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A History of New England Water Supplies

125th Anniversary
New England Water Works Association
American Water Works Association
Defining Our Future Legacy

New England Water Supplies – A Brief History

385 years of drinking water, 125 years of New England Water Works Association

Abstract:

This paper reviews the historical development of New England water supplies in the following areas:

- Water supply from the settlement of New England through to the 1882 formation of NEWWA
- Development of water sources through the years
- Public health issues and the evolution of water quality regulations and water treatment
- The growth of distribution systems and their components
- Disasters, wars and emergency planning
- Water system management issues over the years
- A look at the early NEWWA and the growth of the organization
- Thoughts for the future

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"Our one great object is mutual improvement."
NEWWA's first President, James W. Lyon

Introduction

In 1882, some motivated water supply managers felt that a forum was necessary to exchange ideas and experience. They went on to form New England Water Works Association. This is the story of a group of far-sighted men who made a difference for their generation and all of those that followed. The young but influential organization attracted many brilliant men from different areas of expertise and different parts of the country. The result was advancement of water supply and public health understanding, all with national consequences. New England was truly a leader in developing the science and engineering that saved lives, kept the vital New England cities safe from water shortages and provided reliable service.

My purpose in this history is not just to tell the story of the NEWWA organization and its most famous members. Their story has been told and retold at several points during the organization's life, most notably at the 20th, 50th, 75th and 100th anniversaries. At each of these points, important men who had been present at key moments in NEWWA's history would provide excellent histories of the earliest meetings and the wondrous achievements of a young organization. I highly recommend rereading these journals as they have many insights into the life and times of our predecessors. And yet, while I don't want to diminish the importance of this heritage, there is much more to say. There are literally hundreds of water systems in New England, each with a story to tell for their experience in the past 125 years. There are also many common themes to this collective experience from which a big picture can be drawn.

This paper is meant to discuss the development of New England's water supplies themselves as documented through sources like the NEWWA journal. In the past 125 years, many far-reaching changes have occurred in everyday life: new technologies; major social, economic and environmental changes; different attitudes and expectations from the public, etc. As is seen throughout history, events are driven by underlying causes and water supply evolution is no exception.

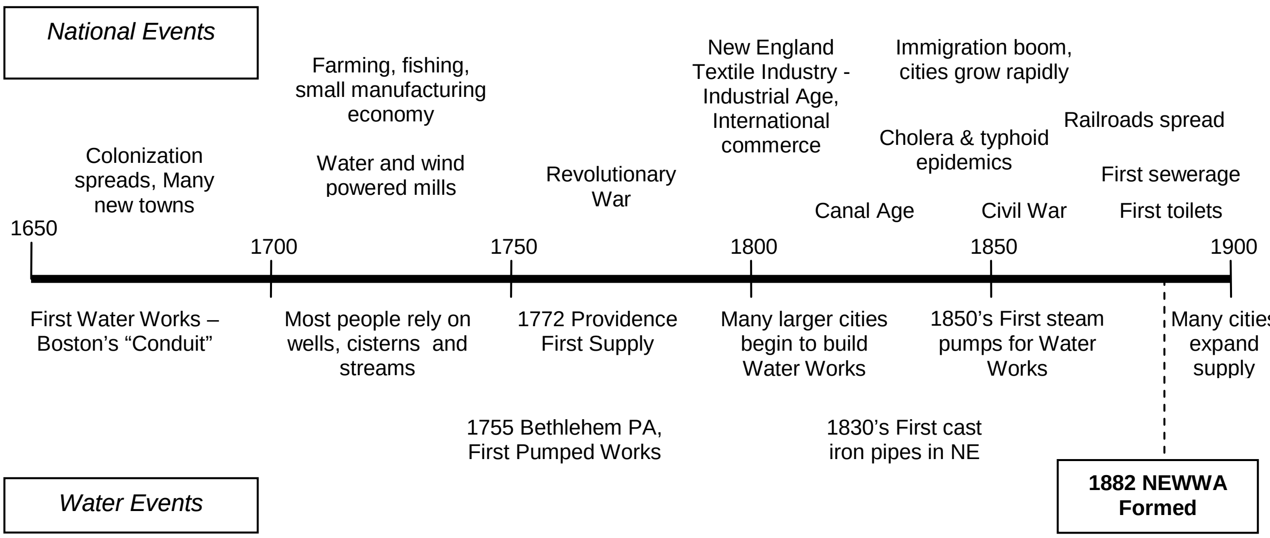
It was more than a happy accident that NEWWA formed 125 years ago. It was a necessity that public health issues be resolved and that New England's growing cities get proper water works to continue to fuel their prosperity. In the first few years after formation of NEWWA, the number of water supply systems doubled. Consider the pressure on this new generation of water supply managers to step up and do the job properly with no formal schooling in water supply. Consider the huge investment made in these works and the consequences of failure of high risk facilities like dams and steam pump stations.

My goal has been to set down what I have learned from reviewing our history. While the performance of New England's water suppliers was notably progressive and successful, not every decision made by NEWWA's members was a stroke of genius. Like everyone else, water supply professionals learn by using their best judgment and then learning from their often unavoidable mistakes. In 1882, much of the science and technology that we take for granted today was not adequately understood. The public health community was in the middle of an epiphany in understanding the role of bacteria in epidemics. Water treatment was primitive and water quality was worsening from pollution. The engineering and materials needed to collect, transport and distribute the water were also primitive. Throughout water supply history, funding has so often been the biggest factor in decision making and a constraint to necessary expansion/rehabilitation work. Many decisions to be made had trade-offs or hidden consequences which continues to be the fate of all water suppliers through to the present day. The lesson learned from this review is that by establishing a forum for sharing of experience among the operators, engineers, vendors and academics of NEWWA, the optimal improvement of water supply practices was assured and the public that we all serve was protected in the best way possible.

In the interests of consolidating the various facts, I have tried to identify where certain technological “firsts” took place as best I could determine. My apologies if I have not given your community proper credit.

Chapter 1 – Drinking water in the early days

Timeline – Drinking Water Before NEWWA



Water supply existed before NEWWA, so a brief review is in order to document water supply choices made by the earlier practioners.

New England waterways were one of the best things about the region, attracting colonists with ample water to drink, water for power and water for transportation. The first colonies chose locations on the coast for commerce and travel but were mindful to ensure access to pure drinking water. Their original choices reflected their modest size. Often a clear spring or brook would be the chosen center of a new community.

Water in New England before colonization

New England was blessed with features that provided much help to development of early water supplies. For one thing, there were abundant natural ponds and lakes. For another thing, there was enough elevation change and transmissive soil to provide good recharge to rivers and to create springs and artesian groundwater flow. Given the abundance of fresh water in the region, Native Americans camped near it but needed no irrigation or supply works as in drier parts of the country.

New England's river water could be colored and slightly turbid in places from passage through swamps but was generally clearer than that from other parts of the country in that it carried little sediment. The water was generally noted by colonists as being soft and "sweet". Soils were predominantly glacially created with more sand and gravel deposits than clay. With little limestone, the water had very little hardness and was somewhat corrosive.

New England's rivers also had more elevation drop than many other parts of the country. This single feature made the industrial revolution possible since the resulting water power was inexpensive to develop and plentiful throughout the region. Mills sprang up wherever it was possible to install a dam and diversion works. Grist mills and sawmills were the forerunners of much more elaborate manufacturing processes that were driven by water wheels or turbines. This guided much of New England's growth since the worker population followed mill growth.

Rainfall in New England was also fairly consistent throughout the year and relatively plentiful. In spite of adequate rainfall, farming in New England never grew to the size and importance of the U. S. mid-west since the terrain was hilly and the soil quite rocky. Extensive irrigation works were not necessary for the farming that did develop.

Example of old pump well – Adams House - Quincy MA

The English colonies begin and spread – 1620 to Revolutionary War

Before New England was settled, Virginia had the first permanent English colony in 1607. There had been explorations of the New England coast by many nations but there was little interest in colonization since there were no easy riches to plunder. It wasn't until the beginning of the 1600's that Europe began to see the New England area as source of raw materials for European industries. Desirable resources included crops, wood, fish, furs and other items in demand in the European economy. At this point, colonization became a privatized effort where colonies were chartered by investors with hopes of significant financial returns. This perhaps explains the entrepreneurial spirit that shows up again when water supplies are needed and private investors step up to develop the first water works.

Typical household dug well from 1700's with bucket on rope pulley

English colonists settled in Plymouth MA in 1620, then the Cape Ann area of Massachusetts in 1625, and Boston MA in 1630. These English colonies then spread in all directions in New England, founding offshoots in parts of Rhode Island, Connecticut, New Hampshire, southern Vermont, and Maine (part of Massachusetts until well into the 1800's).

The English weren't the only ones interested in New England. The Dutch settled in New Amsterdam around 1613 and tried to extend their way into Connecticut. The French settled in northern Maine and Canada in the 1620's, reaching down to Northern Vermont along Lake Champlain. Both the French and Dutch were eventually evicted from present day New England but left much in the way of heritage, most notably the names of many towns. State boundaries for present day Massachusetts, Rhode Island, Connecticut and New Hampshire were set by English rulers but not without some controversies. Vermont's boundaries were eventually set as the new state was added after the Revolutionary War. Maine was split from Massachusetts later in pre-Civil War days in a bit of maneuvering to balance slave states with non-slave states.

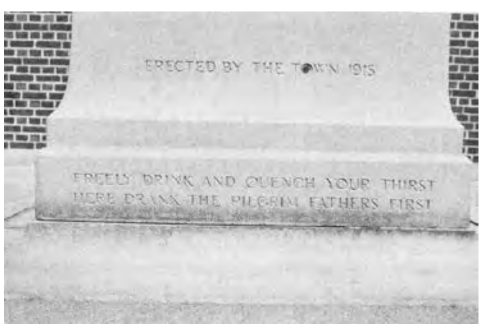
From a water supply standpoint, all settlement in New England was by European settlers and reflected the rudimentary understanding of water, public health and water use technologies that were present in Europe at the time. This meant that the same European habits of infrequent bathing and poor sanitation were transferred to the colonies. The colonies were merely starting with a cleaner slate in terms of having unpolluted water sources to start where Europe had already fouled the waterways near its cities. Water supply technologies such as dug wells and the use of wooden and lead pipes were the rule. Water and wind powered mills provided the power source for anything that could not be accomplished with hand tools.

All early New England cities were coastal in nature, being located in coastal ports (e.g. Boston MA, Portsmouth NH, Portland ME, New Haven CT) or upstream on a navigable river (e.g. Hartford CT, Providence RI, Bangor ME). Even Burlington VT followed this course in that it was settled on a navigable lake. These choices were necessary to allow shipping and commerce but it made life interesting for future water supply planners when residents eventually outgrew local water sources. Other smaller towns popped up at many locations inland as farmers spread and generally bordered on an available river or stream.

The First Water Sources

The first colonies obviously had the first water sources, some of which have been memorialized by the community's residents. These sources were merely a place to bring a bucket and carry home a bucketful or two during the day. Water use habits of the colonists were fairly austere, perhaps several gallons per day per resident. The effort required to bring that amount of weight a fair distance made anything other than essential uses difficult. This was a pretty effective disincentive on bathing and washing and contributed to the general lack of proper sanitation.

Every community had a central water supply point, be it a spring, a well or a river. These were not engineered facilities, but are noteworthy nonetheless. A fine example of a monument to a first drinking water source celebrates the water supply of the original Plymouth colony in



"Freely drink and quench your thirst,
Here drank the Pilgrim Fathers first"

Plymouth's first water source was Town Brook, near the current Mayflower dock

Plymouth's monument to the first water source

Massachusetts. A drinking fountain was dedicated in 1915 at a location on Main Street above Town Brook. The brook, just south of the center of town, was fed from Salton Pond and provided the residents of the town center with potable water until the first water works was built in 1855.

Similarly, Providence commemorated its first water source, the Roger Williams Spring, named for the founding father of Providence Plantation, the colony established by Roger Williams after his exit from Massachusetts in search of religious tolerance. This site, at North Main Street, was designated by AWWA as a National Historic Water Landmark.

Monument to Roger William's spring, Providence's first water source

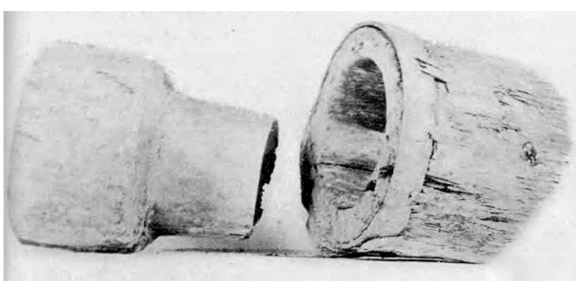
Boston residents put up a plaque at the location of the "Great Spring" at present day Spring Lane, which fed the bulk of the residents in the original community. This spring was the reason why the colonists chose the location that they did after first landing in present day Salem and Charlestown only to find the water sources to be lacking. The "Great Spring" became the center of the rapidly growing community that for a good while was the largest city in the colonies.

It's a pity that the location of the "Conduit" isn't clearly marked at its Dock Square location near Faneuil Hall. This 1652 site was the first actual water works in the US in that it was more than just a place to dip a bucket. Its original purpose was as much to provide fire protection in an area of dense wooden housing as it was meant to supply drinking water. Several uphill springs in the area were connected by means of wooden pipes to a 12' square cistern-like structure in Dock Square that would provide plentiful water for all needs, replenished much more rapidly than a dug well. Once the pipes were laid, it is known that selected homes, those of the people that financed the venture, were then tapped in and provided with running water. Thus, this early water works had intakes, pressure piping, distribution taps and a storage reservoir, albeit on a very modest scale. It helped significantly in subsequent conflagrations in the neighboring areas and served well into the 1700's before becoming too fouled to use. A section of old wooden main from this site graces the NEWWA lobby.

Section of the 1652 "Conduit" pipe, located in NEWWA lobby

The "Conduit", Boston's 1652 supply, the first Water Works in the U.S.

The desire for the convenience of running water in the home wasn't the only driving force that led to development of water works. The need for fire protection was equally important, perhaps even more important at that point. Before brick manufacturing was developed, all housing in the colonies was made of wood, including in most cases, the chimneys. A mud coating was the only protection against flames. Once a fire started, it could very well spread from house to house via the thatched roofs. Colonial homes were generally required to keep cisterns, barrels or other water containers filled for quick response to prevent conflagration. Fire protection was more carefully regulated than water usage or quality, with regulations being adopted to make housing more fire resistant and requirements put on homeowners to be ready to fight fire at any time. Even after brick construction and slate roofs were the norm, wood framing and close proximity in central areas meant a good supply of fire fighting water would be needed.



Examples of wooden pipes from Boston's Jamaica Pond Aqueduct

Moving water around in pipes required workable materials. Colonists had wood in abundance and had knowledge of how to make and join wood pipe sections, a fairly common practice in England. Metal for pipes had to be imported at first until eventually iron works were built. Metal for water pipes was limited to lead initially but in the early 1800's foundries had been able to produce iron plate that could be rolled, riveted and coated with cement to form wrought iron pipe. The production of cast iron pipe in the US began in the early 1800's but the cost was high until improved production methods made it more economical to use by the late 1800's.

Who had the earliest water works? The following table shows the first wood pipe systems, some of which date back well over 200 years.

Water systems built entirely of wood pipes:

City/Town	State	Date	Source	Comments
Boston	MA	1652	Springs	Wood pipes also used in 1796 Jamaica Pond system
Providence	RI	1772	Springs	Providence Water Co., Rawson Fountain Society
Salem & Beverly	MA	1796	Well on Gallow's Hill	Built by Daniel Frye
Portsmouth	NH	1798	Springs	Portsmouth Aqueduct Co.
Worcester	MA	1798	Springs	Built by Dan'l Gooding, later use of Bell's Pond
Peabody	MA	1799	Springs	From Salem & Danvers Aqueduct Co.
Haverhill	MA	1801	Springs/ponds	Haverhill Aqueduct Co.
New London	CT	1802	Spring	Aqueduct Co.
Drewsville	NH	1804	Spring	Smallest village with a water system in 1882
Bridgeport	CT	1818	Springs on Gold Hill	Built by Rev. Elijah Waterman
Hanover	NH	1820	Springs/wells	Hanover Aqueduct Co.
Cambridge	MA	1837	Springs to a reservoir	Cambridgeport Aqueduct Co. supplied a few families
Springfield	MA	1843	Reservoir	Built by Chas. Stearns, taken over by Springfield Aq. Co.
Gorham	NH	1873	Springs	Alpine Aqueduct Co.

Note that the use of wood continued well after metal pipe had become practical and affordable. Wood pipe was still actively installed and used in rural areas like northern New England well into the 1900's. On the other hand, contrary to urban legend, wood pipes in the cities have not been in use since the transition was made to iron pressure pipes in the mid 1800's. An occasional piece of wood pipe may be unearthed in some construction project but modern pressures would have blown it apart long ago, had it been left in service.

Not all of the early water works used wood. Given very low usage, some opted to used a lead pipe of up to 2" or so in diameter which, though limiting, at least may have been easier to keep from leaking than wood. When cast iron first appeared, the size and strength issues were no longer an issue, allowing more capacity and higher pressures for the growing water demands.

The First Metal Pipe Systems through 1850

Community	State	Year metal pipe is introduced	Type – Lead/ Wrought Iron/ Cast Iron	Source at the time
Portland	ME	1812	Lead Pipe	Neck Pond, Munjoy Hill
Montpelier	VT	1820	Lead Pipe	Springs
Dover	NH	1826	Unknown	Springs/pond
Hanover	NH	1829	Lead Pipe	Springs/wells
Durham	CT	1832	Wrought Iron	Cold Spring
Danbury	CT	1833	Lead Pipe	Springs
North Conway	NH	1833	Cast Iron	Artist's Brook
Peabody	MA	1834	WI & CI	Spring Pond
New London	CT	1840	WI & CI	Mill Pond
Worcester	MA	1845	Wrought Iron	Bell's Pond
Chicopee	MA	1845	WI & CI	Brook
Bellow Falls	VT	1848	Cast Iron	Lake Minard
Hyde Park	VT	1850	WI & lead	Springs
Windsor	VT	1850	WI & lead	Dudley Brook

The very early water works from the 1600's and 1700's were by no means complete systems in the sense that we have today. Given the large costs incurred by the private water companies, the expense of a connection was only affordable by the well-to-do and there were no governmental requirements to serve all customers. The poor could always walk to a public well or cistern. The rich folks on the hilltop could have their own well developed or pay a water seller for deliveries.

Access to water was also a function of location since the pipes did not serve all areas. Often the source was barely higher than the area being served so delivery pressures and volumes were limited. Wooden pipes were typically 2"-4" in diameter and early lead pipes were 2" or less so capacities were never what we would consider as robust in this period. Expectations were low and outages were frequent, especially since the wood pipe was notoriously prone to breakage.

Early sanitation

Privies and outhouses were the rule in the 1600's and 1700's. In the more densely settled areas, the facilities were often located in the basement. The waste was held in a tank or pit until the "Nightmen" came to reclaim it for its fertilizer value.

Plaque on Spring Lane in Boston

With the poor understanding of disease, no special precautions were taken around water supply sources. Animals roamed freely, adding copious amounts of waste to drainage that ended up in water sources. People often disposed of unwanted items, ranging from trash to dead animals, into the water body from which they drank. Early industries such as slaughterhouses and tanneries discharged wastes to whatever water body was handy. Cemeteries were located close to urban areas and often in the watershed areas of water sources. An excellent example of this is found on Boston's Freedom Trail where "The Great Spring" on Spring Lane is found one block downhill of 2 graveyards, the Granary Burial Ground and King's Chapel Burial Ground. Needless to say, many early water supplies were in a state of continual contamination. Only when the aesthetics of a fouled supply would become unpleasant were residents discouraged from using it.

Epidemics were frequent and deadly. Communicable diseases like smallpox had visited most of New England with quarantine the typical control strategy. Yellow fever was a seasonal scourge in swampy mosquito areas. Life expectancy was much lower than at present even without the waterborne illnesses of the period. With the close quarters and poor hygiene in poor areas, bacterial and viral illnesses essentially created a reservoir of disease within the community and the wastes from the infected population would be circulated to others, often via the water supply.

Before "germ theory" was advanced as a cause of some diseases, there was a widespread belief that dangerous vapors from unclean areas, called "miasmas", were the cause. There was also a belief among many that poverty, uncleanliness and disease were connected as some sort of punishment for the unworthy, consistent with the religious righteousness of the times. These believers had the expectation that one of water supply's best purposes was for washing down streets and tenement areas to wash away the disease lurking there. Old engravings from the period show horse drawn water barrels being used for street cleaning. Of course, the horses themselves put back as much waste as was washed away at times. Empirical evidence often connected poor water aesthetics to gastrointestinal illnesses at some water sources with resulting loss of confidence among water consumers.

Some famous names that you may not know as early Public Health officials:

Paul Revere – First head of Boston's Public Health Board in 1799.

Benjamin Franklin – In the 1730's, he was the first head of Philadelphia's street cleaning department, a critical public health service given the nature and volume of wastes in colonial days. He later went on to be a strong advocate for sewerage cleanup in Philadelphia. He also started the first fire company there in 1736.

Famous People affected by Waterborne Disease:

- Prince Albert of England died in 1857 of typhoid.
- Abigail Adams, wife of President John Adams died in 1818 of typhoid.
- President Zachary Taylor died of cholera in 1850.
- George Washington was affected by dysentery but survived.
- Louis Pasteur, the influential microbiologist, lost two daughters to typhoid.

Still, with limited population and industry, most of the rivers and large water bodies around New England remained clean through the 1700's and water quality troubles were more local than regional.

The Influence of Europe on American Water Engineering

New England settlers had the benefit of English water engineering examples from which to model their efforts, a mixed blessing at best. Private water companies had been supplying London from as early as 1213. As many as 9 separate water companies supplied parts of the city with water, some from adjacent springs or wells and some directly from the Thames. One water company used water wheels housed in the famous "London Bridge" to pump Thames water up to an uphill cistern for distribution. Of course, all of the Thames withdrawals had serious water quality and sanitation problems, with one unfortunate water company having an intake directly opposite the largest London sewer. With the sanitary problems created by the extremely dense population of this old city, the Thames River was already grossly polluted during this period and featured such colorful periods as the "Great Stink" of 1858. Life expectancy in mid-1800's London was down to 26 years. One notable water supply effort was the "New River", an 18 mile canal built by Sir Hugh Middleton in 1619 that was both an heir to the Roman aqueduct legacy and a forerunner of the modern water diversion from a protected upland source. London would later come to be a leader in sanitary reform but during the early 1800's, the example set for the US was not a particularly progressive one. Other European cities had similar experiences and had the disadvantage of having long ago polluted their available waters.

On the plus side, there was an active scientific community throughout Europe studying such water supply topics as hydraulics and water treatment. Scotland had implemented the earliest filtration of a community water system and France had made many advances in optimizing water withdrawals from a river through early bank filtration systems. European water engineers would continue to be a resource to US engineers during the 1800's. An example of this was noted civil engineer Charles Storrow's major 1830 work "A Treatise on Hydraulics" which was acclaimed in the US as being the best work of its day but was essentially just a compilation of what he had learned in his studies abroad.

Water supply in the rest of the US, New York, Philadelphia, Baltimore
Outside of New England, the major US cities were beginning to seek water supplies. One notable early effort is Bethlehem, PA, home to a Moravian community that developed a piped water supply in 1755 that featured pipes, hydraulically powered pumping and an above ground storage tank to supply homes with running water. The pumping was done with wooden positive displacement pumps and supplied water through wooden pipes. ASCE has recognized this early system as a National Historic Landmark.

