while denying the MWRA's request for a filtration waiver (because the avoidance criteria for inactivation of ***Giardia*** and viruses and the Total Coliform Rule had not been met), nonetheless gave the MWRA until October 31, 1998, to supplement its waiver request.[80] The United States filed this action on February 12, 1998.

The court permitted some preliminary discovery but essentially stayed the litigation pending the DEP's decision on the MWRA's final request for an avoidance determination. That request was submitted on October 31, 1998. The request tracked a staff recommendation that the MWRA reject filtration in favor of ozonation-only, use some of the money saved to subsidize a long-term community pipeline rehabilitation program, and intensify monitoring of the MWRA system. In early December, the MWRA and the MDC updated the WPP as required by the ACO. Ex. 395.[81] On December 22, 1998, the DEP determined that the MWRA's water system met the avoidance criteria of the SWTR. The determination stated that "[i]f at any time the MWRA fails to comply with any such [avoidance] criteria . . ., MWRA will be in violation of the treatment technique requirement and the Department will revoke this Avoidance Determination and require filtration." Ex. 385, at 2. Despite the January 1999 violation of the fecal coliform criterion, DEP declined the EPA's request that it rescind the waiver.[82]

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[80]On February 12, 1998, the ACO was amended to reflect the new deadline.

[81]The DEP approved the revised plan in February of 1999. Estes-Smargiassi, 2:100-101; Ex. 70.

[82]On March 4, 1999, the DEP, the MWRA and the MDC amended the ACO a fourth time to require the MWRA to comply with the avoidance criteria. Ex. 461. A fifth amendment, inserted on June 12, 1999, required the MWRA to complete construction of the ozonation facility by the end of December 2003. Ex. 512, at 2.

IX. THE COMPETING TREATMENT PROPOSALS

The choice confronting the court is whether to order the installation of a full treatment train consisting of DAF/filtration, ozonation and chloramination, or only the later two components (the so-called "ozone-only" option). The competing facilities were both designed by the engineering firm of Camp, Dresser & McKee ("CDM"). The two alternatives, and their advantages and disadvantages, are discussed below.

The DAF/Filtration Alternative

The DAF/filtration alternative supported by EPA is not truly an alternative but a supplement to the ozone-only option[83] favored by the MWRA. The CDM design is based on a conventional four-step filtration module. In the first stage, the water is treated with polyaluminumchloride to promote flocculation (the clumping of low-density particles). Dissolved air is then injected into the water to form tiny air bubbles. These adhere to the flocculated particles causing them to rise to the surface where they are skimmed off. In the second stage, the water undergoes primary disinfection with ozone. The water is then filtered through a 6 foot deep bed of granular activated carbon. Finally, chlorine and ammonia are added to produce a chloramine residual. The plant designed by CDM is intended to achieve at least a 4-log, and possibly a 5-log reduction of ***Cryptosporidium***. Ex. 127, at 8-5; Edzwald, 14:130.

An advantage of DAF/filtration stems from its "more is better" or "multiple barrier" approach. The DAF/filtration system is highly redundant, and each of its components is

[83]Nor is the MWRA's plan truly an "ozone-only" option. The ozonation scheme incorporates the same residual chloramination treatment as does the DAF/filtration alternative.

designed to function (with a greater or lesser degree of efficiency) as a self-contained treatment system.[84]

Another advantage of DAF/filtration is its positive impact on potential regrowth in the distribution system. Ozone is a powerful, opportunistic disinfectant that attacks natural organic matter in water, breaking larger organic molecules into smaller biodegradable molecules, which, if passed into the distribution system, become food for resident microorganisms. Ex. 135, at 10-5. Biodegradable organic matter in water is measured in two ways. The biodegradable dissolved organic carbon ("BDOC") test measures the amount of dissolved organic carbon consumed as natural bacteria undergo incubation. Daniel, 4:143. The assimilable organic carbon ("AOC") test measures the growth of known strains of bacteria as they consume organic material. Rittman, 19:15; Daniel, 4:142. Both tests are experimental in the sense that their accuracy as predictors of regrowth has not been established, although the underlying theory is considered valid. Rittman, 19:77; Daniel, 4:143; Ex. 473. It is not a matter of dispute that ozonation enhances the measurable levels of BDOC and AOC in treated water.[85] Ozonation, as a result, is believed by most researchers to stimulate or contribute

[84]According to Dr. James Edzwald, Professor of Civil and Environmental Engineering at the University of Massachusetts Amherst, the DAF process, standing alone, is capable of achieving at least a 1-log removal of ***Cryptosporidium***.