The first significant municipal system was the Philadelphia water supply. The city sits at the confluence of the Delaware and Schuylkill Rivers, the former being tidal and the latter having more elevation drop and better water quality. In 1801, Benjamin Latrobe of Philadelphia designed and built the first large scale steam engine for municipal water pumping and used it with the first municipal cast iron pipes to pump from the Schuylkill River to a storage reservoir supplying the city with clean water. Wooden pipes were still the mainstay of the distribution system from the reservoir to the customers. The steam engine eventually proved to be difficult to manage and expensive, leading to a rethinking and reconstruction of the supply works in 1822. The new facility, the Fairmount Waterworks, featured hydraulic pumping using water wheels; it served the city proudly for the rest of the 1800's. This facility was beautifully designed in a neoclassical style that resulted in its current use as part of the Philadelphia Museum of Art as well as being designated as an AWWA and ASCE National Historic Landmark. In its day, the Philadelphia Works were considered the finest in the country until it suffered the same fate as many supplies of its day, i.e. the source water quality degraded to the point that other supplies made more sense.

Fairmount Waterworks in Philadelphia
Hydraulic pumps in the building to the right supplied water to open reservoirs on the hill where the Philadelphia Museum of Art now sits

Since the days of the Dutch settlements of the 1623, New York had been supplied by wells and ponds on Manhattan Island. Water quality of these sources was clearly inferior and availability was much too limited for the island's population, but the politics of obtaining a more plentiful supply were difficult to overcome. It wasn't until 1842 that the flow of the Croton River was dammed and diverted via aqueduct to the center of Manhattan to feed a network of cast iron and wooden pipes. The Aqueduct Bridge over the Bronx River is a particularly notable example of an aqueduct in the old Roman style.

Washington and Baltimore similarly constructed diversion works and aqueducts from an upstream point of their rivers to supply the community mainly by gravity. Other western cities that didn't have the advantage of a river with significant elevation drop had to wait for reliable steam engines to be developed to be successful.

American engineering was in its infancy in the early 1800's with most active practitioners being U.S. Army trained. With few colleges providing engineering programs, many civil engineers came up through the ranks of staff constructing the large civil works of the day. Surveyors and canal builders often became the experts called upon to build water supplies when needed. One such man, John Jervis, was educated on the Erie Canal project and went on to build New York's Croton Dam and Aqueduct, then was further engaged to plan and design Boston's Cochituate Aqueduct. Many other New England engineers went on to consult on the water supplies of the other cities that followed.

Water Supply Entrepreneurs
Early water supply wasn't immune from politics and scoundrels. Fortunately, schemes for personal gain were rare but the following is offered as an example:

In New York City in the early 1800's, Manhattan's water supplies were oversubscribed and fouled, leading to a public clamor for improvement. **Aaron Burr** sought a state charter to form the Manhattan Water Co. with the publicly stated mission of securing a supply from the mainland. However, the charter was authorized in a midnight legislative session that somehow included wording that the company could raise excess funds for any purpose. Burr managed to turn the venture into the formation of a successful bank (eventually to become the Chase Manhattan Bank). Unfortunately, he neglected to carry out the water improvements, much to the detriment of the NYC public.

Private vs. public
In almost all cases, the early water supply developers of New England were private water companies that were granted the right to develop the supply. This was mainly the result of the daunting cost of constructing such a supply and the uncertainty that customers would want to pay for the service when, for no cost, they could bring a pail to the local well. Capital funds were typically raised by selling shares with dividends to be paid to shareholders. Service was limited to only the paying customers. Essentially all of the pre-1850 supplies shown in the earlier tables were built by a private water company.

Boston's 1848 Lake Cochituate supply was the first New England water supply developed by a community with its own funds.


Sketch of Boston's Lake Cochituate Intake

Early 1800's – New England Industrialization

Up until the Revolutionary War, New England had an economy based on commerce and limited manufacturing in the large cities, farming and trapping in the smaller inland towns, fishing along the coast and timber in the northern states. Independence brought fundamental changes in the economy as English restrictions on trade and industrialization were lifted. With Europe having its own problems in the early 1800's, the US was poised to become an economic power and a destination for immigrants in search of the land of opportunity.

Lowell Mills on the Merrimack River, supplied from a canal network

After U.S. independence, the U.S. began to pursue industry, which had been pretty much discouraged under British rule. New England had ample water power from rivers so it was naturally attractive for mill development. Manufacturing materials and fuel were supported by the growth of iron and steel mills and coal mines in Pennsylvania. The US south produced vast amounts of cotton (especially attractive for manufacturing after Connecticut resident Eli Whitney's cotton gin is invented), but they couldn't process it to cloth. New England with its river-powered mills took over this job and flourished. Sutter's Mill on the Blackstone River in Providence was the first step in a progression that saw Lowell, Lawrence, Manchester, Holyoke and other cities become major manufacturing centers. While this brought great prosperity, it also added significantly to the waste load being carried by the river downstream of these sites.

At the same time, large scale farming began to shift more to the mid-western states where the land was more easily farmed than rocky and hilly New England. The region's labor force became more concentrated in cities as a result since the needs of manufacturing were still on the upswing. As New England grew, the labor needs of the mills were met at first by the local population, often women and children to a large extent. Employment at a mill was often supplemented by housing in the mill's tenements, adding to the population density in mill cities. With economic problems in Europe, the prosperity of the United States attracted much immigration, not just from England but also from all over Europe. Given the lower wages accepted by immigrants, mills started using immigrants heavily to meet their labor needs. Overall, New England began a period of very rapid population growth that would continue through the rest of the 19th century.

The Need for More Water by the mid 1800's

With rapidly growing population and per capita usage, the first water systems built by the early 1800's reached a stage where they needed more source capacity. The capacities of pipes, storage facilities and other water supply elements were too limiting or, in the case of wood pipes, in too poor condition to continue. Eventually, the water quality of many local sources deteriorated to an unacceptable level for most customers.

As was evidenced in Boston in the 1830's, Jamaica Pond obviously wasn't going to carry the city into the next century. Neither were Providence's springs or many other local sources. The search for the next supply became an exercise in engineering, water quality and politics. The engineers sized the future needs on the best available prediction of population growth and per capita increases, perhaps even a doubling from the current 10 gallons per capita at the time. Of course, they had no way to tell how wrong they would be until more people had access to modern plumbing. Men of wisdom (since there were few real civil engineers yet) were called upon to understand rainfall and flows as necessary to predict available source capacities. The aesthetics of the proposed source had to be studied under summer conditions to predict whether the water would be palatable. The political element often came down to who owned what water rights and what degree of compensation was necessary to do the deal. Of course, all of these early plans were limited or flawed partly due to the poor understanding at the time of the underlying science and engineering necessary to do the job.

Even at this early stage, most water supply builders understood the benefits of going upstream and away from the pollution of the cities to get clean water and elevation for gravity flow. This is a recurring theme for most New England water supplies and one of the reasons why the region suffered less from waterborne disease than many other parts of the country. All of this sets the stage for the events leading up to formation of NEWWA.

Events leading up to NEWWA formation in 1882

Why was NEWWA necessary? The answer is that there were many forces coming into play that were driving the need. It wasn't just a growing public demand for water plumbed into the home or a public expectation that affluence should be accompanied by such conveniences. It was most definitely public health and public safety pressures as understanding about waterborne disease and fire protection issues grew. It was a growing appreciation of the necessary engineering and science to do this difficult job. It was the fact that constructing a water system was a high stakes venture, being the biggest public works project to date in most communities and the most necessary to ensure business prosperity.

Growing water use

The major event of this period was the Civil War, which, like later wars, affected population and resources. New England lost some of its population to the war and to westward migration but overall population increased dramatically throughout the period. Immigration from Europe was vigorous, especially from Ireland. The Irish potato famine occurred from 1844 to 1846 and came at a time when England had its own problems and offered less aid to Ireland, thus starting the immigration wave. In the years following the famine, Ireland had also had epidemics of typhus, scurvy and bacillary dysentery, with the result that in 5 years, Ireland lost ¼ of its population to death (1 million) and migration (2 million), most taking the cheap passage to Boston and New England. Between 1840 and 1860, Boston's population went up by 110%, while its Irish population went from 1 in 50 to 1 in 5.

New England industries continued to prosper, not just from gun manufacturing during the war but all sorts of goods from textiles to complex machinery. Mills were still heavily dependent on water power but the steam engine began to be a viable source of industrial power so that industries were no longer limited by drought flows. Other parts of the country, such as the mid-western states, made use of steam power to become competitive with New England in many heavy industries. Steam engines for the railroads also signaled the end of the Canal Era for transporting goods and allowed much better population mobility throughout the country.

The bottom line was that cities, especially those with manufacturing, continued to grow very rapidly during this period. Cities also grew in terms of annexation of suburbs or adjacent villages. This extended the areas needing water service in many large communities.

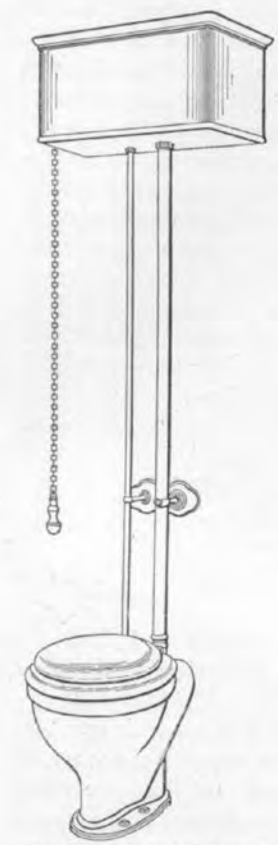


Fig. 41. High-Tank Arrangement of Closet Fixtures.

Early toilet

Growing per capita use

In addition to population growth, the amount needed by the average household had been climbing more rapidly than anyone could have imagined. The impact of plumbing was a major part of this, especially the flush toilet which was becoming an influence in cities. Bathtubs were not as exotic and rare as they once were. Public bath houses offered bathing access for the masses but wealthy people were more likely to install their own facilities. Several inventors had put forward flush tank toilets and eventually solved the sewer gas problems with the S trap design for the bowl. The major hotels in cities began to develop indoor plumbing as an attractive convenience, eventually even providing plumbing for each room.

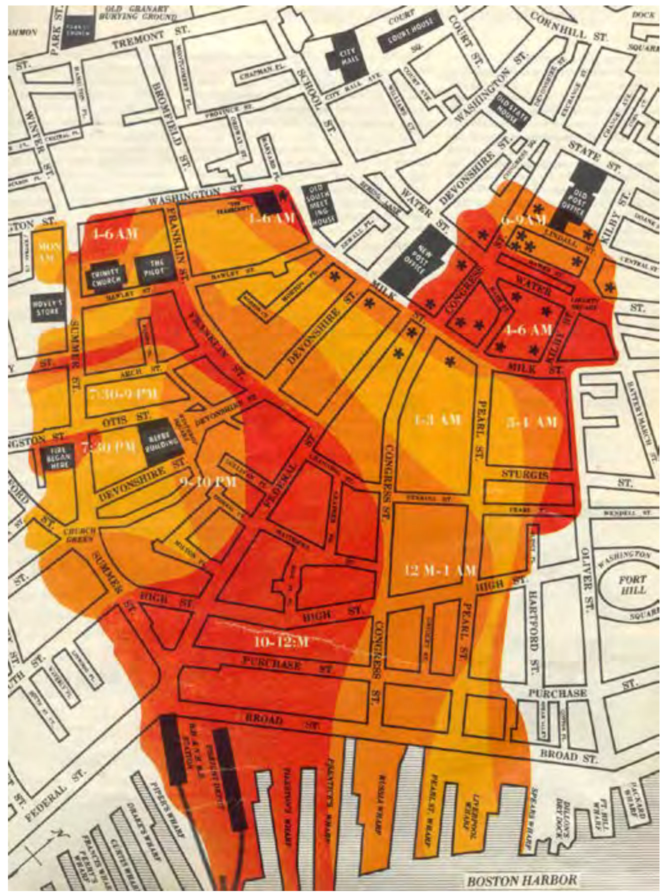
The other factor was the lack of metering on most household services. With only a flat fee to pay, the consumer began to take advantage of the novelty of running water, raising per capita usage by a factor of 10 from the beginning of the 1800’s. With the unreliability of supply in some early systems, some people would leave taps open just to not miss the water when available.

Technology Developments

Towards the end of this period, other technology developments change the public’s expectations of its utilities. The telegraph had been extended throughout the country. The first radio and telephones were invented. Gaslights had been installed in most cities and Edison’s electric light had been invented. Modern conveniences were the rage and the affluent demanded the latest inventions.

Cities had started to develop sewerage works to move the waste away from the people. Collecting sewerage and directing it to the nearest waterway, away from residents, was the normal practice. Often, sewerage was simply directed to the nearest storm drain so that rainfall events would occasionally flush the pipes. This marked the beginning of combined sewers in many urban areas, creating a problematic sewer infrastructure that is still being addressed in the present day. The proliferation of sewer discharges may have improved the aesthetics of urban life but left much to be desired in terms of fouling rivers and streams, especially downstream of inland communities. Large interceptors to collect the sewerage of individual street drains for discharge at more remote outfalls were just beginning to be planned to minimize public impact, with Boston's Main Drain in 1883 being a prime example.

Further development of water resources was slow until the post-Civil War period. Major fires were still a driving force for improvement of distribution systems, the most notable fires of this period being in Boston and Portland. To be fair, it should be noted that each city has a "Great Fire" somewhere in its past. The most destructive fire nationally was Chicago's Great Fire of 1871, which destroyed 18,000 buildings, caused 200 deaths and consequently nearly crippled the insurance industry, with much impact locally on Hartford CT. Boston's Great Fire of 1872 consumed 776 buildings in the heart of the city and was fought over several days by firemen from as far away as Maine. It resulted in 13 deaths and $75 million in damages, again causing bankruptcy of 70 insurance companies. By comparison, Portland's Great Fire of 1866 consumed 1500 buildings and caused $15 million in damages. Responders again included companies from as far away as Massachusetts.



Great Fire of 1872 in Boston, burned the entire area from present Day South Station to Fanueil Hall

These tragedies had repercussions on the water industry. In Boston, there was criticism leveled at the Water Department for having undersized mains in the area. There were no definitive standards on pipe sizes, nor were there any minimum pressure requirements or even standards for hydrants and nozzles. As a result of the 1872 event, Boston revamped its distribution system considerably to increase pipe sizes and available fire flows.

Fire protection measures were evaluated extensively by NEWWA after 1882. The insurance companies learned to minimize their losses by working with the water supply community to ensure effective designs for fire response. The insurance industry began using hydraulic experts like John R. Freeman, one of the more notable hydraulic engineers of the period, to evaluate fire capabilities. Many early NEWWA papers presented nozzle and fire stream studies in support of design standards.

Example of early pipe sizes - 1860 Cambridge MA pipe table, City serves 26,000 persons

Pipe Size	Length	% of Total
20"	180'	0.1%
12"	5950'	4.8%
10"	13180'	10.6%
8"	6000'	4.8%
6"	14955'	12.0%
4"	56263'	45.2%
3"	27989'	22.5%

Note that the majority of pipe is 3" and 4"

The other aspects of water engineering, e.g. dam construction, pipe laying, storage tanks, etc, were still in their infancy with relatively few experts in any discipline. Every new problem was a learning opportunity and there was a need to share the empirically found solutions to the myriad new problems. As was the custom of the times, water supply operation was like many technical occupations – something to be learned by mentoring in a master/apprentice relationship. This can only take someone only so far in a single water system. Thus, there was a clear need for an ongoing forum among water suppliers, scientists, engineers, vendors, academics, and every other specialty that had a stake in improving the performance of the industry. Enter NEWWA in 1882 to meet this need.

Beginnings of Public Health as a Driving Force in Water Supply

In 1882, cholera and typhoid epidemics were still rampant and 2 major misconceptions were still in place, i.e. the mistaken causes of disease and the belief that running water purified any wastes. The "miasma" theory that foul vapors caused disease was still popular since there had been no definitive proof of a disease causing mechanism. The first evidence of waterborne disease was empirical when people drinking from the same source became ill. The finding in 1854 London by Dr. John Snow that users of the Broad Street well developed cholera was a watershed finding for water suppliers and public health authorities everywhere. Microscopes had shown organisms, often called "animalcules" but the connection hadn't been made that bacteria could be the cause of disease.

Example of early waste discharge impacting household well

This changed in the early 1880's when news came from Europe that Robert Koch had successfully isolated the anthrax bacteria, cultured it, infected a second host with the culture, then re-isolated the same organism from the second sick host. This was definitive proof that bacteria were the causative agent and it was then obvious that bacteria in the sewage from infected people was the transmission mechanism that had been causing epidemics. Researchers like Koch and others identified many more bacteria like typhoid and cholera to further reinforce the point. "Germ theory" was born.

Now that this was understood in the scientific and the public health communities, they turned to the problem of how to stop sewage contamination of water supplies. This is where the second misconception occured, the idea that moving water would purify waste in a fairly brief travel, a hindrance to planners trying to get water from further upland supplies. Some source water decisions were poorly made as a result. A classic example of this was Albany's decision to use a direct withdrawal from the Hudson River despite numerous upstream community discharges. This proved to be regrettable when the city had numerous typhoid outbreaks that caused deaths for more than a decade to follow until their water treatment was improved. The original decision was opposed by some but supported by some very respected sanitarians, mainly due to the idea of natural purification. Eventually, the bacteria testing methods coming from Europe would provide a means to debunk this idea.

Armed with the idea that sewage was the culprit, public health strategies made it a priority to avoid the hazard. This meant that the less polluted upland supply was the clearly preferred choice. Sewerage and sewage treatment became even more important. When the use of a polluted supply was necessary, now the emphasis would be on ensuring proper treatment.

There was still very little understood about chemical issues in drinking water and there were certainly industries that had been polluting for some time – tanneries, paper mills and the like. Some operations, like paper mills or cloth dying, would literally turn the downstream river colors. When the biological threats in water were so great as to be among the leading causes of death at the time, the chemical threats were subtle in comparison so they received little attention. However, it was clear that water sources were becoming more fouled from both the spread of industries around New England but also from the increasingly complex wastes being discharged by these industries.

Mid 1800's to the 1882 formation of NEWWA - Forces at work

Why was an organization of water supply professionals necessary in 1882? To sum it up:

- Population was rapidly growing, especially in poor urban areas as a result of immigration.
- Per capita use was growing as a result of greater demand for plumbing.
- Water waste was growing in existing systems since metering was still too expensive to be supplied universally.
- Early water sources were becoming inadequate in volume.
- There were growing concerns over poor quality and disease from water and early water sources were becoming more polluted from sewerage and mill wastes.
- Distribution system capacity was becoming an issue, especially in the area of fire protection.
- Knowledge of water supply science and engineering was limited given the lack of technical schools and the reliance on essentially an apprentice system with on-the-job training or mentoring as the educational means.
- Being a fairly new field, there was a lot of uncertainty at the time over the means and methods of water supply – How do you build a safe dam? What pipe material is best? Is this water of adequate quality and how do you improve it? Uninformed solutions to these problems would lead some individual system operators to poor decisions at great public expense in the absence of consultation with fellow water system operators.
- As more cities and towns built water supplies, citizens of other communities demanded similar service, thus creating a rapidly increasing need for more knowledgeable operators and engineers.

Next steps for larger systems

In the period leading up to 1882, most of the larger communities took another step in a series of steps toward their present day supplies. Some needed better pumping technology to allow them to take the next step. Some, like Hartford, went the other way, deciding against costly pumping of an increasingly polluted source and moving to gravity supply from an upland reservoir. Many needed to dam rivers to get enough water, leading them into the difficult process of obtaining land and water rights, not to mention constructing a safe and effective dam. Each had their own challenges and crafted their solutions to fit their circumstances. Burlington VT, for instance, took supply from and discharged its sewerage into the same water body, which led them to engineer a deep water intake some distance from the city.

Many communities decided on public ownership to get the job done. This was partly to exert control over the effort but, often, the main driving force was to pursue the water supply for its public health benefits, which needed to be extended to the urban poor. Planners recognized that the old ways of using polluted wells and cisterns needed to change and safe public water should be accessible to all. Given the successes of many earlier systems, communities were also less fearful of the necessary level of investment.

The water works, in most cases, represented the single largest expense to date for a community and were celebrated accordingly. As with churches and public buildings, many early facilities were architecturally imposing, even grandiose, to assure that the noble mission was properly respected.

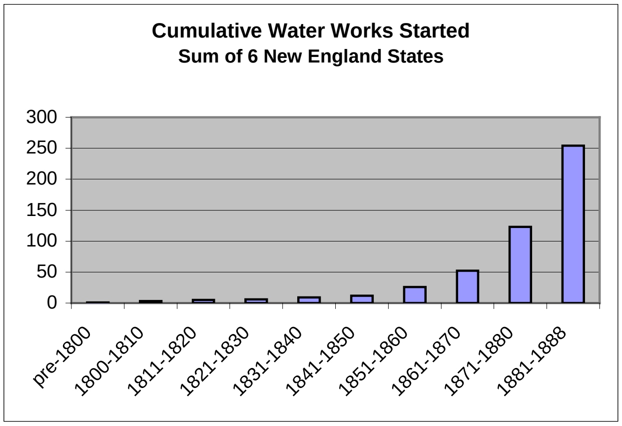
The following reviews the status of the largest New England communities prior to NEWWA:

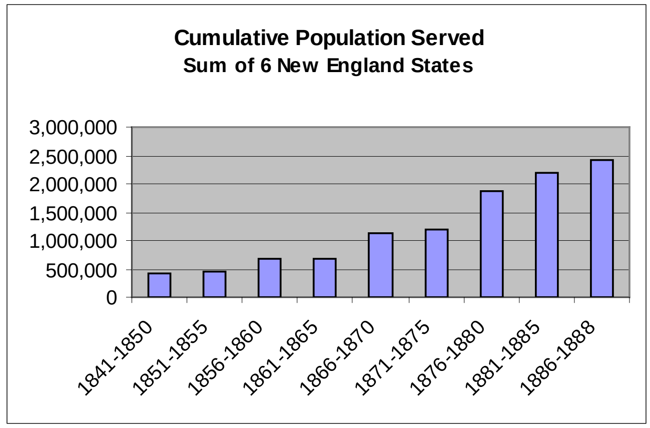
State	**City**	**1850 Source**	**1882 Source**	**Gravity/ Pump**	**Public/ Private**
Massachusetts	Boston Cambridge Worcester New Bedford Fall River Springfield	Lake Cochituate Fresh Pond Bell Pond Acushnet River Watuppa Lake 4 Sm. Reservoirs	Sudbury System Stony Brook Reservoir Lynde Brook Reservoir Acushnet River Watuppa Lake Ludlow Reservoir	Gravity Pumping Gravity Pumping Pumping Gravity	Public Public Public Public Public Public
Rhode Island	Newport Providence	Ponds Springs	Easton's Pond Pawtucket River	Pumping Pumping	Private Public
Connecticut	Hartford New Haven Bridgeport	Connecticut River Mill River Springs	Trout Brook Reservoirs Lake Whitney Ox & Island Brook	Gravity Pumping Pumping	Public Private Private
New Hampshire	Manchester Nashua	Lake Massabesic Pennichuck Brk	Lake Massabesic Pennichuck Brook	Pumping Pumping	Public Private
Maine	Portland	Springs	Lake Sebago	Gravity	Private
Vermont	Burlington	Lake Champlain	Lake Champlain	Pumping	Public

The need for more water operators

The period leading up to 1882 is the beginning of a water supply surge that carries well into the early 1900's. With so many new systems starting up, the qualifications of people stepping in to operate these systems must have been a bit thin. Consider that there were no schools for operators and few qualified engineers. The likelihood is that many stepped into the field with limited technical skills and probably an inadequate understanding of even the limited knowledge of the day.