[85]The phenomenon has been observed in tests involving Quabbin and Wachusett water. See Exs. 466 and 467. Dr. Rittman expressed "a high degree of confidence" that the MWRA's ozone-only option would "greatly increase the regrowth problem and all the risks inherent to it." Rittman, 19:26. Dr. Rittman made particular reference to the experience of Portland, Maine, which uses ozonation-only treatment at a dosage level of 1.5 mg/l (half that planned by the MWRA). According to Dr. Rittman, Portland has experienced a "serious problem" with regrowth, despite consistently lower year-round water temperatures. Rittman, 19:45. CDM's Phillippe Daniel, who commissioned Dr. Michelle Prevost (a respected investigator) to study the Portland system, concluded from her results that Portland had not experienced a regrowth problem. Daniel, 5:68-69.

to regrowth.[86] DAF/filtration, on the other hand, has the capacity to remove substantial amounts of BDOC or AOC (perhaps on the order of 50 to 60 percent) during the screening process. Rittman, 19:46-48, 50.

Another advantage of DAF/filtration is that it permits the use of lower doses of ozone and chloramine during primary and residual treatment, thus reducing levels of DBPs in the distribution system. Edzwald, 14:67, 136. (As designed for the MWRA, the DAF/filtration plant uses half the ozone contemplated by the ozone-only option and 23 percent less chlorine. See EPA Proposed Finding # 326). Finally, DAF/filtration removes algae, crustaceans, insect parts, and other particulates,thereby improving the aesthetics of the finished water.

The Ozone-Only Option

The superior power of ozone as a disinfectant has been understood since the beginning of the twentieth century and, although considerably more expensive than chlorine, has been used extensively as a disinfectant in Europe, beginning in the Netherlands in the 1890's. Aieta, 11:18. The first permanent ozonation facility in the

[86]How much of the observed increase is "food" readily consumable by microorganisms is hotly disputed. Dr. Michelle Prevost of the Ecole Polytechnique de Montreal, after conducting five tests of Wachusett water in 1997 and 1998, predicted that the potential for regrowth after ozonation would be "moderate" to "higher." Daniel, 6:66. Dr. Prevost's work is based on controversial models that essentially fractionate BDOC according to the (presumed) ease by which its constituents can be digested by bacteria (the HSB model) and then attempt to predict the impact of the fractionated BDOC on a specified distributionsystem (the SANCHO model). Rittman, 19:53-54, 58; Daniel, 4:143. While Dr. Bruce Rittman, the Director of Environmental Engineering Studies at Northwestern University, characterized the SANCHO model as an "important advance," he questioned its value as a predictor of regrowth because of its dependence on the output of the HSB model. According to Dr. Rittman, the HSB model has "a lot of limitations" that produce a problem of "garbage in; garbage out squared." Rittman, 19:59, 60. In a more serious vein, Dr. Rittman criticized the Prevost study for failing to disclose how the fractions of BDOC were actually determined. Rittman, 19:56-57. Dr. Pevost was not called as a witness at trial by the MWRA, possibly because she is a supporter of filtration. See Shawcross, 15:73.

United States was built after World War II. Edzwald, 14:24. Interest in ozonation intensified in the early 1990's as concern grew over chlorine-resistant pathogens and the possible carcinogenic effects of chlorine-generated DBPs. Aieta, 11:19. Ozone kills a far wider spectrum of pathogens than does chlorine, without producing organic by-products. Daniel, 5:60. Ozone also has two beneficial aesthetic effects. It bleaches dissolved organic matter in water improving its appearance. It also attacks compounds that produce unpleasant tastes and odors. Id., at 25.

The physical design of the ozonation facility engineered by CDM was described by Phillippe Daniel as follows.

> This is a schematic, an enlargement of a schematic of the ozonation treatment process that I discussed yesterday.
>
> And in this figure, again, the water comes through the Cosgrove Tunnel.
>
> The first step is it goes into the inlet control structure. The inlet control structure is simply for metering and dividing the water amongst the four parallel process plants. There are four ozone contractors in parallel. So it divides the water to each of the ozone contractors.
>
> The water flows into the ozone contractor where there are several application points for ozone. In fact, one of the application points for ozone is not shown, and that application point should actually be right here at the exit of the contractor (indicating). Ozone can be injected at any of these different points.
>
> Now, the ozone is prepared from liquid oxygen that's stored on site. Now, we have opted to store liquid oxygen and bring it on site because it lessens the level of complexity. The operators don't have to worry about a more complex oxygen preparation system on line. It's simply put in.
>
> . . .

> The ozone generator then produces ozone which is injected through diffusers forming small bubbles, and these bubbles allow the ozone and the gas to be transferred to the water where it forms a dissolved concentration of ozone.
>
> Once the ozone concentration is established in the water, the ozone will slowly decay, decrease in concentration, as goes along the contractor. It then flows through a pipeline from these contractors to a part of the storage tank, that 50 million gallon storage tank. A portion of that area is used for allowing the ozone to continue to react and disinfect in the water.
>
> It passes through there until the point where corrosion control chemicals are applied.
>
> And, finally, chlorine and ammonia are applied at the end to form chloramine and the water continues into the rest of the storage tank and closer to the system.

Daniel, 5:43-44. A principal feature of the design is a modular configuration intended to accommodate the addition of a DAF/filtration component, should it become necessary, or a more technologically advanced filtration facility using microscreens, membrane filters, and ultraviolet light. Daniel, 5:79; Aieta, 11:83-84.

CDM's principal design objective was to achieve a 2-log (99 percent) reduction of ***Cryptosporidium.***[87] Confidence that the design will achieve the inactivation goal is based on an animal infectivity study (involving mice) conducted for the MWRA by the firm of Montgomery Watson, working with the Oregon Health Sciences University Laboratory.[88]

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[87]A system designed to achieve a 2-log reduction of ***Crypotosporidium*** achieves a 1,000 times greater inactivation of ***Giardia*** than presently required by the SWTR, and an even greater reduction of viruses. Daniel, 5:57.

[88]As Dr. Aieta testified, there were in fact two Montgomery Watson studies. A replicate study conducted with a greater number of data points achieved results "nearly

As the EPA acknowledges, “animal infectivity studies using the mouse model are the best means for measuring the degree of inactivation/disinfection achieved by various agents.” EPA Proposed Finding # 345. In the mouse model, neonatal mice are force-fed measured concentrationsof oocysts in water treated with ozone. After a gestation period, the mice are “sacrificed” (Dr. Aieta’s euphemistic term) to determine whether they have contracted cryptosporidiosis. Statistical modeling is then used to determine the effectiveness of ozone at different dosage levels. Aieta, 11:53-64. Using Wachusett water, the Montgomery Watson study determined that the CT value for a 2-log (99 percent) inactivation of ***Cryptosporidium*** at 3ºC was 18 mg per liter minute. This value in turn was used by CDM as the basis for the design of the ozonation facility. Daniel, 5:42.

The design challenge described by CDM’s Phillippe Daniel was to ascertain an optimal balance between the configuration of the ozone contact tanks and the level of the ozone dose used so as to consistently achieve the desired CT value. Because the operating efficiency of a plant varies under the influence of external factors (water temperature and the rate of flow), these must be analyzed on a seasonal basis to determine the plant’s limiting conditions. In warmer weather, for example, disinfection kinetics are more favorable, and ozone demand theoretically drops. However, in warmer water, ozone decays more rapidly, while flow (demand) increases, thus a lengthier contact time is required to achieve CT. CDM ultimately concluded that an ozone dose of 2.2 mg per liter minute (“C”) was sufficient to meet the Montgomery Watson target value under the most severe limiting conditions. CDM, however, chose to incorporate a design specification of 3.0 mg per liter minute, 33 percent above the Montgomery Watson “C”

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identical” to those of the first experiment. Aieta, 24:7.

value. Similarly, a maximum flow of 405 million gallons daily was assumed, with a theoretical detention time of 40 minutes ("T"),[89] as against an actual maximum flow observed at Walnut Hill of 330 million gallons.

The EPA's Proposed Finding # 341 criticizes CDM (and the MWRA) for selecting a CT value for the inactivation of ***Cryptosporidium*** that applies "no safety factor." The 3.0 mg/l "cushion" it dismisses as "inadequate" because it addresses only the "C" side of the equation. Id., at n.9. The criticism ignores two other factors that influenced CDM's choice. First, the design specifications are based on the most extreme limiting conditions (temperature and flow) that the plant can be expected to encounter. Second, the 33 percent "cushion" set by CDM is not a ceiling. As Phillippe Daniel explained, once initial demand is satisfied, residual levels become self-reinforcing, causing a build up of residual to a level in excess of the 33 percent cushion. Daniel, 5:51. Finally, the EPA's complaint that CDM gave no attention to the "T" value is contradicted by the fact that 20 percent of the original storage area was converted to ozone tank space to permit a longer contact time than was contemplated by the initial design. Daniel, 6:20.[90]

The EPA also criticizes the Montgomery Watson study. The EPA maintains that Montgomery Watson's CT value was derived from a "best fit" of the data (rather than from

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[89] "Theoretical" because the figure is adjusted by a baffling factor of 0.7 to yield an effective detention time (T^{10}) of 34.5 minutes. Daniel, 5:47, 50.