The following graphs show the rapid growth in this period:





The number of people served by water supplies showed a great increase when the cities with large populations built their water works. Prior to the 1880's, this was still a relatively small percentage of New England communities but a cumulative growth of over 2 million people served is substantial.

The growth in number of water works was even more impressive. In just the decade of the 1880's, over 100 communities started water supplies. Each new water supply had significant responsibilities and risks for the new operators.

The following table documents the sequence of start-ups of New England systems:

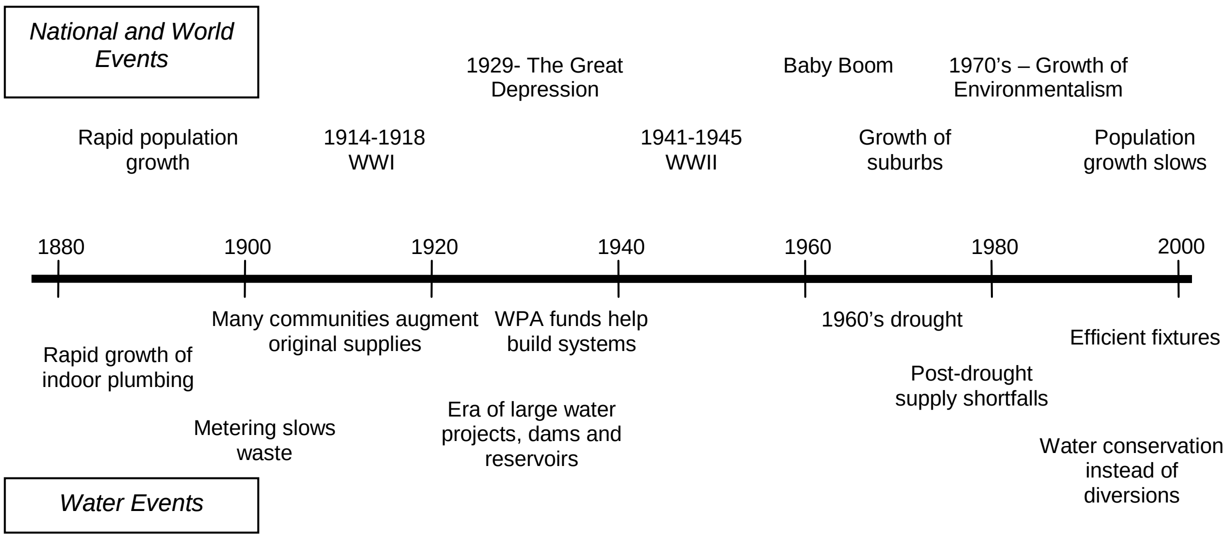
Water Systems Started from 1851 to 1882 (Cast Iron or Wrought Iron Pipes)

Community	State	Year	Community	State	Year	Community	State	Year
Hartford	CT	1851	Medford	MA	1870	Newton	MA	1876
Rockland	ME	1851	Melrose	MA	1870	Springvale	ME	1876
Bridgeport	CT	1853	Everett	MA	1871	St. Johnsbury	VT	1876
Northfield	VT	1854	Fall River	MA	1871	Taunton	MA	1876
Cambridge	MA	1855	Farmington	NH	1871	Agawam	MA	1877
Nashua	NH	1855	Fitchburg	MA	1871	Pawtucket	RI	1877
Pittsfield	MA	1855	Northampton	MA	1871	Bethel	CT	1878
Plymouth	MA	1855	Amesville	CT	1872	Cochituate	MA	1878
Rutland	VT	1856	Concord	NH	1872	Lewiston	ME	1878
New Britain	CT	1857	Lowell	MA	1872	Nantucket	MA	1878
Williamstown	MA	1859	Manchester	NH	1872	Torrington	CT	1878
Birmingham	CT	1860	Norwalk	CT	1872	West Randolph	VT	1878
New Haven	CT	1860	South Hadley Falls	MA	1872	Westborough	MA	1878
Stamford	CT	1860	Arlington	MA	1873	Amherst	MA	1879
Stockbridge	MA	1862	Attleborough	MA	1873	Brandon	VT	1879
Winsted	CT	1862	Augusta	ME	1873	Canaan	CT	1879
Salem & Beverly	MA	1865	Easthampton	MA	1873	Island Pond	VT	1879
New Bedford	MA	1865	Holyoke	MA	1873	Waterbury	VT	1879
North Adams	MA	1865	Lawrence	MA	1873	E. Providence	RI	1880
Stonington	CT	1865	Leominster	MA	1873	Fairhaven	VT	1880
Middletown	CT	1866	St. Albans	VT	1873	Greenwich	CT	1880
Norwich	CT	1866	Turner's Falls	MA	1873	Hingham & Hull	MA	1880
Springfield	MA	1867	Waltham	MA	1873	Thomaston	CT	1880
Burlington	VT	1867	Winchester	MA	1873	Uxbridge	MA	1880
Chelsea	MA	1867	Winooski	VT	1873	Central Falls	RI	1881
Portland	ME	1867	Woburn	MA	1873	Chicopee Falls	MA	1881
Rockville	CT	1867	Bar Harbor	ME	1874	Dedham	MA	1881
Great Barrington	MA	1868	Concord	MA	1874	Lee	MA	1881
Somerville	MA	1868	Natick	MA	1874	Newburyport	MA	1881
Waterbury	CT	1868	New Milford	CT	1874	Plymouth	NH	1881
Webster	MA	1868	Westfield	MA	1874	Shelton	CT	1881
Ansonia	CT	1869	Bangor	ME	1875	Southbridge	MA	1881
Auburn	ME	1869	Brookline	MA	1875	Bristol	RI	1882
Keene	NH	1869	Cheshire	MA	1875	Clinton	MA	1882
Malden	MA	1869	Lenox	MA	1875	Fryeburg	ME	1882
Meriden	CT	1869	Lincoln	MA	1875	Gardner	MA	1882
Vergennes	VT	1869	S. Norwalk	CT	1875	Kent	CT	1882
Providence	RI	1870	W. Springfield	MA	1875	Milford	NH	1882
Haverhill	MA	1870	Athol	MA	1876	Milford & Hopedale	MA	1882
Ashburnham	MA	1870	Danvers & Middleton	MA	1876	Northborough	MA	1882
Brockton	MA	1870	Hallowell	ME	1876	Richmond Furnace	MA	1882
Greenfield	MA	1870	Methuen	MA	1876	Wallingford	CT	1882
Lynn	MA	1870	Newport	RI	1876	Warren	RI	1882

Many more communities started after 1882, in fact, the growth spurt didn't abate until well into the 1900's. With this growth came a greater need for sharing experience, larger systems mentoring smaller systems and NEWWA filled this void.

Chapter 2 – The Search for Water – Growth and Water Source Development

Timeline – Water Source Development



Finding the water has always been one of the main tasks for the water supplier, occasionally a thankless task, even a maligned one. Since the growth of environmentalism in the 1970's, many people picture a water engineer in terms of John Huston's shady Noah Cross character from the film "Chinatown". Most books written about New England water supplies tend to focus on the impacts of reservoir construction, prime examples being "*The Day Four Quabbin Towns Died*" about Quabbin Reservoir and "*The Village of the Dammed*" about Saugatuck Reservoir in the Bridgeport system. The loss of one's home for a reservoir that benefits a distant city is almost certain to create a lifetime of resentment.

The fundamental dilemma is that cities exist where they are because of commerce and they drive the economy of the region to everyone's benefit, even the rural areas that are asked to help provide resources like water. But the cities overwhelm water resources where they exist and have to import water from elsewhere. This wasn't a decision to be taken lightly and the state legislatures became the forum to consider the needs of the many against the sacrifice of the few.

From the perspective of the cities, they have historically offered employment and housing for the bulk of the region's population. From the Revolutionary War onward, New England rose to national prominence on the strength of its manufacturing based economy, not on weakening rural agriculture. This manufacturing took place mainly in the cities, driving urban population growth and causing all manner of support services to be developed, including transportation systems, utilities and, of course, adequate water supply. Industry contributed mightily to the tax base and cities enjoyed the most representation in state legislatures. With the United States making its place in the world on the strength of its commerce, it is no wonder that cities had the power to get what they needed. The construction of large water works were themselves often seen as a boon to the regional economy. Concerns over disruption of rural areas and related environmental impacts were clearly a lesser concern before the change in the nation's environmental consciousness, beginning in the early 1970's.

Hundreds of New England communities had to go through difficult choices to assure that enough water would be available to allow the community to function and grow. Failure to address water supply issues in a timely way could be crippling to a local economy and devastating to public health as was the case when many early supplies became too foul for use. It was a balancing act involving water quality, cost, hydrology, ever changing water supply technology, impact on abutters or existing water mill industries and many other factors. The issues were often highly technical but were subject to politics, as was every large financial decision in a community. NEWWA became a forum for communicating experience in such matters.

The past 125 years has seen the growth of water supplies from modest takings from the local pond, up to damming of rivers and diversions across river basin boundaries. This chapter reviews the situation at the several key points:

Existing Conditions - 1882 (Formation of NEWWA)

In most of the pre-1882 water systems, the original choice of a water source was often very limiting. For convenience or economy, many communities chose wells or springs near the service population. Either these original sources became fouled or they were just incapable of sustaining the type of growth that occurred. For example, Boston's Jamaica Pond had less than 2 square miles of watershed and, while this was workable when per capita usage was less than 10 gallons per capita, it was clearly inadequate after about 1820. By 1882, Boston's next sources, Lake Cochituate and the Mystic River, had become dangerously polluted and were once again becoming too small. The larger cities tended to be in southern New England and had the most challenges in finding a nearby source of water especially since the southern New England rivers were flat and tidal near the cities, good for transportation but poor for drinking water. The following table summarizes conditions in the mid-1800's at some of the larger cities:

State	**City**	**Geographical Limitations**	**Early Source**	**1850 Source**
MA	Boston Cambridge Worcester New Bedford Fall River Springfield	Coastal peninsula, poor river water quality On Charles River, poor river water quality On Blackstone River, mills upstream Coastal city Coastal city On Connecticut River, mills upstream	1652 Springs 1837 Springs 1798 Springs 1843 Reservoir	Lake Cochituate Fresh Pond Bell Pond Acushnet River Watuppa Lake 4 Sm. Reservoirs
RI	Newport Providence	Island, little surface water Coastal city, mills upstream	 1772 Springs	Ponds Springs
CT	Hartford New Haven Bridgeport	Adjacent to Connecticut Coastal city Coastal city	 1818 Springs	Connecticut River Mill River Springs
NH	Manchester Nashua	On Merrimack, mills upstream On Merrimack, mills upstream		Lake Massabesic Pennichuck Brk
ME	Portland	Coastal City	1812 Pond	Pond & Springs
VT	Burlington	On large lake		Lake Champlain

1860 Lake Whitney Dam serving New Haven CT

Northern New England cities tended to have more options in that there were larger, unspoiled water bodies available, with the possible exception of some rivers where logging had already begun to foul the source. Southern New England cities had more difficult choices, often needing to go outside their community boundaries to create reservoirs. Topography had a lot to do with these choices, as more elevation drop in upland areas meant better reservoir opportunities. Many communities availed themselves of a large pond or lake, e.g. Burlington VT or Fall River MA. Very few withdrew directly from rivers, partly due to the uncertainty of low flows in smaller rivers and partly due to poor water quality during summer low flows when algae and upstream waste problems were problematic. The few that did so were on large rivers and were forced to go to early and aggressive water treatment to try to cope with the health problems posed by their chosen supplies.

Late 1800's to 1900 – Post NEWWA boom, Finding sources

Population, Per Capita and Growth of Water Use

	Population Growth Factors	**Per Capita Growth Factors**	**Resulting Water Use**
Late 1800's	⇧ • Rapid immigration • Slight westward migration • Net change was a rapid rise	⇧ • Absence of meters means waste • Indoor plumbing is a novelty • Per capita saw huge increases	*Very rapid growth*

Influence of Public Health

By 1882, the Public Health community had seen enough evidence linking drinking water to disease outbreaks to conclude that risky supplies were a reason for the high death rates of the period. New bacterial findings were continually coming out of Europe from important biologists like Koch and Pasteur and a new philosophy of sanitary engineering was being put forward to react to these findings. Now that the disease mechanisms were better understood, response strategies could be formulated, including better water treatment, more careful waste disposal, source protection and the choice of appropriate high quality sources. Drinking water adequacy and quality fell within Public Health's purview such that choice of a new supply in the early part of the century would give water quality much more emphasis.

This was the age of the first water quality laboratories and water treatment experimentation such as the work done at Lawrence Experiment Station (LES). Experts came from universities like MIT and from private industry to consult on the problems and assist the Public Health community. Such luminaries as Hiram Mills, Allen Hazen, William Sedgewick, Thomas Drown and others associated with LES published numerous early NEWWA papers on water biology/ chemistry as well as treatment techniques. Given the importance of the subject and the rather large jump that New England had on the rest of the country, it is understandable that these men became the foremost national authorities in the field.

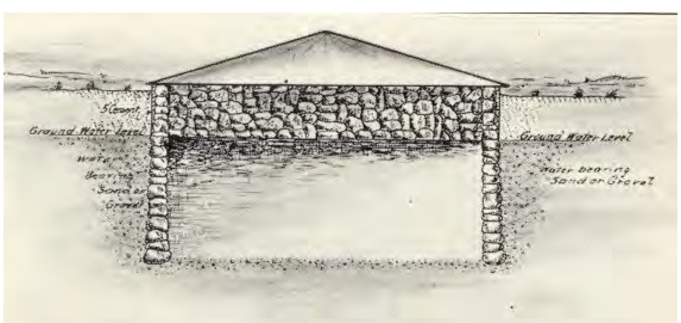
The Massachusetts Board of Health (MBOH), in particular, made clear its intention that water supplies be procured from protected watersheds, as free from wastewater discharges as possible. Its role included studying the adequacy of existing sources and guiding selection of supplies. Their influence was felt well into the 1900's. Not everyone subscribed to this philosophy, as was mentioned previously in reference to Albany's choice during this period to develop the Hudson River for its supply, leading to continued typhoid epidemics into the 1900's, traceable to upstream waste discharges. Hartford CT had made a similar early choice to use the Connecticut River in 1851 but reconsidered in 1867 due to worsening water quality, opting instead to develop a protected gravity flow reservoir system. Bangor ME originally used the Penobscot River in 1875 but eventually developed an upland source for the same water quality reasons. Providence also initially chose, for reasons of proximity, to develop the lower Pawtuxet River, a source whose water quality became progressively poorer until 1922 when the Scituate Reservoir was completed. The 1860 Mystic Water Works serving several communities north of Boston was a similarly poor choice due to the Mystic River watershed having numerous tanneries and other industrial waste discharges, leading to abandonment of the waterworks in the 1890's.

Droughts as triggers

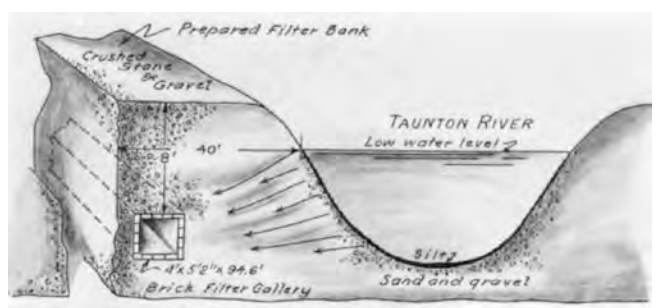
For systems that had already developed supplies, there was a limited amount of experience with runoff through drought periods, leading to occasional overestimation of supply capacity. Severe years or combinations of years were often a revelation in terms of water availability. 1880-1884 happened to be fairly severe drought years in much of New England. The 1890's also had a couple of fairly severe years. As these occurred in the most rapid growth period, the consequences often pushed the community to expand again very soon after completing new works. One of the earliest NEWWA efforts was the publication of hydrologic data and the formation of a committee to study safe yield to assist smaller systems to properly engineer their supplies.

Source development technology

Wells of this age were primarily dug wells or infiltration galleries adjacent to a river. Well drilling was somewhat limited by lack of portable power sources for such machinery. Manually driving relatively shallow well casings into permeable soil was another alternative to groundwater access. Examples of early well users included Taunton, Attleborough, Brookline, Waltham and Newton, all Massachusetts communities that built infiltration galleries adjacent to a river. Most of these supplies needed to build substantial distribution storage to offset mechanical problems with pumps.



Left – Cross-section of typical late 1800's dug well



Example of use of bank filtration to improve water quality –

Inside Attleboro's dug well

Taunton MA

1887 Canton MA pump station adjacent to covered dug well

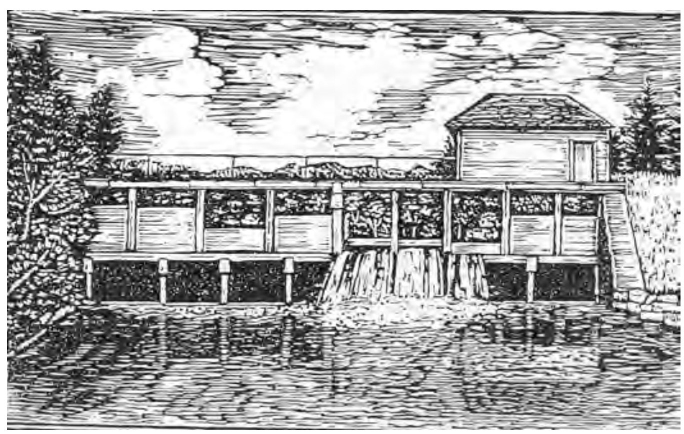
Construction of a dug well has essentially been the same since time immemorial. Towns would find areas with a shallow water table and dig a large infiltration space, then line it with porous rock walls to act as a sump for a pump. Often, such a well would be located adjacent to a pond or river so that water production would be replenished from a consistent water surface. Done properly, this constituted natural filtration and gave reasonably good water quality even under poorer summer conditions. However, many communities using these early dug wells were beginning to find that algae would be a problem in their open distribution reservoirs, which makes some sense given the nutrient loadings in the early urban rivers. The early dug wells also had to be maintained carefully to prevent soil piping and siltation into the well.

Location of potential groundwater was still closer to guesswork than science. Water witching was common but was felt to be hogwash by many. NEWWA discussed the subject, with some knowledgeable water supply men trying their hand at the willow stick and, after some attempts at a controlled experiment, these men found that they could not get any consistent results. This did not stop everyone, some still paid for the service.

Most water supplies in the post 1882 period were surface water supplies. Some communities had a nearby natural lake or pond, so that their technology needs were only for pumping and conveying water. Only a few communities took directly from a river, examples being Saco, ME and Lawrence, MA.


1898 Stripping the bottom of Boston's Sudbury Reservoir with horse drawn scrapers

Many communities opted to build reservoirs, partly to develop storage to increase the sustainable withdrawal, partly to gain water elevation to help with gravity supply and partly to help improve water quality. Even at this early stage, there was a right way and a wrong way to do the job. Early experience with natural ponds and smaller impoundments showed high organic content and poorer water quality. Boston's experiences in developing the Sudbury system in the 1870's – 1880's were presented in early NEWWA papers of this period, documenting the water quality benefits of reservoir detention. The proper preparation of the reservoir inundation area was similarly documented, showing that removal of organic swamp deposits, vegetation and other problem areas would greatly improve future water characteristics. These early papers helped guide many smaller communities in approaching their impoundments properly.


Sketch of early timber Pennichuck Dam, supply for Nashua NH

Another sticky issue of this age was dam construction. Dams had been constructed around New England from the beginning of colonization, the first being a timber mill dam in S. Windham, ME in 1623. Materials had advanced from timber to stone, earth and concrete masonry. Most early dams had been built privately for mills and failure was not an unknown (the first major dam failure in the US was in 1874 in Williamsburg MA, killing 144 people and causing $1 million in damages). Shortly after the 1882 formation of NEWWA, the 1889 Johnstown, PA dam failure took 2,200 lives, still the largest US loss of life due to a dam failure.

There was local cause for concern as well. New England engineers were familiar with the 1842 failure of New York's Croton dam during construction. Within New England itself, there had been several failures of water supply dams including the 1848 failure of Boston's original Lake Cochituate dam during filling, the 1867 failure of Hartford's Dam No. 1 on Trout Brook during a flood event while under construction and the 1876 failure of Worcester's original Lynde Brook dam.

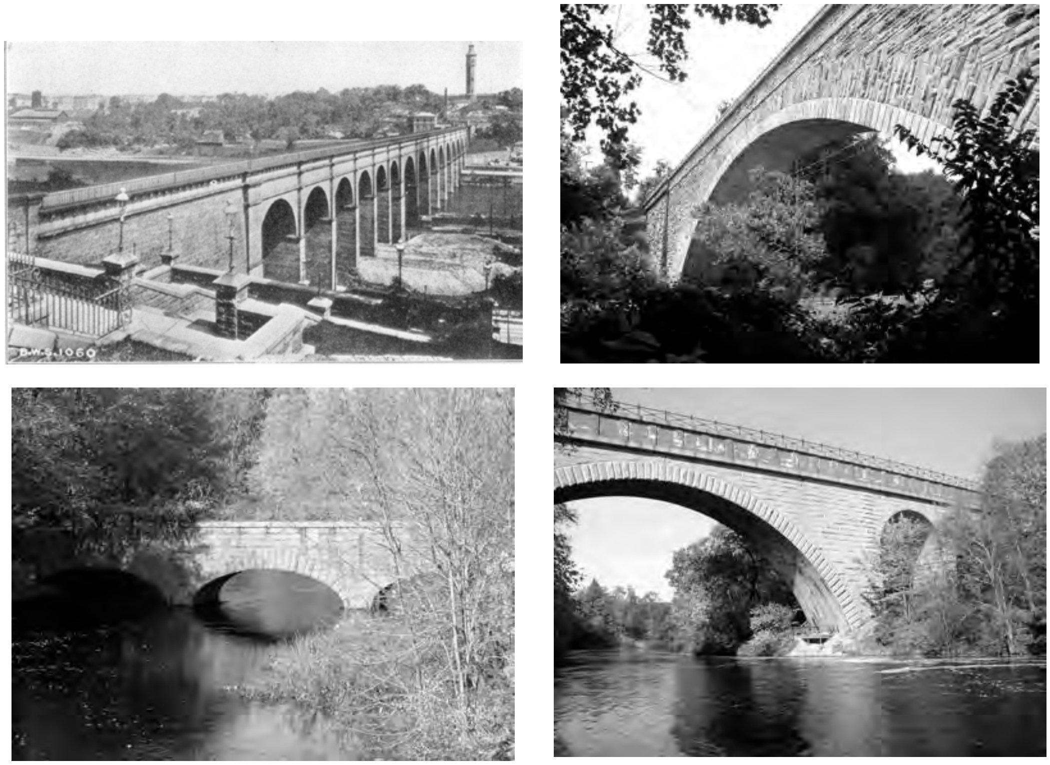
1893 Excavation for Sudbury Reservoir Dam


1893 Temporary housing for Italian masons performing stone work for Sudbury Dam

The mechanisms of failure were varied, including poor understanding of soils engineering in some cases and inadequate spillway capacity leading to overtopping of earth structures in others. Clearly, collaboration among water supply engineers via NEWWA papers and meetings was a positive influence on this field. Such topics as flood flow expectations and proper "puddle" construction for dam cores were covered by early NEWWA papers. The soils engineering aspects of containing water were equally important to those communities building large open distribution reservoirs, which were essentially low dams set on a hilltop.