[90] The EPA's analogy to its selection of a CT value for the inactivation of ***Giardia*** with ozone (which incorporated a safety factor of two) suffers from an apples and oranges flaw. The differing resistances of ***Giardia*** and ***Cryptosporidium*** to disinfection are too gross to permit a proper comparison. Moreover, the EPA's decision to set a high safety factor with respect to ***Giardia*** was influenced by admitted weaknesses in the underlying study on which EPA's ***Giardia*** CT value was based. See Aieta, 11:71-75. David Hiltebrand, who was called by the EPA to opine on the relative merits of the filtration/nonfiltration alternatives, conceded as much, and agreed that of the two studies, the Montgomery Watson study was "definitely [the] superior." Hiltebrand, 23:74. EPA has not yet established a CT value for the ozone inactivation of ***Cryptosporidium***.

an upper confidence interval). See EPA Proposed Finding # 344. EPA does not, however, explain why its preferred statistical method would produce a superior (as opposed to a more elastic) result. The EPA also objects to the fact that the study used only two samples of Wachusett water "having generally similar water quality characteristics." EPA Proposed Finding # 356. The objection appears directed not only at the number of samples used, but at the fact that the water itself did "not reflect the range of water quality parameters ***sometimes*** experienced in the Wachusett Reservoir." Id. (emphasis added). This, too, is not elaborated, most probably because the evidence at trial demonstrated the remarkable stability of Wachusett water. See, e.g., Estes-Smargiassi, 2:140-142.

The EPA's third criticism of the Montgomery Watson study, which has validity, stems from the fact that living organisms, even cloned mice, have complex reactions to stimuli. Even the best designed experiment is susceptible to misinterpretation, technician's error, and misreporting. The result is what statisticians call variability. In biological experiments results commonly deviate, at times substantially, from the mean. Clancy, 15:132-139. Why this is so in mouse-modeled infectivity studies is explained by differences in the natural resistance of mice to disease, variations in the infectivity of the oocyst samples used, the difficulties inherent in administering precise doses to uncooperative subjects, and the problems of detecting an oocyst infection during dissection. Clancy, 15:140-141.

The point that the EPA makes is that variability should cause concern that Montgomery Watson's CT value may be too low, and that without a built-in safety cushion, ozonation may not adequately protect public health. Again, the EPA's argument ignores the fact that apart from the limiting conditions that influenced CDM's design, the plant

incorporates a redundant capacity over and above its planned 33 percent dosage cushion. As Phillippe Daniel explained:

> [i]f we're wrong and our calculations are wrong, [if] there's a flaw in our calculations, then we have the capacity actually to add more ozone. So we have this capacity built into the design. For instance, we can – by changing the way we operate our generators, both in terms of energy efficiency and production output, we can actually dose instead of 3 milligrams per liter, we can dose 4.8 milligrams per liter, and that's still with additional ozone capacity in our standby.

Daniel, 5:54.[91]

The EPA raises a second, also substantial, possible shortcoming of the ozone-only option, which is its potential to stimulate regrowth. As previously noted, there is a consensus among investigators that ozonation contributes to an increase in BDOC/AOC levels by breaking organic molecules into biodegradable matter. Whether ozonation would deleteriously impact regrowth in the MWRA system is, however, a system-specific issue. Camper, 7:116-118.[92] As the EPA admits, evidence that the MWRA system is presently experiencinga problem with regrowth is very weak. Reilly, 20:67-69 (noting that levels of nitrification and heterotrophic plate count ["HPC"] bacteria ordinarily associated with regrowth have not been observed in the MWRA system). See also EPA Proposed Finding # 282. The strongest argument for a regrowth potential stems from the age and

[91]The design incorporates other redundancies or "fail-safe" features. Each of the individual components is designed to operate autonomouslyso that the failure of one will not have a Chernobyl-like effect that impacts on the operation of other components. The plant will have standby power generators in the event of an electrical power failure, and twice the number of ozone generators needed, each capable of operating at 160 percent of capacity. Daniel, 5:55-57. While a catastrophe of Biblical proportions, like the hurricane that apparently traumatized Mr. Hiltebrand, see 23:58, cannot be ruled out, filtration systems, as the Milwaukee experience proved, are also susceptible to catastrophic failure.

[92]This fact tends to discount any analogy to the experience of Portland, Maine with ozonation as well as the debate over whether in fact Portland has experienceda regrowth problem. See Footnote 85, supra.

deteriorated state of many of the pipes in the MWRA's distribution system, which impede maintenance of an inhibiting level of chloramine residual. Camper, 7:108-109, 116.

The most rigorous study of regrowth potential in the MWRA system is the Black & Veatch study conducted by Dr. Ann Camper of the Montana State University Center for Biofilm Engineering. The study used Wachusett water and actual MWRA distribution pipes. While the EPA is critical of aspects of Dr. Camper's study, particularly her use of uniformly-sized pipe, low ozone dosages (0.5 mg/l to 1.0 mg/l), and coupon rather than pipe wall measurements,[93] her results have something to offer to both sides. On the one hand, the levels of HPC bacteria in the water columns treated with ozone were higher than those treated with chlorine. Camper, 7:132; Ex. 240, Figs. 14(a), 14(b). On the other, Dr. Camper found that there was no significant difference (measured in orders of magnitude) in biofilm counts between water treated with ozone and water treated with chlorine.[94] Camper, 7:130-132. The most that can be said on this issue is that the data are inconclusive, and that only experience will show whether ozonating the MWRA's system will cause regrowth to rise to unacceptable levels.[95]

In the third of its criticisms of the ozone-only option, the EPA raises the spectre of "breakthrough," that is, the penetration of the ozone disinfection barrier by pathogens shielded from disinfection by suspended particulate matter. Again, this is speculative

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[93]Dr. Camper testified that organisms in a distribution system are more prolific on pipe surfaces than in the water itself. Camper, 7:108.

[94]The study did not evaluate the probable impact of filtration on the potential for regrowth in the MWRA system. David Hiltebrand testified to studies suggesting that ozonation without filtration is appropriate only in small, coldwater systems with TOC levels below 2.0 mg/l. Hiltebrand, 23:43.

[95]In Dr. Camper's view, corrosion control, flushing, and pipe replacement are the single most effective expedients for controlling regrowth. Camper, 7:135, 137.

and couched in terms of possibility rather than fact. See EPA Proposed Findings ## 374-377. The only relevant study on the subject was conducted by Dr. Stephen Edberg. Dr. Edberg was asked by the MWRA to determine whether elevated levels of total coliform detected at the Commonwealth Avenue Pump Station could be explained by breakthrough. Using molecular fingerprinting, Dr. Edberg looked for matches between bacterial clones in Wachusett source water and clones found downstream of the treatment facility. A match could indicate breakthrough, although it might also indicate regrowth. Edberg, 7:12-13. On the other hand, the absence of a match would indicate that no breakthrough was occurring. Id., at 13. Dr. Edberg's 1997 study found matches for five separate strains of coliform that were "suggestive of breakthrough." Edberg, 7:52-53. In repeat tests in 1998, however, Dr. Edberg found no matches, indicating that if breakthrough had been occurring, a change in externalities had suppressed it.[96]

A final objection lodged by EPA against the ozone-only option concerns the ability of the plant to achieve adequate levels of ozone residual without stimulating regrowth. The bulk of EPA's criticism is directed at CDM's extrapolation of decay rates from the results of demonstration studies conducted in 1994 and 1995 using lower rates of ozone doses (1.0 mg/l to 2.0 mg/l) than the dose (3.0 mg/l) that will actually be used.[97] According to the EPA, CDM's extrapolated estimates are too optimistic and understate the amount of ozone that will be required to maintain an appropriate "C" value. See EPA

[96]In August of 1997, as Dr. Edberg was beginning the first phase of his study, the MWRA increased the chloramine dosage at the Norumbega station and in September moved the primary disinfection point to the Cosgrove Intake. This treatment reconfiguration (coupled with an increase in the chlorine dose) may explain Dr. Edberg's 1998 results.

[97]The demonstration plant studies were intended to calculate the ozone dosage needed to inactivate ***Giardia*** and viruses, hence dosage levels more appropriate to the inactivation of ***Cryptosporidium*** were not used.

Proposed Findings ## 361, 362, 364. The EPA faults the MWRA (and CDM) for not testing Wachusett water containing seasonally high levels of total organic carbon ("TOC"). EPA Proposed Findings ## 367, 370. This latter criticism is based on a "worst case" assessment of TOC levels which may be overstated, as TOC levels in Wachusett water have never exceeded 4.0 mg/l in winter when the highest doses of ozone are required and are generally well below 3.0 mg/l. Hiltebrand, 24:90-93. According to Dr. Aieta, CDM has conducted (albeit belatedly) a demand and decay study using TOC levels of 3.3 mg/l. Ex. 517. This study convinced Dr. Aieta, at least, that "TOCs above 3.3 present no particular challenge in terms of ozone dose residual attainment." Aieta, 24:16-18.