Another technology associated with early water sources was the use of aqueducts to move water long distances, preferably using gravity. Early examples for such works were taken from Roman aqueducts, lengthy masonry conduits of constant slope with an occasional tunnel through a ridge or the use of grade crossing over a river via an arched aqueduct bridge. Boston made early use of such designs for its Lake Cochituate, Mystic River and Sudbury system sources. The earliest such aqueduct bridge was the 1848 Cochituate Aqueduct crossing of the Charles River, still standing but somewhat hidden off of the side of Rte 95 in Newton, MA. The 1878 Echo Bridge crossing of the Charles River by the Sudbury Aqueduct is a particularly good and accessible example of such a structure and has been designated as an AWWA Historical Landmark on this basis. As with the earlier New York Croton Aqueduct, tunneling was a necessary part of routing these grade aqueducts through high ground. Done with drill and blast methods (black powder since TNT was not yet invented), Boston's early aqueducts were also the earliest examples of such tunneling in New England.


Roman Aqueduct bridge – the classic solution to moving water long distances across valleys



Examples of old US Aqueduct Bridges:
Top left – 1832 Croton Aqueduct crossing of Bronx River
Top right - 1864 Cabin John Aqueduct Bridge in Washington DC
Lower left - 1848 Cochituate Aqueduct crossing of Charles River in Newton MA
Lower right – 1878 Echo Bridge crossing of the Charles River by the Sudbury Aqueduct in Newton MA

Other water aqueducts in the southern New England lowlands resembled sewer construction in that they were laid on a constant grade and flowed partly full. Portland utilized an oval brick conduit as part of its early Lake Sebago supply and New Bedford used a 7 mile brick conduit for its Acushnet River supply. Manchester, NH utilized an open canal to bring water from its lake source to its pump station. The engineering and materials developed for canal construction in the early 1800's laid an excellent groundwork for these types of aqueducts. Most communities that did not need the large volume required by a community like Boston, opted to use pressure piping for connecting distant sources.

Politics of water transfers and reservoirs
In this early period, most communities looked within their own borders for solutions. The few that did have to go to a neighboring community did so with relatively low impact projects, such as, Boston's development of Lake Cochituate which merely moved back a few homes as the existing natural pond was raised with a new dam.

However, Boston's next step, the Sudbury system, featured construction of 7 water supply reservoirs and 2 compensating reservoirs (reservoirs constructed specifically to provide streamflow for downstream mills), each of which was in a relatively unpopulated area. This marked the beginning of larger scale displacement impacts associated with reservoir construction and property condemnation, otherwise known as "eminent domain". Prime reservoir land in low-lying areas had always attracted farming, homes, roads, all brought there by the presence of the river. As an example, Cambridge, MA developed a reservoir on relatively unpopulated Stony Brook in neighboring Waltham, but it caused the local farmers to vehemently object since they felt they were losing their most fertile lands. Most issues were settled with compensation but surely resentment remained for a long period afterward.

1887 Cambridge's Stony Brook Dam and Gatehouse, Waltham MA

In those days, it was understood that man would manipulate his environment to suit his needs. There was little concern for preservation of the existing environment since the United States was the land of opportunity with its booming economy. Man was in charge and the fish in the river were clearly secondary to the production of the mill. Therefore, the main focus of water diversion issues of the day revolved only around the impact on downstream mill users. Much engineering time and energy was expended to estimate this impact and find solutions. The preferred impact mitigation method of this period was modeled after the English practice of building compensating reservoirs whose sole purpose was to retain flood flows for later release. This would provide the former river base flow during dry periods. In its Sudbury system, Boston needed to compensate mill owners on the lower Sudbury, Concord and Merrimack Rivers so two reservoirs were constructed, one in the Upper Sudbury and one in the Assabet River watersheds. These later became impractical to operate and were eventually transferred to local control.

In 1907, NEWWA assembled an early expert panel on such compensation for loss of water power featuring such engineering luminaries as Charles T. Main, Clemens Herschel and Leonard Metcalf. Part of this effort was the documentation of water power uses throughout New England and quantification of the amount of "work" that was provided by the water wheels. The work done by these early experts helped resolve many compensation cases as more and more water withdrawals were developed.

One of the solutions to getting cooperation from neighboring communities was inclusion in the benefits of the new supply. To some extent, this helped encourage regionalization. Portland, ME provided supply to 5 villages from its facilities bringing water down from Lake Sebago. Providence, RI began supplying Cranston, Johnston and N. Providence from its Pawtuxet River supply. The largest metropolitan district of the period was the 1895 creation of the Metropolitan Water District comprised of Boston and 12 other communities. A ten mile radius of the Boston State House was used to set future eligibility, later to be expanded to 15 miles. The formation of this district was driven primarily by inadequate or unsafe supplies in the abutting communities and was brokered by the MA Board of Health.

1902 Milford MA Masonry Dam

Private water companies faced many of the same problems and managed to get political solutions such as eminent domain when needed for source acquisition. The driving force was the welfare of the overall community and its economic base which was usually adequate to get permission from the state legislature to take lands and water sources as necessary.

Diversion of water from one river basin to another was unusual at this time mainly because the required volumes were satisfied locally more often than not. This doesn't mean that interbasin transfer was frowned upon in this age from any environmental standpoint. The engineers of the day were of a mind to manipulate rivers as a resource for their purposes, most often for some industrial need such as a mill. The earliest major diversion was Mother Brook in Dedham, MA, which was constructed in 1639 to divert about a third of the Charles River flow via a canal to supplement the seasonally low Neponset River and its mills. The development of canals for transportation in the early 1800's also depended entirely on river diversions. When the canal was meant as passage around a river obstacle, diverted water was returned to the source river downstream of the falls or the mill dam. However, some canals, such as the Middlesex Canal in Massachusetts, took water from one basin to another, from the Concord River to the Mystic River in the case of the Middlesex Canal. With all the technological advances in the era, the ability and desire to "improve" on nature had advanced faster than the underlying understanding of river ecology. This was just one aspect of the New England environment that had changed dramatically from the beginning of European settlement. Other major changes had come from the clear-cutting of the New England forests by early farmers and draining of swamps everywhere for development of the land. This was simply consistent with the view of such things at those times.

Protecting or enhancing supplies

Most watershed lands were devoid of trees in the late 1800's, having previously used as farm land. Many of the larger surface water supplies started reforestation programs, partly to help prevent erosion and partly to minimize plant detritus and farm fertilizers from reaching reservoirs and aggravating algae blooms. At this early stage, there wasn't much recreational pressure, nor were there many supplies that developed regulations governing permissible activities on reservoirs.

The period saw the first attempts at source protection. Some communities, like Nashua NH, restricted mill development on its supply tributaries or began considering ways to intercept waste. Boston MA constructed filter beds on Pegan Brook, a tributary of its Lake Cochituate source, to receive the noticeably foul discharge from a local reform school. Fall River MA began a major sewerage diversion program to direct discharges away from its Watuppa Pond source.

Status of Largest Supplies at 1882

State	**City**	**1850 Source**	**1882 Source**
MA	Boston Cambridge Worcester New Bedford Fall River Springfield	Lake Cochituate Fresh Pond Bell Pond Acushnet River Watuppa Lake 4 Sm. Reservoirs	Added Sudbury System in 1870s, Mystic River in 1860 Added Stony Brook Res. In 1887 Added Lynde Brook Res. in ? Acushnet River in 1865 Watuppa Lake in 1871 Added Cherry Valley Res & Ludlow Res. In 1873
RI	Newport Providence	Ponds Springs	Easton's Pond & Paradise Pond in 1876 Directly from Pawtucket River in 1870
CT	Hartford New Haven Bridgeport	Connecticut River Mill River Springs	Trout Brook Reservoirs in 1865 Lake Whitney on Mill River in 1860 Ox & Island Brook, Pequonnock River in 1857
NH	Manchester Nashua	Lake Massabesic Pennichuck Brk	Lake Massabesic in 1872 Pennichuck Brook in 1855
ME	Portland	Springs	Lake Sebago in 1867
VT	Burlington	Lake Champlain	Lake Champlain in 1867

1900 to 1930 – Continued pressure for new sources

In general, water demand in cities continued to grow throughout the period. There were some lags in growth during World War I but immigration was fairly consistent throughout.

Population, Per Capita and Growth of Water Use

	Population Growth Factors	**Per Capita Growth Factors**	**Resulting Water Use**
Early 1900's	⇧ • Rapid immigration • Cities become extremely crowded	⇩ • Plumbing becomes much more common but more metering cuts waste for a slight reduction	*Rapid growth*

Influence of Public Health

Waterborne disease had declined significantly by 1900, then dwindled down to insignificance by 1930 as water suppliers began to use treatment, especially chlorination, to good effect. The state

Public Health agencies still had a large say in maintaining supply adequacy but advances in treatment technology allowed safe use of virtually any source. Preference was still clearly for starting with the best water quality and most protected supplies possible for reduced risk.

Droughts as triggers

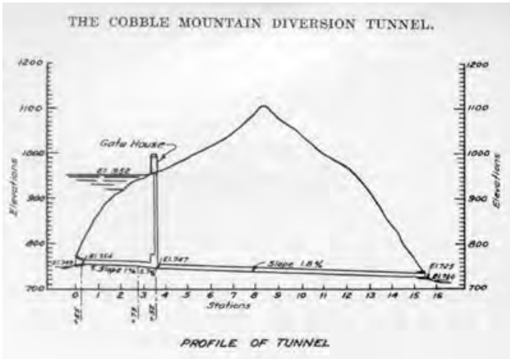
In this period, there was a lengthy period of consistently below average rainfall and runoff from 1910 through to 1920. This didn't necessarily constitute a drought to many systems but it did cause reevaluation of the safe yield of many sources. It also added urgency to the need to augment some larger systems' source capacity.

Wachusett Reservoir drawdown during the 1920's while Quabbin Res. was being debated

Source development technology

Water supply dams got bigger and more complicated. A number of very large water supply dams were constructed in this period including the Providence RI's 1922 Gainer Dam at Scituate Reservoir and the Cobble Mountain Dam by Springfield MA, a hydraulic fill dam of 263' height (tallest in New England and completed in 1932). The Cobble Mountain source was also notable as an early use of deep rock tunneling that was intended to flow full and under pressure, one of the earliest examples of such a design. Large masonry structures or "puddled" earthen dams were no longer the only available methods. The advances in pumping technologies in the early 1900's allowed use of hydraulic fill methods for larger structures, simplifying and improving the placement of a watertight core. Cobble Mountain Dam and Gainer Dam were both done by this method.

1922 Gainer Dam at Scituate Reservoir, Providence RI supply



1932 Springfield MA's Cobble Mountain Tunnel, the first deep rock tunnel made to be pressurized.

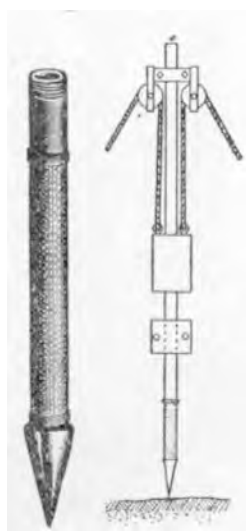

1932 Springfield MA's Cobble Mountain Reservoir


1905 Construction of Gloucester MA dam corewall


1905 Completed Gloucester MA Dam

Many communities opted for the simpler development of well supplies. There was a prevailing sentiment that surface water was more prone to water quality problems and that groundwater, with its natural filtration, was safer and very economical to develop since treatment was usually


1933 Driving a tubular well


Well point

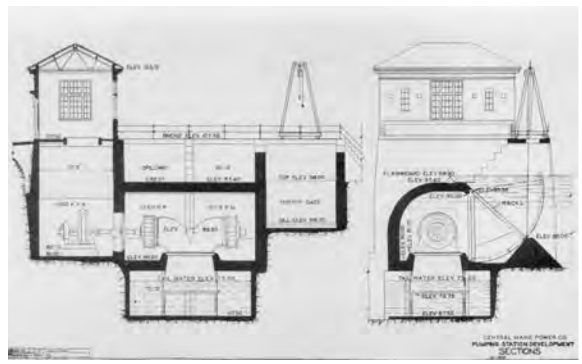

Early artesian well

unnecessary (except for those wells with iron and manganese problems). In the early 1900's, well technology had advanced to the point that construction of very large dug wells and infiltration galleries was no longer necessary. Tubular wells could be drilled into suitable soils having relatively shallow groundwater and connected to pumps to withdraw the necessary volume. It was common to install multiple wells with a common pump, with some supplies installing dozens of wellpoints in a well field. Often these early well fields used suction type pumps which limited the possible depth to relatively shallow water tables. With the development of submersible pumps, wells could be drilled to substantial depths, up to several hundred feet.

Politics of water transfers and reservoirs

Water was being managed and moved around in a big way in the rest of the country. Agencies like the Corps of Engineers had been given a mission to control flooding and navigation of rivers. They approached this with gusto and began building flood control dams and channel improvements across the country.

1925 Waterville ME hydroelectric power station with water supply pumping done by generated power



1925 Waterville ME hydroelectric plant

The western states had federal support for farming and began massive irrigation projects to reclaim desert land. In California, Los Angeles went after the Owens River with its notorious 1913 acquisition of land and water rights from the Owens valley farmers. Boston based engineers, Frederick Stearns and John R. Freeman consulted for Francis Mulholland, the man who led the expansion of the Los Angeles system. Their specialty was to help design and build the system of 226 miles of aqueducts, tunnels and pipeline to carry the Owens River to Los Angeles, an engineering achievement that was viewed by engineers as one of the wonders of the modern world but which went somewhat unheralded by the public due to the controversy surrounding the project. Also in 1913, San Francisco developed the Hetch Hetchy Reservoir in a valley that many thought was the equal of Yosemite, beginning John Muir’s lifelong pursuit of its restoration, planting the seeds of environmentalism that would blossom in the 1970’s. All in all, the country was manipulating its rivers in a big way.

Nearby, the New York water system had expanded from the Croton to the Catskill system and was already eyeing the Delaware. The Catskill system had added 2 more large reservoirs to the 12 smaller Croton system reservoirs and was connected via a new high pressure aqueduct system to the city. Despite these huge increases in capacity, the New York system was again strained by drought. The 1925 proposal to develop reservoirs on the Delaware River watershed brought a law suit that reached the Supreme Court before the 1931 ruling granted New York the development rights.

New Englanders developed many new large sources in this period. The urban areas continued to grow and many southern New England supplies needed source expansion. The new Metropolitan Water District serving the Boston area finished constructing the Wachusett Reservoir in 1905, one of the last big masonry dams. This only brought temporary relief since, by the 1920's, the combination of increasing use and the mild drought years in the 1910's and 1920's brought about the need to go further. For the Boston area, this meant proposing the construction of the Quabbin Reservoir, a straightforward engineering solution, but a difficult political problem. Not only did the reservoir require relocation of several communities but it also began a major interstate water dispute, since removing much of the flow from the 186 square mile Swift River watershed would reduce flow in the Connecticut River. For much of the 1920's, the proposal was studied and restudied. People impacted by the project argued that it was either not needed or that there were local alternatives in eastern Massachusetts that were adequate. One such alternative plan was floated by a group that included Allen Hazen, the hydraulic and water treatment authority. His plan suggested treatment and diversion of just about every eastern Massachusetts river, a complex and risky solution that could have introduced poorer water quality, subjected Boston to more drought risk and depleted river flow in some currently stressed river basins. These discussions didn't end until the Massachusetts legislature adopted the Quabbin plan and the Connecticut lawsuit heard by the Supreme Court was dismissed in 1927. In a sign of the concerns of the times, the lawsuit was mainly about navigation on the lower Connecticut River, not whether there would be an impact on the river environment.

Hartford continued to build its multi-reservoir Nepaug system but its demand also continued to grow, leaving concerns that additional capacity would be needed. The Hartford Metropolitan District Commission was created in 1929, bringing in several towns to the system.

In 1922, Providence moved from its old Pawtuxet River source to Scituate Reservoir. This alleviated their source issues until well into the 1960's. Many other supplies like New Haven CT and Worcester MA added upstream reservoirs on its watersheds to capture more of the available runoff for improved safe yield, with the result that the original streams were impounded into a series of cascading reservoirs.

In each of the larger reservoirs, the issue of moving people out of the way was becoming substantial. Wachusett Reservoir inundated parts of 4 towns and required relocation of 2,000 people. Scituate Reservoir also took parts of 8 villages and relocated 1600 people. The towns that were affected were some distance from the large cities and were typically once vital communities when the local mill was in its heyday, but had actually lost population once the mills closed. The acquisition of property by water supply agencies became a study in real estate wheeling and dealing with some people settling early and many holding out for more money. Some were happy to leave and felt that the real estate payoff was a win for them and some were unhappy to be forced from their homes regardless of the price.

1925 New Bedford deep intake on Quitticas Pond

Boston's 1905 Wachusett Reservoir was also the first major interstate water dispute since the Nashua River was a feeder to the Merrimack River with all of its industrial users, including some from New Hampshire. Impact and compensation discussions drew many of the regions most expert engineers. In the Wachusett case, rights to develop the reservoir required only a fairly small release to the river but compensation was successfully arranged in the form of payments for damages or replacement of some mill turbines with steam power.

Protecting or Enhancing supplies

With the creation of large reservoirs came pressure to use those reservoirs for recreation. As automobiles became more popular, the idea of traveling out to remote water bodies became more possible. People wanted swimming access in some cases, the use of boats for fishing or other recreation. There were documented incidents of contamination from recreational activities from this period. Understanding that the waste from even a small source like a fishing camp had been responsible for many past outbreaks, water suppliers were generally resistant to opening more access, regardless of the public pressure. In this period, NEWWA helped advocate restricting watershed activities and developed committee reports recommending strict regulations for public use of watersheds.

Status of Largest Supplies

State	**City-**	**1882 Source**	**Mid 1900's**
MA	Boston Cambridge Worcester New Bedford Fall River Springfield	Sudbury System in 1870s, Mystic River 1860 Stony Brook Res. In 1887 Lynde Brook Res. Acushnet River in 1865 Watuppa Lake in 1871 Cherry Valley Res & Ludlow Res. In 1873	Wachusett Res in 1898, Quabbin in 1939 Hobbs Brook in 1897 Holden system, Pine Hill Res, Quinapoxet Quitticas Pond in 1899 Same Cobble Mt. In 1932
RI	Newport Providence	Easton's Pond & Paradise Pond in 1876 Directly from Pawtucket River in 1870	Same Scituate Reservoir in 1922
CT	Hartford New Haven Bridgeport	Trout Brook Reservoirs in 1865 Lake Whitney on Mill River in 1860 Ox & Island Brook, Pequonnock River in 1857	Nepaug Supply 1917, Barkhamstead Res in 1940 Added smaller upstream reservoirs Added Saugatuck Res in 1942
NH	Manchester Nashua	Lake Massabesic in 1872 Pennichuck Brook in 1855	Same Added small upstream reservoirs
ME	Portland	Lake Sebago in 1867	Same
VT	Burlington	Lake Champlain in 1867	Same

1930 to 1970 - Source expansion as water use grows

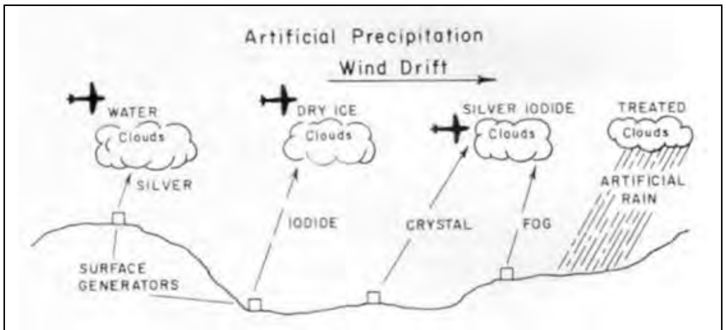
Population, Per Capita and Growth of Water Use

	Population Growth Factors	**Per Capita Growth Factors**	**Resulting Water Use**
Mid 1900's	• WWII slows growth • Population starts shift from cities to suburbs	• Droughts, depression, WWII all inhibit water use	*Slow growth*

This period began with the Great Depression and its major impact on the economy and overall quality of life. Then just as the economy began recovering, along came World War II with its impact on both the population and, once again, the economy. Water use grew slowly through this period but accelerated rapidly after the war as the "Baby Boom" followed. Population began growing rapidly and the desire for single family housing coupled with the affordable automobile and improved highways brought suburban expansion around cities. The period ended with the beginning of a population shift away from the old industrial cities but growth of the surrounding metropolitan areas. This period marked the beginning of a trend of migration out of the region as a whole as the warmer climate and opportunities in California and Florida drew more emigration their way.

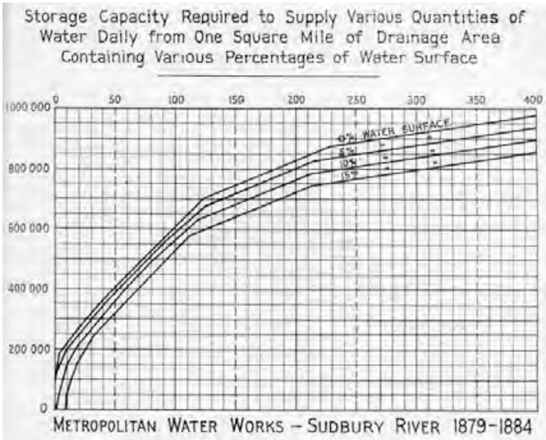
Influence of Public Health
Public Health had a lesser role in this period given that water treatment had essentially eliminated the earlier disease threats. While other threats emerged (discussed in the next chapter), Public Health officials influence over water supply was intended to improve performance than to correct serious deficiencies.

Droughts as triggers
For most of this period, there were only occasional dry years like 1957, but then the 1960's brought the most severe drought ever recorded in New England. Water suppliers had never seen anything like it as river flows and reservoir levels dropped to record lows. Coming as it did on the heels of the Baby Boom growth spurt, it stressed most water supplies to record low levels. The combination of 4 successive years of record low rainfall left even the largest sources depleted and looking at emergency options. Even extreme measures like cloud seeding were considered by desperate communities.

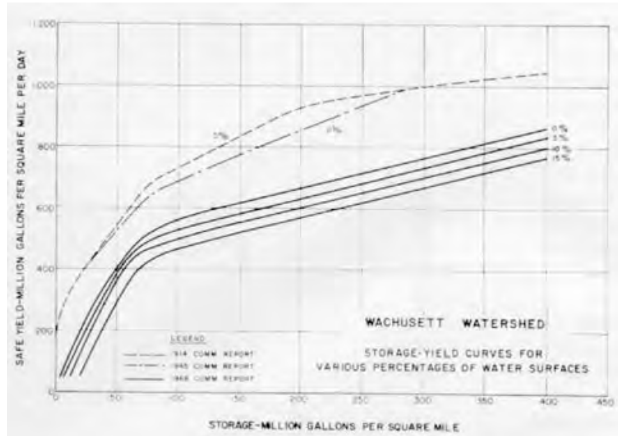


From a late 1960's paper, cloud seeding was considered by some desperate communities

This set the tone for re-evaluation of safe yield for many systems. NEWWA's safe yield committee also reviewed and revised the safe yield estimation curves developed in the early 1900's downward as a result. The other long term effect was to bring about a major review of the adequacy of east coast water supplies by the Corps of Engineers. This included the Boston and Providence metropolitan areas and led to new water supply augmentation proposals in the 1970's.



Example of 1904 NEWWA Safe yield committee curves for estimating safe yield

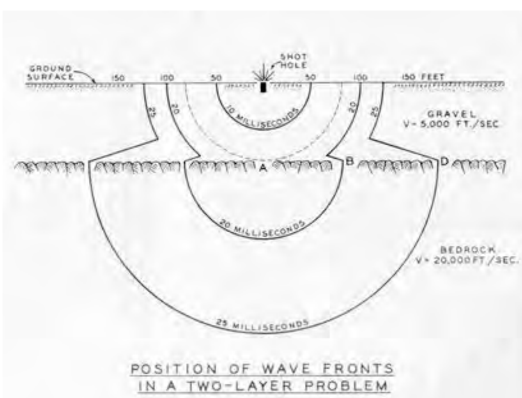


Example of 1968 revised NEWWA Safe yield curves – Note the reduction

Source development technology

Once again, more large reservoirs were built in this period, the largest being Quabbin Reservoir's hydraulic fill dams. Greater use was being made of concrete dams like Bridgeport CT's Saugatuck Reservoir.

During this period, many more communities developed ground water sources. Groundwater location technology using seismic methods was more consistently reliable in predicting production capacity. Deep well drilling methods and pumping equipment improved to the point that groundwater was an easily implemented, economical and reliable source method.



Seismic location of water table

Fig. 1.—Radioactivity Well-Logging Instrument Truck.

Radioactivity monitoring instruments would be lowered down a well casing to categorize soil layers

Politics of water transfers and reservoirs

During the Great Depression, government spending on big public works projects was accelerated to jump start the economy. Nationally, this meant that water projects were ubiquitous. Large hydroelectric projects like the Hoover Dam in 1935, and the Grand Coulee Dam in 1941 were built in this period. Nationally, Los Angeles diverted flow from the Colorado River to meet its growing needs. New York moved to add the Delaware system to bring its capacity up to present day levels. All of these were controversial projects with interstate law suits.


Construction of hydraulic fill Winsor Dam at Quabbin Reservoir, MA – Note that the Dam is named for Frank Winsor who also built the Gainer Dam for Providence

Quabbin Reservoir, the largest man-made New England supply source, was finally built. Completed in 1939, it took until 1946 to fill completely. Its water quality was everything that engineers predicted it would be and its seemingly limitless volume encouraged Boston's MDC to abandon some of its older sources like Lake Cochituate and some of the Sudbury system reservoirs. Of course, the optimism of the 1940's turned into pessimism in the 1960's as Quabbin was drawn down to 45% full in the drought of the 1960's while demand projections showed even higher water use was ahead.

Hartford CT also built its largest reservoir during this period, the Barkhamstead Reservoir. Similarly, Bridgeport CT also completed its Saugatuck reservoir.

This period is remembered by many for its displacement of communities and residents. Quabbin required relocation of 2,700 people and literally ended the existence of 4 towns. A total of 7,613 graves were moved from 35 cemeteries, buildings were removed and the land stripped of any vegetation to prepare for the reservoir. Barkhamstead and Saguatuck Reservoirs had similar but proportionally smaller impacts. In comparison, New York City had even larger impacts with 26 towns being removed and 6,500 people displaced for its Catskill and Delaware systems.

Again, the communities impacted were old mill towns that had gone from prosperity in the early 1800's to stagnation and population drop in the 1900's. The people were again bargained with for land compensation and the projects were seen as inevitable. It is notable that this was hardly the first or last time that an unfortunate few had to get out of the way of a public works project that was needed for a larger public good. Creation of the interstate highway system in the mid-1950's cut swaths through many populated areas. Urban renewal in older cities condemned property and removed unwilling residents in sweeping projects, an example being the West End reconstruction of Boston. All in all, New England's large reservoirs were built with minimal controversy and few incidents when compared to other major civil works.

In essence, reservoir construction had become a more difficult siting issue in this period but one that left behind a desirable and scenic resource. It is notable that such projects in the 1930's and 1940's were seen by most people as positive for the economy. WPA financing helped build Quabbin and many other large water facilities, putting many unemployed people to work.

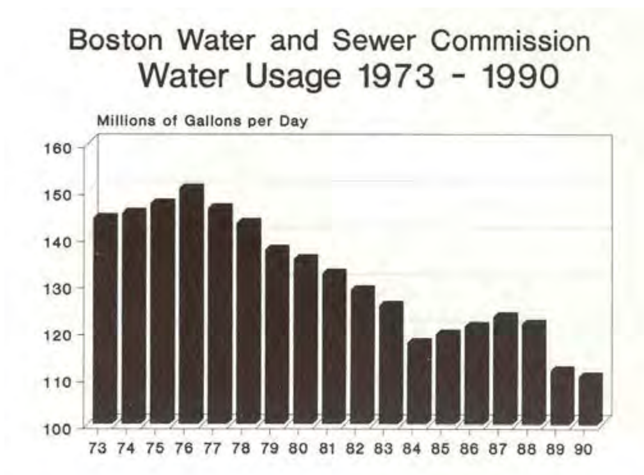
Protecting or Enhancing supplies

With the pressure to do more with less, some water supplies began to look at the state of their watershed forests with a mind to increase runoff by selective cutting. Many NEWWA papers of this period looked at a proper mix of hardwoods and conifers and suggested active forestry programs.

Recreational pressure was still a political problem now that people lived closer to sources. Land acquisition around reservoirs and regulation of allowable activities were given more attention to help control risks.

1970's to the Present Day - Slowing down the growth

Population and water use growth continued through the 1970's. In the 1980's, population stabilized as household size decreased and emigration to other parts of the country continued. Bedroom suburbs of large cities saw the most growth as better transportation systems allowed people to commute from further away. The inner cities themselves lost population through much of the period but many saw some revitalization in the 1990's as real estate booms brought urban renewal, updating the housing stock. Sewer charges began to be billed according to water consumption, which began to have an effect on price elasticity. As water got more expensive and water conservation began to be felt, per capita water use began to drop. Efficient fixtures and appliances became readily available and even required as plumbing codes began to require more efficiency.



Boston had success reducing water use through aggressive leak detection and meter replacement

Population, Per Capita and Growth of Water Use

	Population Growth Factors	Per Capita Growth Factors	Resulting Water Use
Late 1900's	• Baby boom in late 40s to early 50s • Automobiles/trains allow rapid growth of suburbs • Growth slows in 1980s	• Water saving devices more common later in period • Plumbing code changes • Per capita stabilizes or goes down slightly	*Rapid growth in 1950's-1960's, slow growth in 1980s*
Now	• More but smaller households • Slight emigration results in stable population	• Industrial/commercial users conserve, price effect • Widely available water saving fixtures and appliances	*Stable in region, growth in some areas*

Influence of Public Health

Public health issues associated with drinking water once again became an influence in this period with the discovery that some supplies were being fouled by heretofore undetected contaminants. New technologies like the gas chromatograph/mass spectrometer allowed discovery of volatile organics, pesticides, PCBs, and a variety of chlorinated organics. In 1962, the book Silent Spring identified the consequences of DDT use and generally promoted environmentalism. On a national level, the 1978 investigation of Love Canal demonstrated the severe health effects of pollution leading to a concerted effort to identify hazardous waste sites and clean them via programs like Superfund. Locally, this exposed dozens of hazardous waste sites around New England, many of which had affected water supplies. Throughout the 1970's, researchers actively identified more and more carcinogenic and mutagenic substances and found that many were present in water supplies. All of this contributed to a national push to address the public's growing concern over water quality, resulting in the passage of the 1974 Safe Drinking Water Act which established water quality regulations limiting these contaminants.

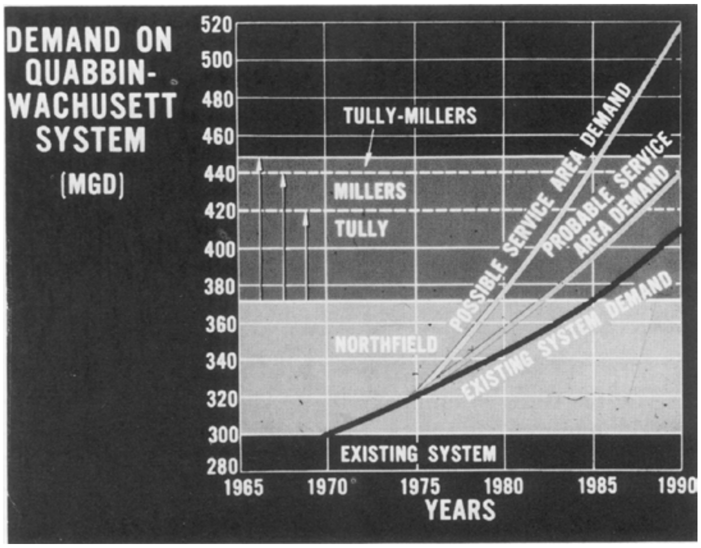
The end result for water suppliers was the finding that some severely polluted industrial sites had indeed caused contamination of water supplies forcing their removal from service. Many systems wrestled with the difficult decision of whether to treat the contamination. In some cases, the technology existed to do the job but the stigma of past health effects, perhaps even involving fatalities, simply made reactivation with treatment unacceptable to the consumers. Thus, some systems found themselves suddenly short of capacity and needing source augmentation once again.

Droughts as triggers

The impact of the 1960's drought was felt through the 1970's in that large scale planning continued into that period. There were occasional dry years thereafter (e.g. 1980) but nothing comparable to the 1960's.

Source development technology

The drought of the 1960's had clearly identified safe yield problems for many New England supplies, some of whom have struggled with capacity shortfalls to this day since new source development began to be much more tightly regulated. The old means and methods of source development were no longer reliable or effective in the face of this pushback.



Corps of Engineers demand projections for Boston MDC

The post-60's drought problems were exemplified by the experiences of two of the larger systems, Boston and Providence. The Corps of Engineers review of eastern water supplies in the 1972 Northeast Water Supply Study (NEWS) had projected the continuing growth of both the Boston and Providence metropolitan areas to the point that supply augmentation appeared necessary well before the year 2000. Both areas had been looking at alternatives, Providence focusing on the Big River proposal and Boston MDC on the use of Connecticut River water. Providence's proposal was creation of another large reservoir (60' tall dam, 27 mgd safe yield), straightforward in an engineering sense but difficult politically in the age of growing environmentalism. MDC proposed to take advantage of their large Quabbin Reservoir storage by flood skimming the Connecticut River in a novel way, using the Northeast Utilities pumped storage facility to take water from the upper reservoir only under high flow conditions through a tunnel to Quabbin. Both projects were met with considerable resistance by the donor areas, i.e. rural Rhode Island and western Massachusetts. The projects were also strongly opposed by downstream interests and environmental groups everywhere.

The other major source issue of this period was the sudden loss of capacity to contamination. Some smaller supplies that had lost sources to contamination were forced to regionalization as a solution, examples being Bedford MA and Woburn MA who turned to the MDC. Others like Dedham MA and Burlington MA developed treatment such as airstripping of problem volatiles. The expense of aggressive treatment technologies and disposal of the removed contaminants became important decision factors.

For groundwater sources, the finding that conservative pollutants could reach the wells was a revelation that countered the popular notion that groundwater was a safer alternative to surface water. Such pollutants as leaking gasoline tanks and improperly disposed industrial wastes were found to have traveled substantial distances to reach drinking water wells. The hazardous material generator that caused the problem may have been financially responsible for damages but getting the problem rectified and collecting damages were not so easy. The period brought new well drilling techniques that would allow deeper wells into fractured bedrock. This allowed more access but, for most groundwater systems, the main focus turned to protection of aquifer recharge areas with better modeling of groundwater movement to understand risk.

One notable area where new technology may be changing source development possibilities is in desalination. As membrane technology improves, the economics of desalination may become more competitive. The first such significant project in New England is a proposal by a private company, Aquaria, to treat the brackish waters of the Taunton River for Brockton and other potential southeastern Massachusetts customers. The project is currently in environmental permitting in 2006 with hopes of proceeding in coming years. A successful demonstration may present an interesting option for coastal areas.

Politics of water supply sources and pollution
The 70's and 80's were the decades of large water project controversies. Even as the memories of the 1960's drought were fading, the 2 largest new supply proposals, Providence's and Boston MDC's were still being debated. The major point of contention was "need", i.e. whether the projects were really necessary. By 1980, a number of water use factors had changed somewhat, population growth didn't follow the projected increases and factors like per capita and non-domestic usage began to show downturns. The water/sewer bill was becoming noticeably high, prompting people to both modify habits and to seek more efficient fixtures. In a parallel to the energy crisis, industry was quick to cut utility costs by simple efficiency measures like eliminating once through cooling. For the first time, the idea that water use would continue to rise indefinitely was questionable and no build alternatives such as leak reduction and water conservation were begun to be seen as effective solutions.

Another significant change in this period was the growth of environmentalism as a political force. After the National Environmental Policy Act of 1969 and other environmentally protective legislation, the impact of projects on the natural environment now had to be fully described and justified. Rare and endangered species presence was now stopping projects, as occurred in 1977 when the snail darter stopped construction of the Tellico Dam in Tennessee. Wetlands were better understood and protected for their beneficial uses. Putting the needs of the ecosystem ahead of man's needs/desires was certainly a different approach than had been tried up to this point, showing a growing public appreciation of nature. Perhaps this was a form of atonement for the centuries of abuses that were heaped on the rivers but it remains troubling that water supply withdrawals have become regarded by some as a negative thing. The balancing of environmental needs versus water supply constraints on a community's growth and prosperity has become and will continue to be a recurring political theme.

The final significant factor in this period was the public reaction to water resources being transferred from one river basin to another, perhaps more importantly from one political area to another, regardless of whether they were in the same state. It clearly rankled the people in western Massachusetts to be proposed as a donor area for Boston's water needs regardless of the small percentage of river water being discussed. It was especially disturbing when water use studies identified a relatively large amount of unaccounted-for water in the MDC service area. The MDC Northfield project never became an interstate controversy because it never got that far, being essentially made a last resort by successive state actions. It did, however, become a lightning rod for setting restrictive controls. In 1978, Massachusetts state water policy emphasized water conservation over augmentation, then the 1984 Interbasin Transfer Act and 1986 Water Management Act were passed to further put in place controls that directed efficiency first, then use of local resources before considering a large new water transfer. Boston MDC's situation was then changed significantly in 1985 with the creation of the Massachusetts Water Resources Authority. Their enabling legislation further reinforced the mission of the new agency to focus on water conservation before consideration of any other supply solution. MWRA then proceeded with a successful water conservation program, bringing water demand to within safe yield by the early 1990's.

In Providence, the Big River proposal began when the Rhode Island Water Resources Board was formed in 1964. The new Board spent $7.5 million on property from 200 landowners in anticipation of building the project. As with the MDC proposal, the project was attacked on the basis of need and consideration of other alternatives. There was also resistance to the project on environmental grounds for the unavoidable physical impact that a large reservoir will have.

In 1990, EPA ruled against funding the project, citing a substantial level of environmental impact, including potential loss of 575 acres of wetlands, 10 ponds, 17 miles of streams and 2500 acres of forest. The project has been in limbo since but has not been entirely abandoned. This falls in place with the national trend in which more dams are coming down than going up. As with the Boston area, water demand has stabilized and life goes on reasonably well, at least until the next major drought.

Elsewhere, the impact of contaminated sources was felt for decades after the first contamination discoveries in the 1970's. Remediation and treatment of the contaminated sources was very costly, but often made necessary by the lack of other options. If the contaminated supply had a very negative connotation, as did Woburn MA's wells G and H that were the presumed cause of leukemia deaths, then public confidence could not be restored and the supply could not be reused. Meanwhile, untapped groundwater resources in stressed basins could not be counted on as a replacement solution due to difficulties in getting development permission. Now that many of the early Superfund issues are essentially cleaned up, there will hopefully be fewer large surprises. Certainly, this isn't the end of problems given the recent emergence of new threats such as MTBE and perchlorate as the latest example of how improved detection technology will continue to influence source use and abandonment. Changes in tolerable contaminant levels, such as the recently more restrictive arsenic standards, may also impact source viability.

One continuing sticky question is when and how to abandon a poor quality source, a problem that will only become more acute in the future as more wells become problematic from such simple issues as elevated iron/manganese, saltwater intrusion or buildup of conservative substances like nitrates or slow degrading organics where subsurface waste disposal takes place. The environmental protections and regulatory hurdles put in place to help rivers and ecosystems make replacement of these sources extremely difficult. This may increase regionalization or much more sophisticated treatment.

Protecting or Enhancing supplies

The important lesson of this period was the definition of contributing areas, be it watersheds or aquifer recharge areas and the reduction of risky contaminant sources. This meant more sewerage works, acquisition of key watershed lands, better sanitary surveys and controls over certain watershed practices.

Are we done yet?

The region's relative population and water use stability is a good thing but complacency should be avoided. Most supply issues get too little attention until an extreme drought forces the issue, often too late to avert a crisis. Hopefully, a fine balance can be achieved in the future where reasonable water use efficiency is required, but water supply augmentation is allowed where needed for relief from chronic shortfalls.

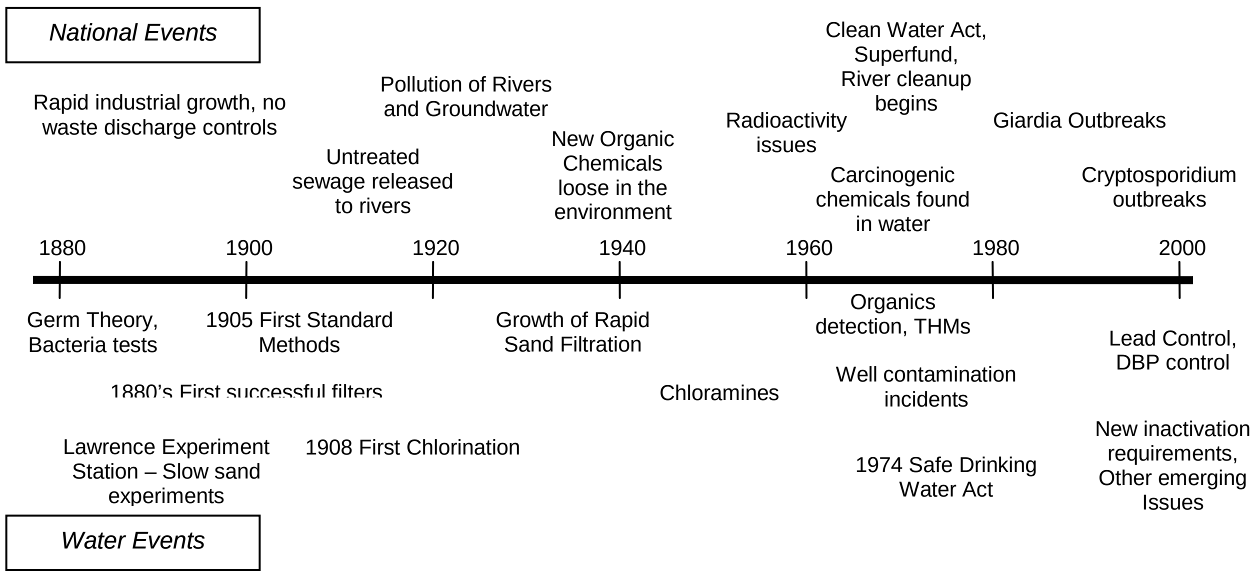
The bottom line is that the age of the large water supply project is probably over in New England, despite the continuing mega-projects in places like China and California.

Public Water Supply Sources in 1985

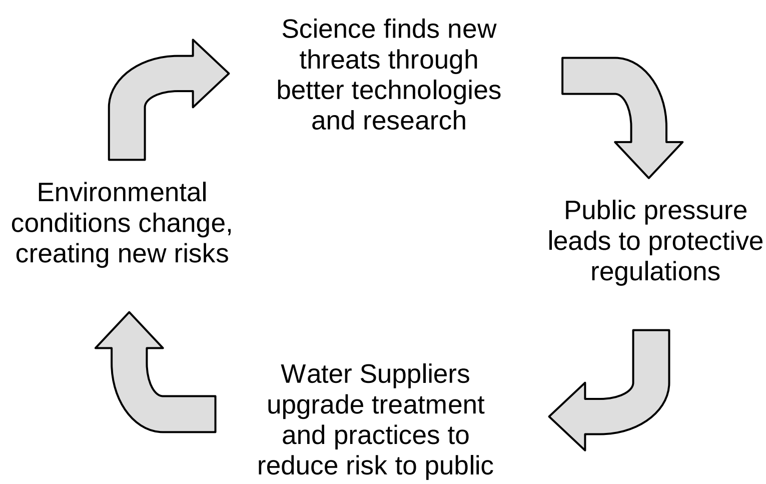
State	Population served	Ground Water MGD	Surface Water MGD
Connecticut	2,680,000	66	296
Maine	829,000	24	84
Massachusetts	5,330,000	181	586
New Hampshire	637,000	28	61
Rhode Island	884,000	15	101
Vermont	343,000	17	36
Total New England	10,703,000	331	1164

Chapter 3 – Public Health and Water Quality, Water Treatment

Timeline – Public Health, Water Quality, Water Treatment



Much of what we know to be true about water quality and treatment was probably only truly understood in the past century, often only in our own lifetime. This is a bit troubling, considering that sources of pollution are as old as the communities we live in but it is the nature of science and engineering to learn from experience. From the beginning of water supply, we continue to struggle with a cycle in which understanding of health issues is slowly gained as the underlying science is revealed, followed by problem solving and resulting water treatment improvements. The following illustrates the factors in this cycle:



This chapter reviews the emerging threats, the factors that affected treatment strategies and the water supplier's response through NEWWA's history to date. The key periods of interest are discussed in the following:

Late 1800's to 1900 – Post NEWWA boom, solving waterborne disease problems

Public Health/Drinking Water Issues –
The end of the 1800's was still notable for its widespread epidemics. The earlier part of the century had episodes of Asiatic cholera as the disease swept around the world in cycles. Locally, typhoid was omnipresent and flared up in epidemics wherever improper sanitation allowed it to do so. Mortality from bacterial and viral epidemics was so prevalent that life expectancy was still under 50 years on average and lower still among the urban poor. Around the time of NEWWA formation, the Germ Theory of disease became more widely accepted as a potential explanation to many diseases, replacing the miasma theory (foul vapors) and other quasi-religious theories of disease being a form of retribution for sinful ways.

The drinking cup – a common practice in public fountains of the late 1800's and the source of much waterborne disease transmission


1914 Public Fountain

The idea of microscopic germs carrying disease came from Europe, primarily Germany and France, where the foremost scientists were just arriving at their discoveries. Louis Pasteur had been studying microbes since the 1860's and had categorized many functional aspects such as aerobes versus anaerobes but had not yet isolated a disease-causing agent. Pasteur went on to develop many immunization and bactericidal techniques that helped the health community improve early care immeasurably. In 1876, Robert Koch, a German, was recognized as the being the first scientist to isolate a bacterial disease causing agent, in this case, *Bacillus Anthracis*, known commonly as Anthrax. He also went on to isolate *Tuburcule Bacillus*, the cause of tuberculosis, and *Typhus Bacillus*, the cause of most waterborne illnesses at the time. More importantly, his isolation methodology became a widespread success for bacteria testing and his postulates for the process of proving a microbe to be the cause of a disease became the gold standard in the field.

Identification of probably the single most important bacteria for water supply came in 1885 when T. Escherich identified the Bacterium coli, showing it to be responsible for diarrhea and gastroenteritis. Eventually, his name was associated with that nemesis of water suppliers everywhere, the *Escherichia coli*.