X. IS THE LEVEL OF RISK ACCEPTABLE?

The most authoritative risk assessment of the ozone-only option was provided by Dr. Charles Haas, Professor of Environmental Engineering at Drexel University, United States Chairman of the International Water Association, editor of the journal ***Quantitative Microbiology*** and the principal author (with Dr. Joan Rose and another) of a respected treatise, Quantative Microbial Risk Assessment (1999). Dr. Haas is a member of the EPA's Technical Working Group on Microbials and has previously testified as an expert witness for the EPA.[98] His particular expertise is the assessment of microbial risks in drinking water. In that capacity, he performed the risk analysis of New York City's non-filtered water system for the Academy of Science's National Research Council, among others. Haas, 8:76-83.[99]

At the MWRA's request, Dr. Haas performed a quantitative risk assessment of MWRA water using the threat of ***Cryptosporidium*** infection as its baseline.[100] Id., at 83. In assessing the risk associated with MWRA water, Dr. Haas used three statistical

[98]From a perusal of the many EPA-generated exhibits in evidence, Dr. Haas would appear to be one of the authors most often cited by the EPA as an authority on water quality issues, perhaps second only to Dr. Mark LeChevallier.

[99]The EPA offered the testimony of Dr. David Ozonoff, the Chair of the Department of Environmental Health at the Boston University School of Public Health, ostensibly to offer a rebuttal risk assessment. Dr. Ozonoff testified in very general terms about the beneficial aspects of DAF/filtration. I have discounted his testimony as it became apparent during cross-examination that Dr. Ozonoff has no expertise in water quality issues. He has testified "maybe a hundred times" as a plaintiff's expert in asbestiosis cases. Ozonoff, 21:124. Dr. Ozonoff has some unusual views on issues of general causation, not all of which impressed the courts to which they were offered. See Ozonoff, 21:127-128, 135-136.

[100]As Dr. Haas testified, ***Cryptosporidium*** is the most disinfection-resistant of known pathogens. If ***Cryptosporidium*** can be controlled at acceptable levels, so too can less-resistant pathogens such as ***Giardia***, human enteric viruses, and bacteria. Haas, 8:84.

methods, a point risk assessment, a so-called "Monte Carlo" simulation,[101] and a comparison of the level of risk posed by MWRA water to that of other large water systems. Haas, 8:85-86. As an acceptable level of ***Cryptosporidium*** risk, Dr. Haas used the EPA's one infection per 10,000 population per year (10^{-4}) standard.[102]

As described by Dr. Haas, the point risk method of analysis

> is one in which we take the inputs to the calculation, the "inputs" being the concentration of oocysts in water, the amount of water that people ingest, the dose-response relationship and the reduction due to treatment. And we characterize those by single numerical values in order to develop an estimate of the risk that would result from that exposure.

Haas, 8:89.[103]

The specific "inputs" or assumptions that Dr. Haas incorporated were very conservative. He assumed a daily average personal water intake of 2 liters and a ***Cryptosporidium*** infectivity constant of 238 oocysts (the constant used by the EPA in its analysis of the regulatory impact of the IESWTR). He also used infection, rather than the manifestation of illness, as the indicator of infectivity. From this, he calculated the daily intake of ***Cryptosporidium*** oocysts acceptable under the 10^{-4} standard (in daily terms, 2.7×10^{-7}) to be .0033 oocysts per 100 liters of water.

In the final step of the point risk analysis, Dr. Haas took the number of confirmed and presumed oocysts found in MWRA water in samples collected between 1995 and

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[101]As its name suggests, the Monte Carlo simulation is a form of uncertainty analysis.

[102]See Footnote 32, supra. The 10^{-4} standard was used by EPA to develop regulatory strategies for the control of ***Giardia*** and viruses. Haas, 8:88.

[103]As Dr. Haas pointed out, point risk estimate analysis is used regularly by the EPA's own statisticians, including Dr. Messner. Haas, 8:89. See Ex. 112, at 4-7 to 4-11.

February of 1999,[104] and divided that number by the total volume of water tested (using the Poisson method)[105] to estimate a pre-treatment oocyst concentration in MWRA water of .035 oocysts per 100 liters.[106] He then concluded that a 1-log inactivation of ***Cryptosporidium*** would be sufficient to bring the level of risk within the 10^{-4} standard, while noting that the MWRA's planned 2-log ozone inactivation will lower the point risk assessment by an additional factor of ten (to $10^{-5)}$). Haas, 8:118.[107]

The second assessment performed by Dr. Haas used a Monte Carlo uncertainty analysis. As Dr. Haas explained, the Monte Carlo method differs from the point risk analysis "in that rather than looking at a single numerical value for water ingestion, for the

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[104]Dr. Haas also conservatively assumed that all presumptive oocysts in the dataset were viable and infectious of humans, and moreover, that no human exposed would be immune to infection. Haas, 8:113, 116.

[105]The Poisson method, as Dr. Haas illustrated, is more reliable than the average density method and is the method that the EPA itself recommends. Haas, 8:100-103; Ex. 398.

[106]Dr. Haas disregarded the 1994 MWRA dataset principally because "the numerical values of apparent oocysts that were reported by the laboratory for that year were so high as to be unbelievable." Haas, 8:105. He also pointed out that the MWRA had selected a more sophisticated laboratory to do its analysis in 1995 and that the testing results have been internally consistent since. Haas, 8:105, 108, 112-113. Having heard the evidence and argument on this contentious subject, I agree with Dr. Haas' decision to exclude the 1994 data.