Of course, like many other advances in science, there were still many skeptics in this period, including many highly regarded individuals. One such was Max Von Pettenkofer, a respected German man of medicine who felt so strongly that the Germ Theory was just so much humbug that he conducted a public experiment by drinking a vial of live typhoid that was sent to him by Koch. He was fortunate to survive but a couple of his students that joined him in his experiment did get sick. When the City of Hamburg conclusively demonstrated the effectiveness of filtration as a barrier and confirmed that the typhoid bacillus was the cause of an outbreak of disease, Mr. Von Pettenkofer became a reviled figure in his community for having delayed water supply improvement.

Detection Technology

In the 1880's, scientists moved from culturing bacteria in liquid media to agar in 1882 and culture dishes (courtesy of J.R. Petri) in 1887. This allowed easy collection of bacteria samples for enumeration and further microscopic evaluation from the face of the solid media. By 1900, most of the diseases caused by bacteria had been identified, with viral diseases still not being understood. This didn't mean that bacteria testing was, in any way, a routine thing, but the test was at least available as a diagnostic health tool by the end of this period. Many New England state Boards of Health began routinely conducting bacteria tests as a check at about this time.

Ellen Swallow Richards – A woman pioneer in water supply:
Born Ellen Swallow, she graduated MIT in 1873 with a degree in chemistry, marrying Prof. R. H. Richards in 1875. Among her achievements, she worked in the employ of the MA Board of Health with William Ripley Nichols and Thomas Drown, the foremost authorities on water supply chemistry. She oversaw the analysis of over 20,000 water samples and directed the preparation of the "Chlorine Map" of state waters, all while continuing to teach at MIT.

She never joined NEWWA but was a well known water supply figure of her day. She furthered opportunities for women in science and is recognized in a display at the Smithsonian's American History Museum.

Water pollution caused by chemicals was still poorly understood. Only a few water quality tests were available to help characterize waters. In 1867, Sir Edward Frankland had developed the albuminoid ammonia test as measure of pollution and it was adopted by some water supplies as a means to categorize source waters. Another early effort was the use of the so called "chlorine" test to categorize water quality in rivers. This was, in essence, really a chloride test but it was considered indicative of sources of pollution in some inland waters. MA Department of Public Health conducted an early survey of all statewide surface waters and published a "Chlorine Map" around 1890 in what can be considered a first sanitary survey of regional water quality conditions.

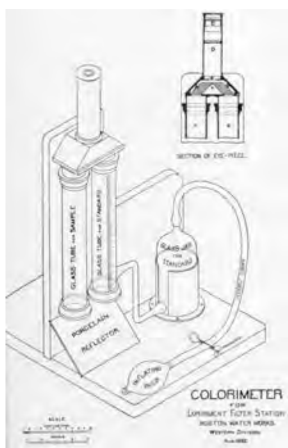
Other tests involved aesthetics like smell and taste. There was also measurement of particulates in water by paper filtering; a further test being to burn the filter and weighing the residue to check the organic portion versus the inorganic portion of the residue.


First water supply laboratory in US at Chestnut Hill offices, Boston MA

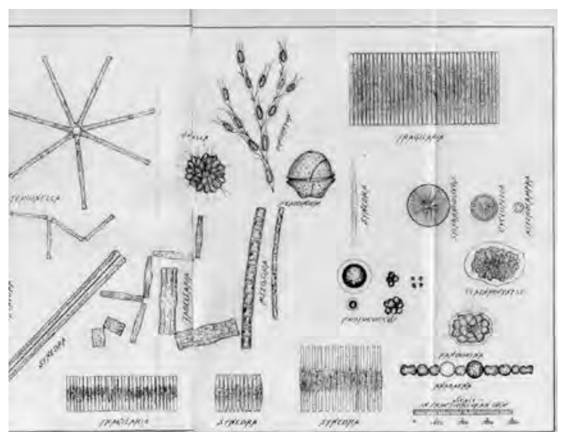
By the end of the period, turbidity, color, hardness, albuminoid nitrogen, free ammonia, nitrates, nitrites, chlorides, total plate count, and bacteria coli were commonly performed. Remember that you still needed a horse and buggy to collect the samples at this point.

One notable achievement in this period is the emergence of the water supply laboratory. The first laboratory in the nation operated by a water supplier was created in 1889 by Boston Water at its Chestnut Hill facilities. This laboratory was run by George C. Whipple, an MIT trained biologist, under the direction of Desmond Fitzgerald, an equally important hydrology/water quality expert in early NEWWA. They published a wealth of data on algae and other microscopic analyses and continued to pioneer water quality analyses into the early 1900's when standards became available. Mr. Whipple went on to run the Brooklyn NY system and then joined Hazen, Whipple & Fuller, a significant early water supply consultant, all with ties to MIT and MA BOH. Another pioneering effort was the public health laboratory in Providence RI which was developed to assist statewide water supply analysis as well as clinical analysis of disease.

Regulations



1892 Colorimeter


1889 Algae chart developed by F. Forbes Brookline MA

There simply were no meaningful regulations in place on water suppliers at this time. Public Health Departments had assumed responsibility for inspection of health related problems, including waterborne disease. They strived to understand causes of disease in their communities but there was no easy way to quantify any immediate threats. If a water supply was suspected of contributing to waterborne illness, some sort of corrective action was recommended by the health authorities. This was more likely to be a matter of relocating a water intake or a problematic waste discharge than a change in water treatment.

Nationally, the 1893 Interstate Quarantine Act gave powers to the Surgeon General to make regulations to prevent communicable disease. This is notable since it laid the groundwork for the U.S. Public Health Service's initial attempts in the 1900's at establishing drinking water quality regulations, at least for interstate carriers.


Original Lawrence Experiment Station buildings

Role of Public Health

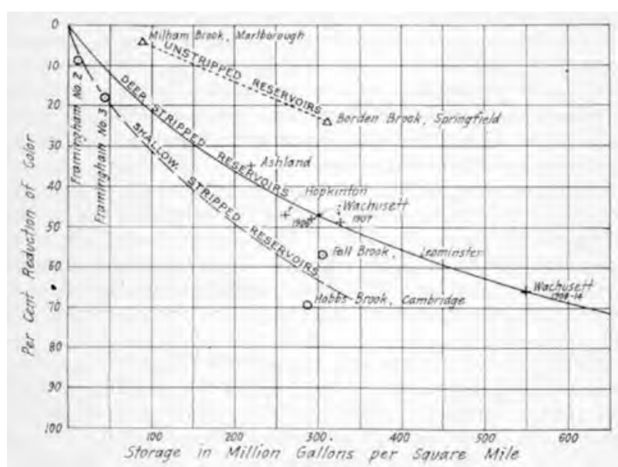
The single most important event in New England in the late 1800's was the start up of the Lawrence Experiment Station on the banks of the Merrimack River in Lawrence, MA. Founded in 1887 by the MA Board of Health, the facility was intended to study water and sewerage treatment issues. In 1886, MA BOH's committee on Water Supply and Sewerage selected its 1st chair to be Hiram Mills, former Chief Engineer of Essex Co., the mill near the Lawrence site. MA BOH also required monthly community testing by 1886 regulations. The facility developed a close link with Massachusetts Institute of Technology and employed many graduates in key roles. In the earliest days, William Sedgewick, the sanitarian/biologist, Thomas Drown, the chemist and Allen Hazen, the hydraulics engineer were the key players.

> **Quote from Allen Hazen:**
> *"For every typhoid death, someone should be hanged since it was preventable"*

This was the first of 2 nationally important efforts that defined water treatment for the decades to come. Lawrence Experiment Station defined the proper methods of slow sand filtration, not to mention developing a variety of water quality testing and sewerage treatment methods. The Louisville experiments on rapid sand filtration in the 1900's then built on that work to add rapid sand filtration experiments.

Role of Water Treatment

With the understanding that bacteria were the cause of many problems, treatment began to take on much more importance in this period since there were certainly many water sources that were vulnerable to bacteria laden discharges.



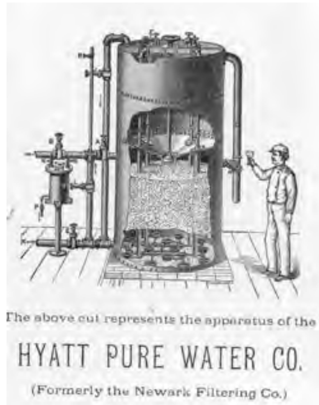
1916 – Color reduction through reservoir bottom preparation

Several important initiatives are worth noting in this period:

1. Use of reservoirs to improve water quality – The empirical evidence that detention in a reservoir improves source water quality was an early finding, supported by research by key NEWWA members as larger reservoirs began to be built. The other empirical finding that influenced members was the need for surface preparation of the area to be flooded. It was observed that vegetation

and swampy areas tended to impart taste, odor and color for a lengthy period after construction.

2. Filtration – With disinfection still being unknown, the methodology for removal of unwanted contaminants was pretty much limited to filtration. A variety of methods were tried in this period, most notably in trying to use natural methods such as bank filtration or placing a manually cleaned filter bed over a collection gallery. There was little knowledge of the effectiveness of filter media or methods. Municipal size filtration plants were uncommon, with most communities attempting outdoor filters of some sort. Some communities with smaller flow requirements tried the smaller mechanical all-in-one devices.



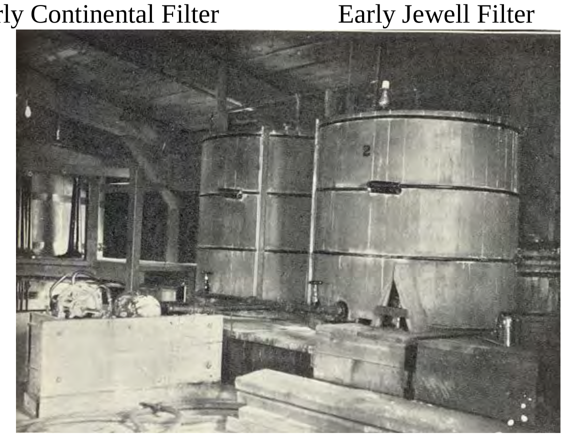
1887 Hyatt Filter

1887 National Filter

Early Continental Filter

Early Jewell Filter

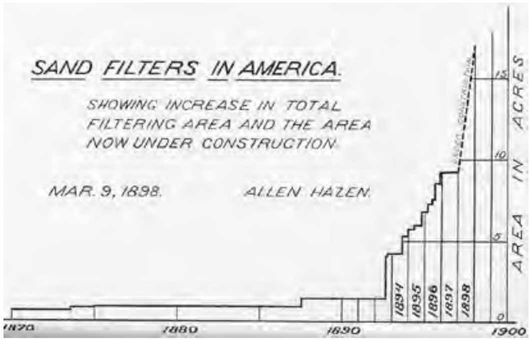
3. The patenting of filtration apparatus – In the late 1800's, inventions were coming fast and furious. Many entrepreneurs were looking to patent a process or a device to make their fortune, filtration being no exception. Many all-in-one devices were developed that featured some unique aspect to allow patenting. These devices usually looked like a large fully enclosed canister housing the filter media and under-drains and were named after their inventors or their companies. Some of these early devices are shown in the illustrations.



1900 Warren Filter

4. Slow sand filtration – This method had been around from earlier European experience but the newly understood need to remove or inactivate bacteria began new interest in adapting the slow sand filter to bacteria removal.

5. Removal of waste streams – Many communities tried to remove as much waste as possible from watersheds by directing waste streams away from intakes and, where the discharge could not be avoided, put open filtration beds to intercept and remove as much offending material as possible.



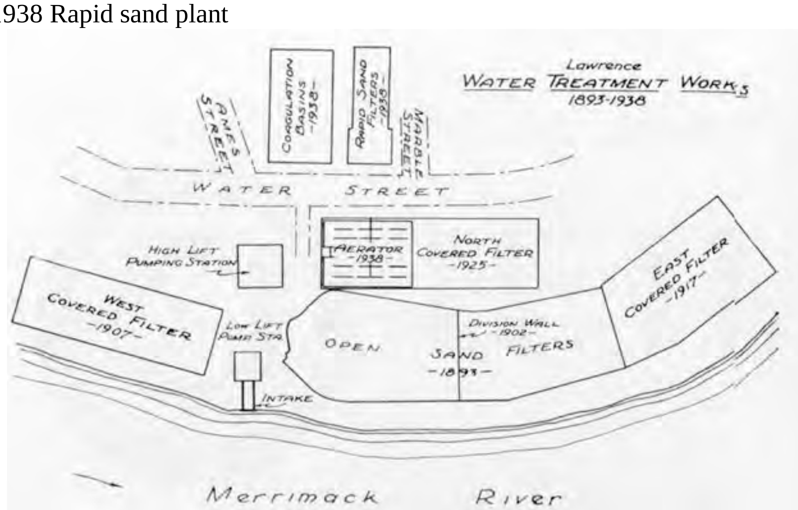
Trend in filtration up to 1898


1892 Covered filters

Lawrence Filters – Evolution over the years


Original 1893 open slow sand filters


1938 Rapid sand plant

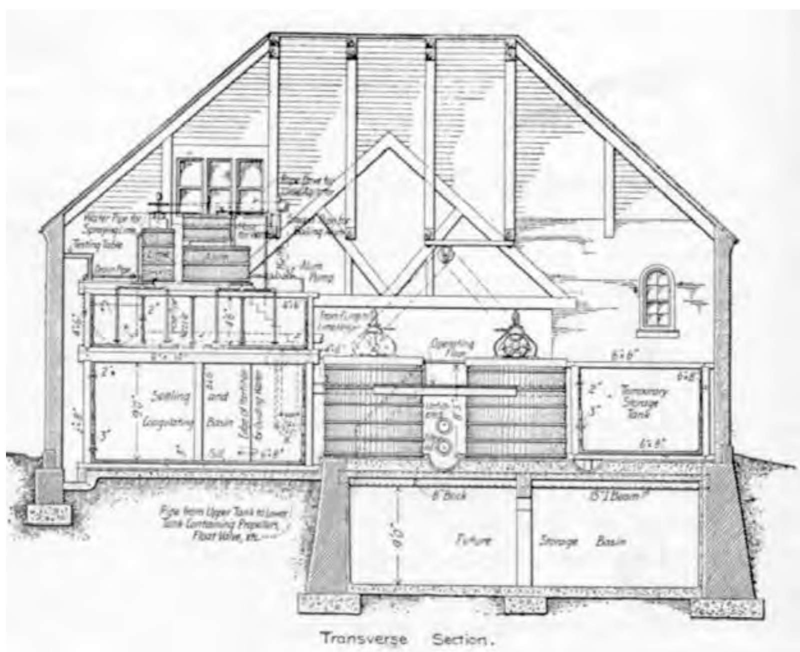


Changes to Lawrence MA filter site through 1930's

European water treatment experience was studied carefully by key NEWWA members. One important report was Kirkwood's 1869 report on European filters, its page's filled with carefully sketched plans and cross-sections and a wealth of detail on methods of cleaning and operation.

The late 1800's were the beginning of a period of fundamental research that developed effective filtration methods through empirical trials. The important local effort was the Lawrence Experiment Station's (LES) efforts at slow sand filtration. Filter sands and other media were studied, courtesy of Allen Hazen, fresh from his MIT graduation. His reports on effective sand particle sizes were invaluable to proper media designs that followed. The LES pilot testing developed effective flow and loading rates, necessary cleaning methods and all manner of practical guidance to optimize success. The Lawrence Experiment Station's laboratory continued to pioneer bacteria and other water quality testing methods to helped document filtration performance and, in the use of the heavily polluted Merrimack River, they certainly had an appropriate challenge. The end result was their claim that any New England water could be successfully treated, no matter the degree of pollution. Many New England supplies adopted the slow sand filter based on their success.

In 1898, the next major advance began when George W. Fuller, another MIT graduate who trained at Lawrence Experiment Station, began his benchmark work on rapid sand filters at Louisville, KY. He went beyond just the mechanical aspects of filtration to start looking at coagulants to optimize performance. This effort continued well into the 1900's and pretty much defined the principles of "conventional treatment" with coagulation, sedimentation and rapid sand filtration.



1896 Reading MA iron removal plant

Aesthetics

Even with all the concerns over disease, aesthetics were still very much a focal point of the industry. Algae problems were widespread in older reservoirs that hadn't been properly prepared to the point that the customers would lose confidence and clamor for treatment. The use of algaecides was still not widespread.

Presence of iron and manganese was also problematic where it occurred. Without oxidants, the only workable solution for afflicted supplies was to aerate as much as possible and then filter with normal sand and gravel filters.

1900 to 1930 – The beginnings of modern water treatment

This period marked the beginning of water treatment as we currently understand it, with water supply engineers finally beginning to gain ground on biological threats. Not only did disinfection emerge as the single most effective measure against disease causing organisms but rapid sand filtration also emerged as an effective and reliable municipal scale process.

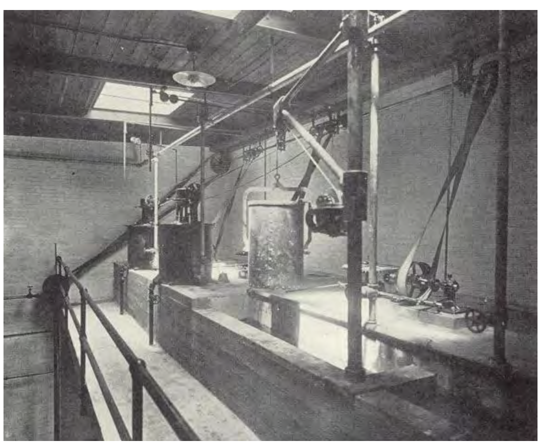
Public Health/Drinking Water Issues

The epidemics that marked the 1800's were now understood – bacteria and sewage based pathogens were the cause and treatment was the solution. While there wasn't a complete agreement on the most effective form of treatment, disinfection was certainly felt to have promise. The power of chlorine as a disinfectant was demonstrated in experiments well before its first use in a municipal water supply in 1908 in New Jersey. Leading up to that point, there was some understanding that calcium hypochlorite had germicidal properties but the other breakthrough was experimentation with passing electricity through water, also documented to have had a germicidal effect. Lawrence Experiment Station did some early experiments on this before the1908 start of municipal chlorination and concluded that the electricity was really producing hypochlorite ion that was the real germicidal agent. After the experimentation, the electricity process was judged to be potentially useful but less important than other methods.

Typhoid deaths per 100,000 population

State	**1900**	**1910**	**1920**	**1930**
Connecticut	32.0	14.7	4.1	1.0
Maine	28.2	20.3	9.0	3.6
Massachusetts	22.0	12.5	2.5	0.9
New Hampshire	22.1	10.7	6.8	1.9
Rhode Island	28.7	13.6	2.8	1.6
Vermont	33.8	14.0	10.5	1.9
United States	35.8	23.5	7.9	4.8

Around New England, acceptance of chlorination was widespread, especially by those supplies who were the most at risk, while the most vocal dissent was by Massachusetts Board of Health. They were still the biggest proponents of proper source selection, that being protected upland waters free from sewage introduction, and they felt that proper filtration still was the most effective barrier to biological agents. There was also some resistance to adding a chemical of any sort to the water supply, especially one that had some negative aesthetic qualities.



1910 Mixing tank for chloride of lime, first chlorination in New England, Newport RI

1910 Newport RI Water Treatment Plant

At any rate, New England began to practice chlorination well ahead of the rest of the country, with Newport RI being the first to do so in 1910. By the 1930's, most surface water supplies had implemented some form of chlorination and the waterborne disease rate had dropped to be virtually nonexistent. This is not to say that disease epidemics were no longer occurring, non-waterborne diseases like the Spanish Flu of 1918 and the early polio epidemics caused an enormous death toll throughout New England, but at least typhoid dropped off of the leading causes of death list by the end of the period. Many people acknowledge chlorination as one of the biggest health advances of all time.

Detection Technology

In one of the most important advances in water quality testing, the American Public Health Association and the American Water Works Association collaborated in 1905 to define testing methodology in a publication, the first edition of Standard Methods, which could be the agreed upon basis of proper water testing. An effort that was mainly prepared by New England men, this was a necessary precursor to developing water quality regulations since it leveled the playing field for smaller systems that didn't possess much lab expertise and it defined rigorous methods to assure consistent results. The APHA and AWWA also set in motion a process of review and updating that insured that improved methods were being properly peer reviewed and incorporated in subsequent editions. New editions followed in 1912, 1917, 1920, 1923, 1925, 1933 and so forth and featured input from such NEWWA luminaries as Gordon Fair, Abel Wolman and Malcolm Pirnie.

The idea of using coliform as an indicator organism dates back to this period. The coliform test was intended to indicate the presence of fecal contamination, setting in place the biological monitoring strategy that we have followed to this day.

This period also marked the beginning of an understanding of viruses as a cause of disease. After the 1900 discovery that yellow fever was caused by a virus, some of the more problematic diseases, like polio and other potentially waterborne agents, began to be better understood. Virus testing was still in the realm of health laboratories, not water labs.

Detection of chemicals was advancing as well, including tests for many metals such as lead testing in 1906.

Regulations

The first attempt at national regulation came in 1914 with the development of U.S. Public Health Service's Interstate Carrier Standards (a.k.a. the "Treasury" standards), applying only to water served by such carriers as trains with interstate service. No municipal systems were subject to these standards but they did constitute the first attempt to establish defensible maximum contaminant limits. These focused on biological contaminants with a 100/cc limit for total plate count and not more than 1 in 5 samples to have *B coli*. There were no physical or chemical values adopted. States were able to reference these standards for their own purposes as needed and many adopted them as guidelines.

In 1925 USPHS updated these standards to make 1 coliform per 100 ml the standard for post chlorinated water. This update also established standards for lead, copper, zinc, and excessive soluble mineral substances. This update represented the first introduction of the risk concept, i.e. defining the allowable exposure to contaminants based on health studies.

Role of Public Health

George W. Fuller's filter experiments at Louisville began to bring about change within the industry. No longer were the very limited patented systems being used but the prototypical rapid sand filter plant became the most widely used design. The use of coagulants and multi-media filter beds ensured excellent particulate removals followed by disinfection to complete the defense against biological threats.

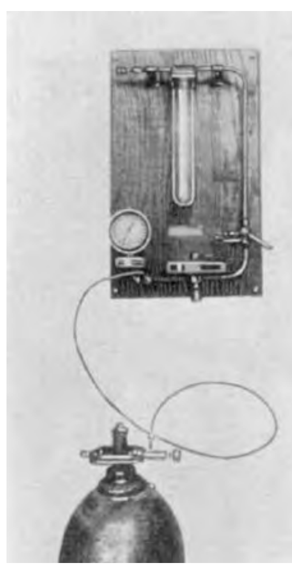
Of course, the world was not standing still and new contaminants were beginning to appear. In the 1920's, leaded gasoline becomes the standard, creating more free lead in the environment. Similarly, industries continued to develop more products involving organic chemicals such as dyes and solvents. Even radioactive materials were being introduced with a poor understanding of their fate in the environment, a famous example being the "radium girls" of the watch industry who were being sickened when they wet their brush points with their lips as they painted clock faces. As the industry was catching up to one threat, more would emerge.

Role of Water Treatment

With the large number of new sources being developed, water suppliers still did their homework and prepared reservoirs for optimum water quality performance, the need for which was made clear in the late 1800's. Watershed management was viewed as a complement to water quality performance with a trend toward avoiding deciduous trees and minimizing overland runoff.

Chlorination went through a cycle where initially most communities had to adopt cumbersome methods, then the chlorine industry stepped up to develop more reliable equipment. While chlorine gas was available in 1908, safe pressurized containers were not, so the first chlorination systems used chloride of lime or calcium hypochlorite as these were the only safe transport methods of the time. This required transporting granular chemicals and mixing them in solution tanks, then using early generation solution feeders, with many problems encountered in mixing and proper pacing. It was a difficult and labor intensive solution.

Wallace & Tiernan, the earliest New England practitioners of chlorine gas feeders, started in 1913, applying chlorine gas directly into the water stream until the 1922 development of the vacuum solution feeder. Chlorine gas compression became workable and common in the 1920's and this was a huge advance in



First Wallace & Tiernen chlorinator

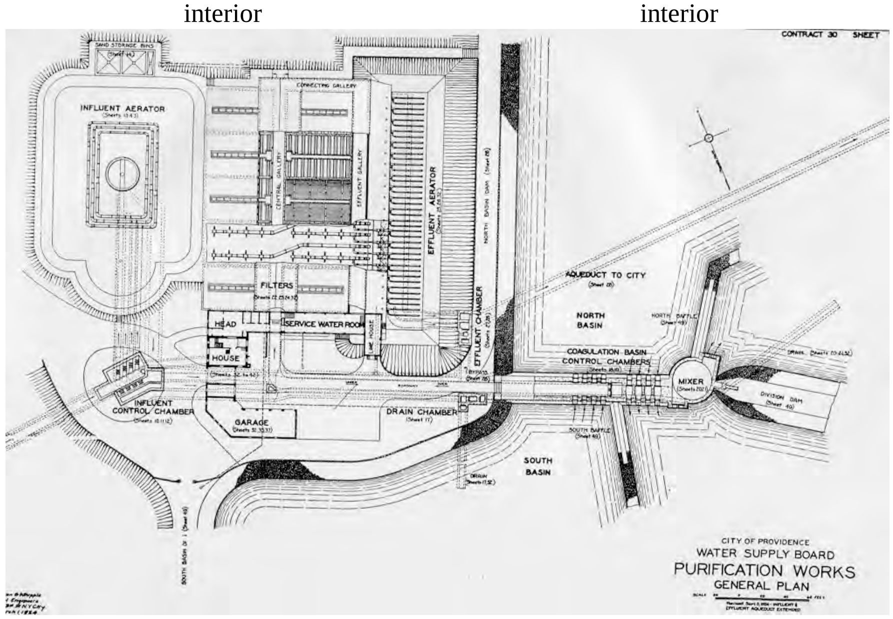
1916 Wakefield MA gas chlorinator – 1st in Massachusetts simplicity of delivery. The use of a pressurized gas container to provide the gas feed driving force removed the need for mechanical pumps and even allowed for some rudimentary flow pacing.

The science of chlorination took a bit longer to understand. In 1919, Holman and Enslow defined the concept of chlorine demand, which helped operators understand issues like reactions with other materials, which helped with proper dosing. The verification of residual was done manually by the ortho-tolidine-arsenite (OTA) test which was cumbersome for an operator to perform. Understanding of the relationship of hypochlorite ion formation to pH and breakpoint chlorination came well after this period.

The use of chlorine was also seen as bit of a panacea with the philosophy of "more is better" in play at times. "Double chlorination" became a way of improving source water tastes and odors. Superchlorination was often used to not just destroy tastes and odors, but also with the intent to destroy any and all pollutants in a sort of magic bullet approach. Dechlorination would by necessity have to follow the superchlorination. Obviously, detection of organics, such as disinfection by-products, was not possible at this point in time. Chlorine doses in the range of 10-20 mg/l were not uncommon and doses over 100 mg/l were recorded in some more heavily polluted supplies.


1918 Providence RI slow sand filter interior


1918 Providence RI slow sand filter interior



1926 New rapid sand Providence RI Water Treatment plant

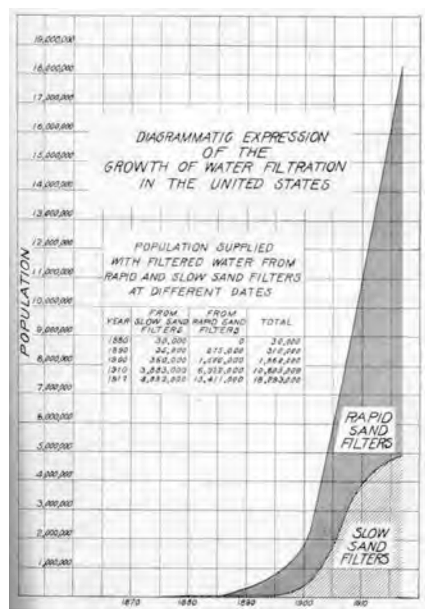
The first chloramination nationally was tried in Greenville, TN in 1926 for taste and odor control, followed shortly in Cleveland, OH in 1929. This was probably a reaction to more than just the free chlorine taste, quite likely it was also due to the presence of industrial pollutants, like phenols, that were producing reactions with chlorine to form unpalatable by-products.

“Conventional treatment” became understood to be coagulation, sedimentation, filtration and disinfection in this period. New filtration plants typically used rapid sand type designs while older slow sand plants saw no reason to change. Allen Hazen, the hydraulics expert, had developed the concept of surface loading rates in 1904 as a means of controlling the sedimentation process. He actually postulated the use of multiple trays but this didn’t get any further attention until much later in the century as most communities were satisfied with conventional contact basins and mechanical sludge collection equipment. The period also saw much work in developing proper coagulation controls as iron and then aluminum salts were tried and effective dosage rates were empirically developed.

In the area of filtration, more work had been done on different medias. The idea of multiple medias had been around since the 1800’s, with everything from sand to sponge being tried. Anthracite coal was discovered to be effective by accident at Harrisburg PA in about the 1920’s, which started its use in dual media given its favorable size to weight relationship to sand, allowing the coarser anthracite particles to be on top in the media bed.

The main focus of the 1920’s and 30’s was on improving filter performance, e.g. better backwash to solve media control issues. Underdrains were improved in the 1920s using tile blocks or better nozzles. The upward expansion of stratified filters was carefully managed to clear solids without loss or disturbance of media.

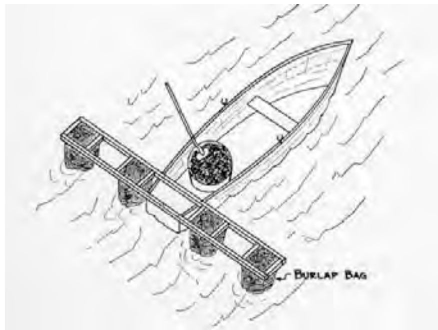
This period also had the first attempt at mass medication via the water supply. Well before fluoridation was ever considered, there were attempts to use water supply to correct iodine deficiency in areas where the absence of iodine in the natural environment was causing incidence of goiter, an endocrine system problem. Iodization was generally not necessary in New England but happened as close as Rochester NY in 1923. The practice was eventually discontinued when a substitute method was developed, i.e. iodization of table salt.



1917 review of filtration showing shift to rapid sand filters after 1900

Aesthetics -
Iron and manganese began to get more attention in the 1900’s as demand for cleaner laundry drove many to treatment for removal of the offending substance. Most often, chlorine use for disinfection was now precipitating the otherwise dissolved Fe/Mn so removal was made more necessary. Removal was done mainly by oxidation followed by lime coagulation/filtration. One other taste and odor tool first appeared in 1929 when powdered activated carbon first became available.

The emergence of copper sulfate as an algaecide was an important development. Its use began locally in Ludlow MA in 1904, once again demonstrating the idea that those in most dire need take the step to advance. The local source was notoriously plagued by nuisance algae and the public demanded a solution. After some experimentation, the application of copper sulfate by boat was declared a success. This brought about widespread interest throughout New England and adoption of copper sulfate as "the" algae solution, which it remains to this day. Application methods were frequently discussed with most developing some means of spreading from a specialized boat. Occasionally, alternatives like chlorine were tried during this period. Chlorine was viewed as such a powerful new tool that its use was tried in any aesthetic situation, even in the source reservoir. Fortunately, this didn't catch on.



1930 copper sulfate boat


1924 Chlorine gas application to reservoir

1930 to 1970 – Reacting to the new pollutants

Following the post-war period, the general lack of attention to pollution in the environment was catching up to the entire country. Once again, industry was moving into new areas like plastics and pesticides and producing new organic threats. Locally in New England, paper mills, textile mills, metalworking plants and food industries continued to operate unchecked by pollution controls. Greater use of synthetic fertilizers was occurring in farms nationwide. Mercury was used extensively in the 1940's to 1950's, while the effects of bioaccumulation were not understood until the 1960's. As key environmental events exposed vulnerabilities, the public health community was finding that the consequences of pollution were more subtle in both speed and impact than a disease epidemic but extremely hazardous to health nonetheless. The idea of exposure to carcinogens and mutagens was replacing biological risk as the key problem in the minds of many in the drinking water public by the end of this period.

On the environmental awareness front, the 1950's brought air pollution of many cities to a crisis stage, eventually leading to acid rain issues in New England and other northern states. In 1965, lead in gasoline was exposed as a significant health problem, forcing the industry to shift away from lead additives while again highlighting lead control in the urban setting as an important health issue. In the area of water pollution, the 1969 event where the Cuyahoga River in Ohio caught fire and produced flames over 5 stories tall highlighted the sad lack of controls on industrial discharges to waterways.

The direct detection of many of the associated contaminants in the water supply wouldn't hit until after 1970 as detection technology caught up with the presence of newer, more complex substances.

Public Health/Drinking Water Issues

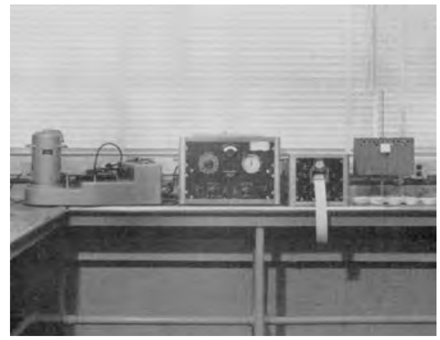
The issues of the day had shifted from biological threats to emerging chemical threats. Pesticides and herbicides became an emerging threat in many watershed areas as farming competition forced many farmers to try chemical control of pests and nuisance plants. Compounds like DDT (created in 1944) were heavily used, becoming environmental hazards and further finding their way into water supplies from agricultural runoff. The DDT story was documented in the 1962 book "Silent Spring" by Rachel Carson which was one of the driving forces in the new environmental consciousness that emerged around 1970 when the first Earth Day was celebrated. Another emerging chemical problem came from the increasing use of polychlorinated biphenyls (PCBs), which, after creation in 1929, had been used extensively starting in the 1940's in electrical equipment and other industrial uses. Conventional treatment struggled with removal of some of the new compounds.

Similarly, in the 1960's, the detergent industry began using alkylbenzenesulfonate with phosphate to improve sudsing. This improved laundry performance but it did so, once again, at the expense of the environment and the drinking water supply as the extra phosphate led to eutrophication of receiving waters and more nuisance algae species. The foaming of some streams was also attributed to this compound, leading to a groundswell to remove the product later in the 1970's.

One minor biological issue of the era was the discovery around 1960, that nematodes (microscopic worms) were abundant in many polluted rivers and, further, that they were making it through surface water treatment in some systems. This made for some interesting microscopic images and news stories but the organism was only marginally a health issue in the sense that the nematodes themselves were not dangerous, they simply may have harbored other pathogenic bacteria. They had some significance to taste and odor issues but faded as a health concern with time and the emergence of other more problematic organisms.

One of the prevailing health issues in this period was notable as being somewhat water related, that being the polio outbreaks of the 1940's and 1950's. As a viral disease, there had been major outbreaks dating back to around the turn of the century. Transmission was concluded to be principally by direct contact via swimming or other bodily contact in a polluted water body. As with every other disease, the waste from an infected population carries large amounts of the causative agent. The polio virus was very well suited for water transmission so the presence of so many untreated or poorly treated sewage discharges was part of the problem. Polio outbreaks have been experienced in past centuries but the incidence increased in the 1900's. This led some health experts to conclude that the improved water treatment following widespread use of chlorine, a proven virus killer, actually may have increased epidemics in the 1900's by removing the public's earlier low level exposure to small amounts of the virus in undisinfected drinking water, thus removing the positive immune system response that was present in the past.

Radiation was also an emerging issue throughout the period. During the Cold War period that followed World War II, the arms race precipitated a significant increase in open air testing of nuclear bombs worldwide, starting in 1951. The ensuing fallout traveled around the globe and contributed measurable amounts of radiation in New England, a fact that was accidentally discovered by scientists in 1953 in Troy, NY. This eventually led to global agreements that curtailed testing as the other nuclear powers agreed that this was a bad idea. The 1979 Three Mile Island nuclear plant near-meltdown disaster was another interesting example of a potential radiation threat. The 1986 Chernobyl incident actually did release radiation but did so far enough away to be a non-issue to the US.



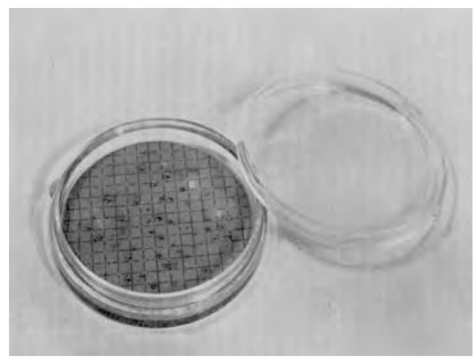
1955 Lawrence Experiment Station radioactivity monitoring

With this new awareness on radioactivity as a health issue, testing began to reveal that some bedrock wells in New England had naturally occurring radioactivity from trace sources like radon and other radionuclides. This again undermined the old belief that groundwater was inherently the lowest risk source.

Detection Technology

In the area of biological threats, the development of the membrane filter test greatly simplified coliform bacteria testing and enumeration of results. The Army chemical corps originally developed the membrane filter as part of its biological warfare agent detection. It declassified the method in 1951, allowing Millipore filter to bring it to market. Standard Methods published the method in its 10th edition, after 1953 lab studies proved the method to be viable. The method continues to be the mainstay of current day Coliform Rule testing.

1955 Membrane filter



1958 Coliform plate

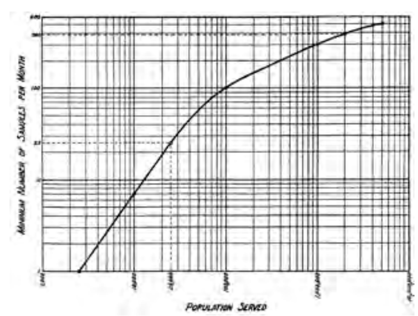
While there were many advances in test methods, especially in chemical detection, the most significant advances were in organics detection. The Carbon Chloroform Extract (CCE) test, developed in 1952, gave a quick reading of organics presence that could be used isolate individual compounds. In the 1960s, the Gas Chromatograph/Mass Spectrometer added a powerful tool for rapid testing with scanning capability and quantification of individual compounds. This new method enabled the alarming discoveries in the 1970's.

1954 New Britain CT Lab

Regulations

In 1942 U.S. Public Health Service updated its "Interstate" standards again, this time using an advisory committee. This update added a minimum number of samples, defined the appropriate points in the distribution system and added the right of state or federal inspection at any time. Chemicals were regulated better with new maximum permissible amounts for lead, fluoride, arsenic, selenium, salts of barium, hexavalent chromium, heavy metals or "other substances having deleterious effects". The update also set maximum concentrations for copper, iron, manganese, magnesium, zinc, chloride, sulfate, phenolic compounds, total solids and alkalinity.

In 1946, a further USPHS update added hexavalent chromium standards. A 1957 amendment authorized use of membrane filter technique.



1944 USPH population based coliform sampling requirement

With the help of a new advisory committee, the USPHS, set forth limits in 1962 for alkyl benzene sulfonates (detergents), barium, cadmium, Carbon Chloroform Extract (CCE, a measure of organic residue), cyanide, nitrate, silver and 28 other existing regulated constituents. These were mandatory limits for health related contaminants and recommended limits for aesthetic concerns like taste and odor, but, once again, these were only legally binding to 700 water systems that supplied interstate carriers (<2%) of the nation's water systems.

In a significant development in 1969, USPHS tested 969 public water systems serving 18.2 million people and found that 41% did not meet the 1962 guidelines, some being potentially dangerous. This was one of the main driving forces for establishing the eventual 1974 Safe Drinking Water Act.

On the environmental side, the 1948 Water Pollution Control Act created the first federal funding for wastewater treatment to start the clean-up of the nation's river. This was followed by the 1956 Federal Water Pollution Control Act (amended again in 1965, 1966, 1970, and 1972). The Water Quality Act of 1965 set stream water quality standards for receiving waters and began establishing a means to require treatment of waste discharges.

Among other environmentally driven regulations, the 1963 Clean Air Act and the 1968 Wild and Scenic Rivers Act began a series of protective legislative requirements that began to improve the quality of source waters.

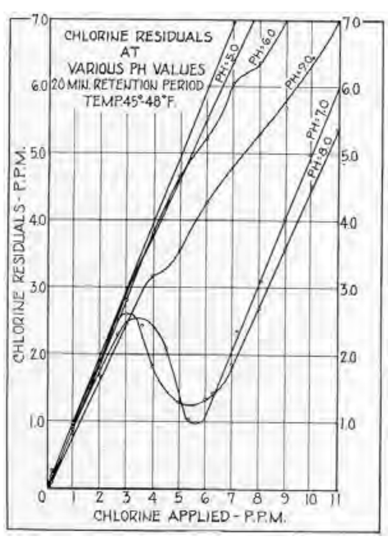
Role of treatment

The period saw the general improvement of all technologies associated with conventional treatment.

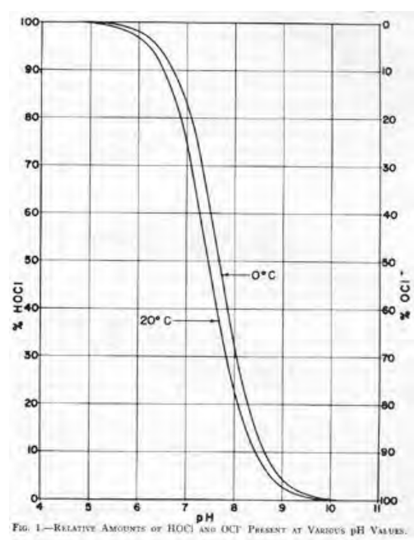
In the area of disinfection, chlorine gas was the most used disinfectant, largely due to its simplicity and reliability. There were, of course, much written in the NEWWA Journal of the need for proper safety practices as container sizes grew to ton cylinders for the larger users. On the plus side, Wallace & Tiernan developed better flow pacing in 1950's making the chlorination process even more reliable.

Several other disinfection developments are worth noting in this period. The first is the emergence of chloramination, initially as a solution to the taste and odor associated with free chlorine or as a solution to keeping persistent residuals in systems with very long travel times. Some water supplies began chloraminating in the 1930's but actually had to revert to free chlorine due to ammonia shortages during World War II. By 1948, the relative disinfection strength of chloramines was proven to be considerably less than free chlorine but its effectiveness on control of nuisance organisms and slime growth was found to be a plus. Ratio control was found to be the key to effectiveness.

In the 1930's, the breakpoint reaction became better understood, but it was only in 1943 that the finding that pH affected the hypochlorous/ hypochlorite species and consequently the potency of the residual. The tendency on dosing was still to be fairly generous on dosage with some supplies routinely pushing breakpoint dosages or superchlorination/ dechlorination.

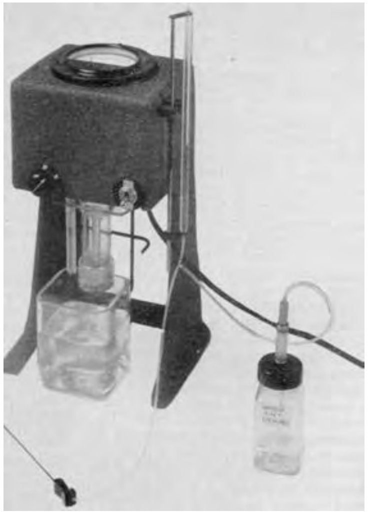


Breakpoint chlorination diagram



pH relationship on HOCL species graph by Gordon Fair

In other disinfection developments, the calcium hypochlorite product HTH was developed in 1927. Chlorine dioxide was available but infrequently used from a cost standpoint, with a few supplies choosing to use it where there were phenols that were producing undesirable aesthetics during chlorination. From a control standpoint, the ortho-tolidine-arsenite test gave way to amperometric titration in 1942. Procedures for disinfecting mains with chlorine were also adopted in 1947 by AWWA.


Chlorine amperometric titration

In the area of filtration, the 1950's saw more performance improvements, primarily due to better media combinations and the development of polymers. Granular activated carbon (GAC) was developed in 1960s with the initial expectation of use in taste and odor control. Similar to anthracite coal, GAC offered advantageous granular size to weight ratios that allowed good bed stratification in a multi-media filter plus it had notable adsorbtion properties. Polymers were available as a filtering aid as early as 1945, with Nalco, Dow, and Calgon contributing various types of ionic and anionic polymers. Up until this time, all flocculation was done using iron or aluminum salts and the polymers enhanced floc formation considerably. Paddle type flocculators became the most common type, with some plants using static mixers or turbine agitators (first used with Infilco's solids-contact clarifier). In this period, Thomas Camp of MIT became renowned as a flocculation expert, with his 1955 paper, *Flocculation and Flocculation Basins*, being considered a civil engineering classic.

Better methods of collecting filtrate were developed, for example, the 1934 porous plate filter bottoms that were studied by T. Camp at Providence's water treatment plant. Mud ball problems in backwash led to surface washing, use of compressed air, and other media agitation to get better media uniformity and reduce breakthrough. Filter controls also improved using flow metering, pneumatics, and better electronics.


1939 Biddeford ME filter gallery


1923 Putnam CT filter gallery

Jar tests for coagulant dosage control had been used for years but had some difficulty in translating to actual filter conditions. The 1950's development of the zeta meter allowed direct measurement of zeta potential, allowing better adjustment to actual conditions. Some water treatment plants began using pilot filters for actual performance control.

One fairly unconventional method that came in this period was the Diatomaceous Earth filter, first developed for armed forces in WWII. The method offered minimal capital expense but somewhat more difficult and costly operation than conventional treatment. The first DE municipal plant was in Gasport NY in 1949 and was followed by several New England installations.

Much water treatment plant construction occurred in this period with varied architectural styles

1943 Hinsdale NH WTP

1943 Beverly MA WTP

1939 Willimantic CT WTP

1942 Rockport ME WTP

1943 Groton CT WTP

1954 New Britain CT WTP

The following table gives a brief breakdown of water treatment in New England at about the midpoint of the 125 year life of NEWWA:

State	**Communities with slow sand**	**Population served**	**Output MGD**	**Communities with rapid sand**	**Population served**	**Output MGD**
Connecticut	6	285,300	26.62	20	327,800	36.38
Maine	5	20,300	1.73	13	75,300	7.72
Massachusetts	17	378,300	33.20	9	292,700	26.38
New Hampshire	4	21,700	1.67	6	16,200	1.73
Rhode Island	0	0	0	8	567,800	45.14
Vermont	1	6,600	1.50	2	27,300	1.73

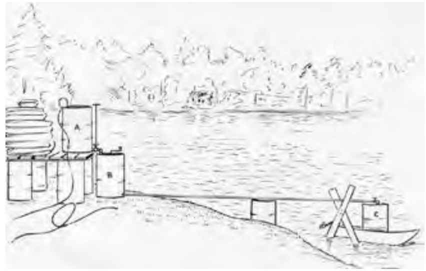
From E. Sherman Chase 1944 paper – "*Water Filtration - Present Practice & Trends*". Approximately 25% of the population of NE is filtered at the time.