[107]The EPA's principal criticism of the assumptions used by Dr. Haas is directed at the MWRA's sampling results. EPA argues that the testing method itself is so deficient, that it is possible that "a concentration of 30 to 100 oocysts per 100 liters, which Dr. Haas has predicted could lead to an outbreak of cryptosporidiosis, is likely to be reported as a non-detect using the IFA method." EPA Proposed Finding # 424. This might be true if the dataset consisted of but one or two samples. Even assuming the lowest suggested oocyst recovery rate of 12 percent for IFA testing, it is mathematically impossible that in four years of regular sampling, there would be no instances of oocyst detection indicating the level of concentration that the EPA suggests might exist, much less no detection at all of a confirmed oocyst. As the MWRA observes, the EPA itself has said that one year of data collected under the IFA method are sufficient to predict the risk of ***Cryptosporidium*** infection in a water system. Ex. 398, at 404, Fig. 4-2.

concentration of oocysts in the water, and a single curve for the dose-response relationship, we look at distributions that characterize those input values." Haas, 8:119. These distributions are then run through thousands of computer simulations in which values are randomly selected until a stable point risk estimate is reached. The result using the Monte Carlo method Dr. Haas determined to be "entirely consistent" with the result obtained by the point risk method. Haas, 8:124.

In his final analysis, Dr. Haas compared the average concentration of oocysts in MWRA intake water to those tabulated by Dr. Mark LeChevallier in surface water treatment plants and to the data collected from unfiltered systems under the ICR. In all instances, MWRA water compared favorably to water provided by similarly-sized unfiltered water systems (that is, it posed a lower risk of infection), including those of Seattle, Portland (Oregon), and New York City. With respect to filtered systems, Dr. Haas found that raw, untreated Wachusett water contains a lower concentration of oocysts than the treated water in the 70 filtered systems studied by Dr. LeChavallier. Haas, 8:127-128. In quantative terms, the risk of a ***Cryptosporidium*** infection from water ***after*** treatment in the filtered systems was ten times greater than the risk of an infection from MWRA water treated without ozone. Haas, 8:129.

XI. ULTIMATE CONCLUSIONS OF FACT AND LAW

(1) The story of Wachusett water quality in the last decade has been one of continuing improvement, in some respects gradual, in others dramatic, as MWRA management has sought to renovate the MWRA's system to avoid filtration. The milestones in this progress I identify as: (a) the passage by the Legislature of the 1992 Watershed ProtectionAct; (b) the strong public support generated by conservation groups for the MDC's largely successful efforts (to date) to preserve and protect the Wachusett watershed; (c) the full implementation of the gull harassment program; (d) the interim reconfiguration of primary and residual disinfection treatment and corrosion control; (e) the replacement of open storage reservoirs with covered storage facilities; (f) the implementation of an aggressive program to clean and/or replace mainline pipes; (g) the institution of a program to encourage rehabilitation of community distribution systems; and (h) the sewering of septic systems in the Towns of West Boylston and Holden.

(2) The Wachusett Watershed Protection Plan, as conceived and implemented, has been effective in maintaining the integrity of the watershed as a barrier against contamination of the Wachusett Reservoir.

(3) I find credible the testimony of MWRA officials that the installation of filtration will diminish public support for the Watershed Protection Plan and will lead to increased public pressure to open restricted MDC lands to general recreational uses.

(4) There are no issues affecting the quality of Quabbin Reservoir water.

(5) There is no present threat posed by ***Cryptosporidium*** to the quality of Wachusett Reservoir water.

(6) As designed, the ozonation facility to be constructed by the MWRA will adequately address any potential future threat posed by ***Cryptosporidium*** to Wachusett Reservoir water.

(7) Chlorination, as currently applied, is adequate to address any present threat posed by ***Giardia*** and viruses to the quality of Wachusett Reservoir water.

(8) Ozonation will significantly enhance the MWRA's capacity to inactivate ***Giardia*** and viruses.

(9) A combination of ozonation and chloramination will effectively inactivate any of the known "emerging" pathogens.

(10) There is no present threat posed to the quality of water in the MWRA distribution system by known disinfection by-products.

(11) Ozonation will significantly reduce levels of disinfection by-products in the MWRA distribution system.

(12) Ozonation will improve the aesthetic quality of the MWRA's finished water.

(13) Ozonation will increase the level of biodegradable organic matter (measured by BDOC or AOC) in the MWRA distribution system.

(14) Levels of BDOC and AOC in the distribution system may be exacerbated by the need to address higher than anticipated levels of total organic carbon.

(15) Ozonation has the potential of stimulating an unacceptable level of regrowth in the MWRA distribution system.

(16) Pipe rehabilitation, flushing, and corrosion control are more effective means of combating regrowth in the MWRA distribution system than is filtration.

(17) I find credible the testimony of MWRA officials that the added costs of installing DAF/filtration treatment will have a substantial financial impact on the MWRA's program to encourage community pipe replacement and rehabilitation.

(18) There is insufficient evidence to suggest that the MWRA system presently suffers from any problem of breakthrough.

(19) Any risk to public health entailed by selection of the "ozone-only" option is within acceptable levels.

(20) Ozonation plus DAF/filtration is a superior technology, offering greater protection against excessive levels of regrowth, a minimum of a 2-log increase in the capacity of the treatment plant to inactivate ***Cryptosporidium***, and better water aesthetics.

(21) No disinfection technology, including DAF/filtration, can offer a 100 percent guaranty of safe drinking water.

(22) Because ***Cryptosporidium*** is not a current threat to Wachusett water, consideration of the costs and benefits of DAF/filtration is permitted by the amended SDWA.

(23) It is misleading to present the dollar costs of DAF/filtration in per capita, rather than gross terms.

(24) The expenditure of $180 million to achieve less than a 1 percent improvement in the capacity of the MWRA's treatment plant to inactivate ***Cryptosporidium*** is not an efficient or productive use of limited public resources.

(25) "The . . . reason that it matters whether the nation spends too much to buy a little extra safety is that the resources available to combat health risks are not limitless." Stephen Breyer, Breaking the Vicious Circle: Toward Effective Risk Regulation 18 (1993).

(26) The MWRA system is in present compliance with the filtration avoidance criteria of the SWTR.

(27) The potential for regrowth and the possibility of breakthrough are not filtration avoidance criteria.

(28) The MWRA was not in compliance with the fecal coliform avoidance criterion of the SWTR in January of 1999.

(29) The MWRA's noncompliance with the fecal coliform avoidance criterion is attributable to its use of an enhanced recovery method of testing, a fact of no legal significance.

(30) Fecal coliform bacteria are poor predictors of the presence or concentration of pathogens in water.

(31) Public policy does not support the ordering of DAF/filtration based on a single instance of noncompliance with the fecal coliform avoidance criterion of the SWTR.

(32) The MWRA has instituted an effective surveillance program to detect ***Cryptosporidium*** and other potential future threats to the safety of its drinking water.

(33) The modular design of the proposed ozonation facility and the completion of a design for a complementary DAF/filtrationcomponent will permit the prompt installation of filtration should it become necessary.

(34) The case for DAF/filtration of MWRA water, while ably presented, has not been made, either from a cost-benefit perspective, or independently, as a matter of scientific necessity.

(35) The "ozone-only" option favored by the MWRA is a sound alternative to DAF/filtration when competing demands for limited resources and the level of risk from all potential threats to the safety of MWRA water are considered.

ORDER

For the foregoing reasons, the request of the United States for an Interim Order of Injunctive Relief is DENIED.[108] The MDC's Motion to Dismiss is DENIED as moot. The court will ORDER that the MWRA give it notice of any future violations of the avoidance criteria, and will retain jurisdiction for the limited purpose of deciding whether at some future date, relief of the kind requested by the United States is warranted.

SO ORDERED.

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UNITED STATES DISTRICT JUDGE

[108]In concluding its brief, the United States raises the alarming prospect that this decision "has [the] significant potential to compromise the ability of the United States to enforce the SWTR. To the extent other courts adopt this [c]ourt's reasoning, a public drinking system that fails to meet one or more of the avoidance criteria . . . can attempt to resist compliance by seeking to demonstrate . . . that adherence . . . is not necessary for the protection of public health. The United States would have to undertake the time and expense of a full trial in each such instance . . . ." EPA Proposed Finding # 492. The direfulness of this prediction is, I think, inflated. Water utilities are very vulnerable to public pressure. It is doubtful that managers of a contaminated water system who refused or resisted steps necessary to protect public health could expect a very long tenure. From the testimony I heard, and from the MWRA internal memoranda entered in evidence, I do not glean any desire on the part of MWRA management or its employees to provide unsafe drinking water to MWRA consumers. Perhaps of more immediate relevance, the seven years of constructive collaboration between the MWRA and the EPA on a strategy to avoid filtration demonstrates that the EPA does not make a habit of mindless enforcement of the SWTR. I think any judge would agree that a substantial, systemic violation of the SWTR should be answered by the near-automatic grant of injunctive relief. But I would not expect to see many more categorical enforcement actions like this one brought on minor and remediable instances of noncompliance with the SWTR.