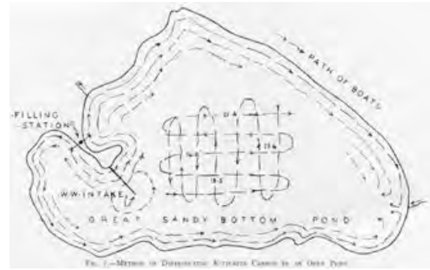
As can be seen from the few communities served, there were still many unfiltered supplies at the time.

Aesthetics

There were the usual problems just as there are today, i.e. algae and red water. Algae went through a bit of a growth spurt in the 1960's as the detergent industry began to fortify its detergents with phosphates for better sudsing. The result was more nuisance species and increasing eutrophication of surface waters. Copper sulfate treatments were still the preferred solution to algae but other new tools like powdered activated carbon were occasionally tried.


1966 Copper sulfate dosing through ice using a hole and an outboard motor


1947 Powdered activated carbon use at Pembroke MA



1947 PAC application plan Pembroke MA

Iron was beginning to present more problems as the cast iron pipes aged. With the poor coatings on the early generation of cast iron, it wasn't long before the coatings broke down. With the normally corrosive New England waters, rapidly growing pipe scales were causing episodes of discolored water, which, in turn, caused a resulting public push for better iron control to save their laundry. This led to development of phosphate inhibitors in the 1940's with the early preference being sequestration to keep red water down.

In the world of corrosion control, Langelier published his index in 1936, helping many understand the kinetics of metal corrosion. Lead dissolution was not considered a huge problem at this time so pH control strategies were not yet common and most water supplies managed pH only so far as necessary to support other conventional treatment processes. Excessive hardness had never been a big issue in New England so fairly few attempts at lime softening were needed.

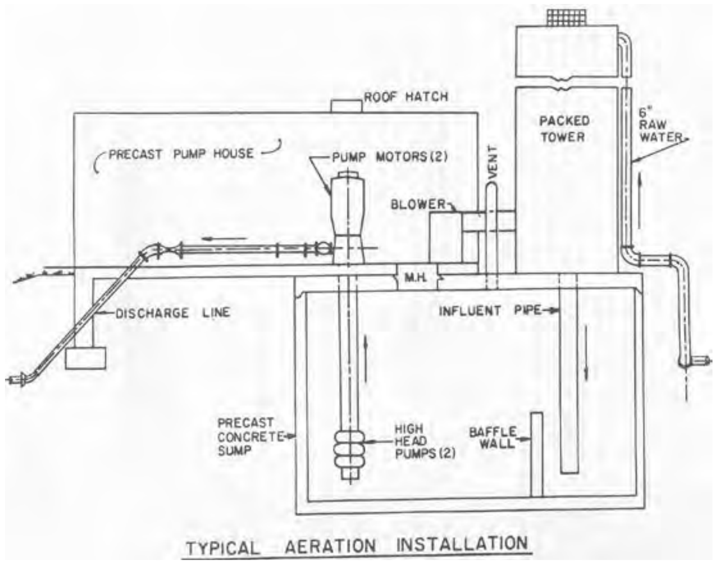
New source water issues emerged in this period such as chlorine reactions with newer chemicals, especially phenolic compounds that produced a particularly noticeable taste and odor, an issue that emerged in 1942. This led to some changes in water treatment, including the use of potassium permanganate for pre-oxidation, a practice that became common in the 1960's. Some systems added aeration to help with volatile organics, more to cure the aesthetics problem than to deal with any health effects. Granular activated carbon became a popular treatment media in the 1960's for the same reasons.

1970 to Now – Emerging threats

Public Health/Drinking Water Issues –

The 1970's was the beginning of the modern era of government regulation. Not only did the causes of pollution get regulated but the 1974 Safe Drinking Water Act began the process of truly ensuring the safety of the nation's water supplies. The late 1960's survey by U.S. Public Health Service of drinking water quality nationwide was eye-opening in that, despite having the means and methods to treat water effectively, a substantial percentage of U.S. water supplies were delivering unsafe water. In this historic first survey looking at organic chemicals, the survey revealed dissolved organics frequently exceeding the 200 microgram/l recommended limit on CCE. There was a public outcry for national regulation as a result.

Water supplies began to benefit from the public push to clean up the environment. After the series of environmental disasters in the 1960's, the government also cracked down on stream pollution from any and all sources while simultaneously funding municipal wastewater treatment. The 1965 Clean Water Act began a series of initiatives that saw discharge limits placed on municipal and industrial discharges in the NPDES program. Pesticides and herbicides were more restricted, especially those that had been found to have serious bioaccumulation consequences like DDT. The point sources of very hazardous materials were regulated under CERCLA and the Superfund was established in 1980 to begin removal of contamination.



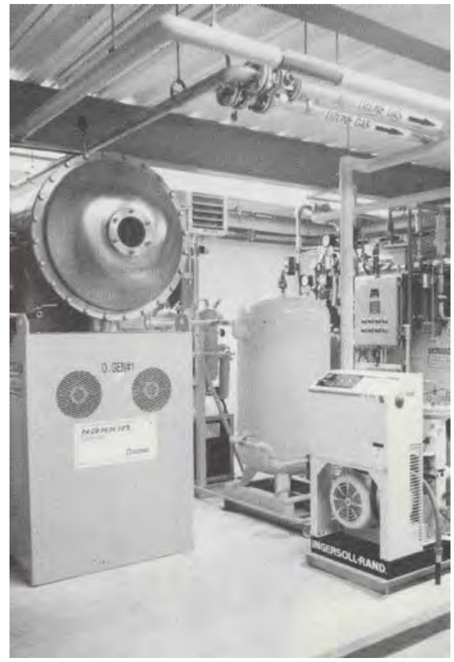
1988 aeration for VOCs

A series of new public health threats emerged in the 1970's, starting with the discovery that disinfection by-products, like tri-halomethanes, were carcinogens. This came after the CCE test allowed organics testing and after a 1974 EPA study in Louisiana detected 66 organic compounds, many being the result of disinfection byproducts. Concurrently, epidemiological studies by Environmental Defense Fund in Louisiana found higher cancer rates in the Mississippi River water users than in local groundwater users, linking the chlorinated organic compounds to cancer. Suddenly, the water supplier's best friend, chlorine, was potentially the cause of significant problems.

This was closely followed by the 1976-77 National Organics Monitoring Survey study of 113 supplies which identified 700 specific organic chemicals but found that tri-halomethanes (THMs) were the most widespread. In 1978, EPA proposed a 2 part strategy, first to control THMs, second to control synthetic organic compounds in sources by use of granular activated carbon (GAC) as a required treatment step. Environmental Defense Fund filed suit to push for organics control, but many opposed the GAC requirement. In 1979 EPA promulgated the THM rule but in 1981 EPA withdrew the GAC requirement after considering arguments by opponents.

A 1977 National Academy of Science study, first in series of nine, put forward a basis for development of regulations that attempted to use health effects to establish maximum contaminant levels. They proposed 5 classes of contaminants: microorganisms, particulate matter, inorganic solutes, organic solutes, and radionuclides. This remains the model for science based development of water quality regulations.

The discovery of other contaminants like organic solvents, PCBs, heavy metals and other industrial wastes coming from point sources, such as the 1970's-1980's Superfund sites, was a huge impact on water supplies in urban industrialized areas. Not only were some surface waters at risk but now even groundwater, long considered the safer of the surface/subsurface source options, was found to be at significant risk.


1997 Package ozone plant

The response to biological risks in the 1970's began to shift away from considering only bacteria and virus inactivation as the key performance measure of disinfection control. Locally, Berlin NH had a severe Giardia outbreak in 1978. With an increasing number of Giardia incidents nationally, the public health community and regulators realized that there were more disinfection resistant pathogens (Giardia being the foremost) which were causing waterborne illness. This led to the need to update the indicator organism strategies for more thorough disinfection. The research for inactivation of Giardia produced much more strict control of disinfection variables like pH, temperature, dosage and contact time. In the 1990's, cryptosporidium emerged as the next organism to drive risk response when some significant events, like the 1993 Milwaukee incident that infected 400,000 people, demonstrated the potential of this organism to cause significant public health problems. The fact that the cryptosporidium oocyst was extremely resistant to chlorine began to bring about a significant shift in regulatory disinfection control strategies. Water suppliers today are now feeling the impact of this as current cryptosporidium regulatory efforts will soon require substantial and expensive treatment changes.

The issue of lead in drinking water also came to a head in this period, the problem being associated with lead service pipes and lead solder, but the regulatory solution being corrosion control treatment requirements on the water supplier. The banning of lead pipes and lead solder in the 1986 SDWA Amendments just stopped the problem from growing and today most water systems are now faced with the threat of replacing any remaining lead services simply because existing lead soldered copper joints and brass fixtures alone could cause non-compliance with the lead standard. This issue has received a great deal of research and much fine tuning of corrosion control strategies.

On the environmental front, the growing awareness of pollution drove the public to demand government regulation of many areas, including air, water, solid waste, endangered species and so on.

The performance of water suppliers and the aging of water treatment plants were also found to be an issue. A 1973 General Accounting Office report on 446 water systems found only 60 in full compliance with bacteria standards and sampling requirements. SDWA oversight was deficient in 5 of 6 states studied. The report noted that many water treatment plants needed expansion due to hydraulic overloading or disrepair.

In 1988, Ralph Nader's study of drinking water, in partnership with the National Wildlife Federation, challenged EPA and Congress that not enough enforcement was being done. The next decade or so was spent with environmental groups pushing for more stringent regulations while water suppliers were trying to cope with all of the new requirements. In 1993 EPA submitted a review of SDWA, finding that the cost of compliance with the regulated 84 contaminants to be $1.4B nationally with a significant shortfall in available funding. The local reaction to this published cost of improvements necessary to get in compliance was that not only was it underestimated but it was also was an unfunded mandate. Unlike the Clean Water Act funding for sewerage works, the huge cost of these required capital improvements had to be borne by the communities and their ratepayers. This continues to be the case as more emerging issues are regulated and costly upgrades are needed. In an effort to support communities, EPA funded and developed the state managed revolving loan program in the late 1990's.

In addition to the emerging environmental threats to water quality, the 9/11/01 attack on the World Trade Towers brought concerns over terrorism. This meant that water supplies needed to consider how to monitor for intentional contamination. This was a significant departure from the use of indicator organisms and sewage contamination since there are literally hundreds of chemicals, biologicals and radiologicals known to be harmful if introduced into the water supply. The other departure is that water quality in the entire distribution system now requires monitoring, not just the sources. While this is not subject to regulation yet, it has raised a new and difficult challenge. The result thus far is that some communities have expanded the use of on-line monitoring or periodic sampling for broad indicators of contamination. More research is underway on better technologies which may make this practical for everyone.

Detection Technology

The CCE test that started the furor over the presence of chlorinated organics was complemented by the gas chromatograph/mass spectrometer (GC/MS). This allowed the rapid and accurate detection of specific organic compounds.

Detection of metals took a major step forward in the 1970's with the development of atomic absorption methods, followed in the 1980's by Inductively Coupled Plasma (ICP) methods.

Biological detection also took some steps forward in this period. Alternative coliform tests were developed, like the enzyme based tests that use presence/absence and dilution schemes to provide a most probable number. As before, the incubation period for enzyme based tests still requires a lengthy turn around for results. Virus, giardia and cryptosporidium testing continues to be a difficult sample collection process and generally requires specialized equipment and procedures. Rapid immunoassay techniques also became available in the 1960's to help with identifying some specific contaminants. Some of these have evolved into the immediate detection kits used by HazMat responders for biological threats.

In the post-2001 world of contamination detection, multi-parameter monitoring stations for simple physical/chemical indicators have been used by some larger systems. These may prove to be helpful to overall operations as they will enhance understanding of dynamic water quality conditions

Regulations

This period reversed the federal government's laissez faire attitude with regard to the environment and pollution. A swarm of regulations of interest to water suppliers followed:

Year	Regulatory Change	Significance
1970	Creation of the Environmental Protection Agency	Established the agency that would become responsible for water and waste risks to public health
1970	Occupational Safety and Health Act	Established all hazard safety standards
1972	Clean Water Act (amended in 1977 & 1987, replaced the older Federal Water Pollution Control Act)	Established goals for river water quality, regulated waste discharges and provided grant funds for upgrading community wastewater plants
1972	Federal Insecticide, Fungicide & Rodenticide Act	Controlled the use of pesticides, banned some like DDT
1973	Endangered Species Act	Established protections that would stop projects like reservoirs that impact critical habitat
1974	Safe Drinking Water Act (amended many times since then)	The first universal national drinking water standards
1976	Resource Conservation and Recovery Act	Required protective changes to dumps and underground storage tanks
1976	Toxic Substances Control Act	Established a cradle to grave system for tracking industrial chemicals
1980	Comprehensive Environmental Response, Compensation & Liability Act, a.k.a. Superfund	Responded to establish a cleanup plan for serious hazardous waste sites
1983	EPA issues first National Priorities List	Established a ranked listing of all significant hazardous waste sites
1986	Emergency Planning and Community Right to Know	Established an emergency response hierarchy for chemical hazards
1999	Section 113 of the Clean Air Act is amended to require risk management plans for hazardous gas release	All large gaseous chlorine or anhydrous ammonia users had to submit RMPs

Many of these had direct effects on water supplies. Most were beneficial in the sense of cleaning the source waters, but some constrained source development since removal of waters from rivers was in conflict with environmental impact considerations.

The evolution of the drinking water regulations themselves is noteworthy. The 1974 Safe Drinking Water Act (SDWA) established the first truly national primary drinking water regulations. The original act was mainly a framework to establish the process of regulation and the roles including the state primacy role with federal oversight. It also set up violation reporting standards and established the schedule for development of the National Interim Primary Drinking Water Regulations (NIPDWRs) using the NAS studies of health effects as the basis. It established 2 steps of regulation setting, the first being Recommended Maximum Contaminant Limits (RCMLs), then Maximum Contaminant Levels (MCLs). It also allowed the option of specifying a treatment technique where necessary if the contaminant was beyond the removal ability of conventional treatment. In 1975, the NIPDWRs were published, creating the first comprehensive limits on drinking water contaminants.

As mentioned previously, EPA promulgated the THM rule in 1979 and withdrew the embedded GAC requirement in 1981.

The 1986 SDWA amendments were a significant step forward. The amendments were a reaction to concern over the slow pace of regulations, with Congress passing PL 99-339 (SDWA 1986) as a mandate to get moving on further regulation. Among other things, it required:

- Mandatory standards for 83 contaminants by 6/89
- Mandatory regulation of 25 new contaminants every 3 years
- National Interim Drinking Water Regulations to be renamed to National Primary Drinking Water Regulations
- Recommended Maximum Contaminant Levels to be replaced with Maximum Contaminant Level Goals
- Required designation of Best Available Technologies for each contaminant
- A specification to be developed for filtration of surface supplies
- Disinfection of all surface supplies (based on Giardia as the most difficult organism to inactivate)
- Monitoring for unregulated contaminants
- A ban on lead solders, pipe and flux
- Wellhead protection and protection of sole source aquifers
- Streamlined and more powerful enforcement

The 1988 Lead Contamination Control Act (PL 100-572) followed with the finding that water coolers released lead. It required testing of water at schools and day care and recalled lead lined coolers. This was followed shortly by the 1991 Lead and Copper Rule. This established the testing protocols and required response actions that we are bound to today.

Amendments to the Clean Air Act also created a significant impact on larger systems when Risk Management Plans were required to be submitted in 1999 for gaseous chlorine and other hazardous gases. The threshold was such that the presence of a ton cylinder triggered the need for a plan and follow-up risk disclosure and emergency response planning needed to be done in affected communities. This created a powerful incentive to switch away from bulk gaseous chlorine.

Other water specific regulations followed, including a significant group in the last decade:

1996 Information Collection Rule
1998 Interim Enhanced Surface Water Treatment Rule
2000 Radionuclides Rule
2000 Public Notification Rule
2001 Filter Backwash Recycling Rule
2001 Arsenic Rule
2002 Unregulated Contaminant Monitoring Regulation
2002 Long Term 1 Enhanced Surface Water Treatment Rule (repl. the 1998 Interim Rule)
2004 Updated Lead and Copper Regulations
2006 Stage 2 Disinfectants and Disinfection By-products Rule
2006 Long Term 2 Enhanced Surface Water Treatment Rule

These updates were intended to bring about solutions to such threats as cryptosporidium, THMs, and lead. The process of finding new contaminant threats continues to the present day so there will certainly be further regulation. Near term possibilities include regulation of perchlorate and the proposed Ground Water Rule, aimed at finding and remediating problem sources.

Role of treatment

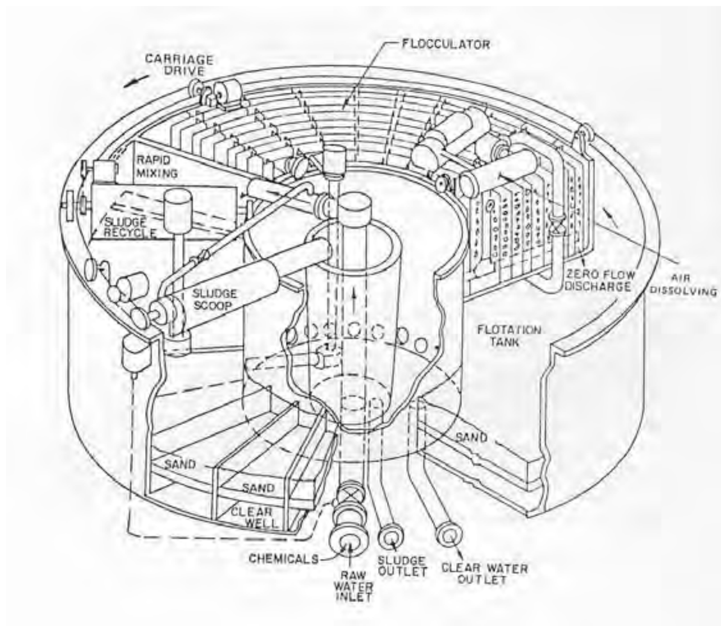
In the world of disinfection, this period featured the emergence of alternative technologies, namely ozone and ultraviolet light (UV). Ozone had been around since the earlier part of the century but the expense, safety, lack of proven equipment and lack of a stable residual discouraged its use until about the 1970's when European supplies began to use it. Some U.S. supplies began to follow suit in the 1980's. On the plus side, its power as a disinfectant and its benefits on taste and odor issues made it attractive to some water supplies. The recent finding that ozone is effective on cryptosporidium will make it even more attractive to those communities that need to get in compliance on that as well. Ozone is likely to be more widely used by surface water supplies in the future.

This era was also a period where the old methods of conservatively high chlorine dosing needed to change because of the disinfection by-products issues. Many water supplies were caught in a balancing act where more stringent disinfection requirements forced a high dose to be effective while the high dose led to problems with DBP compliance. While some communities switched to chloramine residuals to minimize formation during travel in the distribution system, others tried to remove the precursors or to control dosage more carefully to just meet inactivation requirements without aggravating disinfection by-product formation. This was definitely the end of the more is better philosophy when it came to chlorine dose. The other chlorination trend was concern over gaseous chlorine safety, bringing some supplies to consider conversion to 15% sodium hypochlorite solution. This wasn't a clear cut choice due to the reliability of the gas systems and the significant expense of the conversion, but transporting gas cylinders through sensitive public areas created enough controversy to force some communities to switch.

Pretreatment methods underwent some changes as well. For one thing, hydraulic capacity in many old treatment plants would not allow adequate performance under higher demands. Retrofit solutions tried to make some of these old spaces work. For a time in the 1970's and 1980's, plate settlers and tube settlers were much in demand in these retrofit applications to take advantage of their greater surface loading area for unit volume. Other developments included upflow solids contact flocculators, some of which included an air driven pulse to periodically keep the floc blanket uniform. These pulsator-clarifiers produced better performance in solids removal in the sedimentation step than past conventional sedimentation tanks. The most recent trend in pretreatment is dissolved air flotation which is very effective at treating low turbidity waters like those found in New England. This process uses compressed air to lift particles to a waste weir, somewhat the opposite of sedimentation. All of these processes have reduced loadings carried over to filtration with much improved performance.

In the filtration process, the period saw much more hydraulic performance out of filters. Where conventional treatment had always dictated standard rates of 2 gpm/sf, better pretreatment and multimedia beds began to allow much higher loading rates, as much as 5-10 times greater than before. This had a positive impact on filter construction costs. Another interesting development in rapid sand filtration was the use of biologically active carbon (BAC) media, again an idea that was first successfully used in Europe in the 1960's before appearing in the U.S. This was a variant on GAC media that embraces the idea that some biological activity will occur within the media and uses that activity to further break down source water organics during passage through the filter. In one sense, this is like crossing an old sand filter with a rapid sand filter but the biologically active layer reaches deeper into the bed in the BAC process. Filter controls improved as well with better backwashing and better monitoring of performance from new devices like particle counters.

With all the available water resources in New England, desalination was only seriously looked at by communities on small coastal islands. However, by the 1990's, membranes for reverse osmosis had progressed to the point that the technology is becoming more cost competitive. The first municipal size project using membranes is expected to begin construction soon in Taunton MA using brackish water from the estuary of the Taunton River.



1985 First dissolved air flotation

With the strong SDWA focus on lead control, many more communities began adding phosphate or silicate additives. At this point, the previous iron control methods using hexametaphosphates as sequestering agents had little benefits for lead. Many communities tried orthophosphates to produce the internal pipe coating that would inhibit lead corrosion. This was a successful strategy in many locations but a problem in other communities, especially those with open storage where algae growth was problematic. PH control was actually the most frequently chosen solution, with lime or caustic soda being the most popular chemicals.

With the finding that many sources had volatile organic contamination in the 1970's, quite a few groundwater sources had to resort to treatment, most often resorting to aeration and GAC contactors.


1954 Fluoride probe

Fluoridation also became a widely used process in this period as the Public Health community, especially the American Dental Association, the American Medical Association and the World Health Organization, all endorsed the process. The technique of using the water supply for delivery was first tried in 1945 in a series of pilot communities. Research on the effects was conducted for the next 15 years or so before the public health community concluded that it had positive results and no negative health effects. Widespread implementation didn't take hold in most communities until the 1970's as local Boards of Health would make the decision to introduce fluoride, following which, the water utility would install the equipment and start the feed. To say that this was not without controversy is an understatement but the effort produced a documented decline in tooth decay.

Aesthetics

The same old villains, algae, iron and manganese, were still at work in this period and were still essentially treated the same way. More research on the taste producing compounds within algae was able to identify the mechanisms that cause the problem and how chlorine reactions aggravate some problems but, in the end, copper sulfate still remains the most effective control measure.

Firsts in water treatment

The following is an attempt to collect information on New England systems and the early steps taken by some communities to purify their water:

Treatment	1st in US	1st in NE	2nd in NE	3rd in NE
General				
filtration for aesthetics	Richmond 1832			
filtration for bacteria		Lawrence MA 1893		
Early attempts				
Charcoal, sand & gravel		Stockbridge MA 1862		
Sponge, charcoal & sand		South Norwalk CT 1875		
Unsuccesful attempts		Providence RI 1871(infiltration basin)	Springfield MA 1873 (lateral flow)	Brockton MA 1880 (tiles on res bottom)
Succesful Attempts				
Natural Filters (Bank)	Whitinsville MA 1870	Whitinsville MA 1870	Lowell MA 1872	Waltham MA 1872
Slow sand	Poughkeepsie NY 1872	St. Johnsbury VT 1882 (coarse filter in place from 1827), 3rd in US	Nantucket MA 1892 (algae removal)	Lawrence 1893 (6th in US)
Mechanical Filters				
Clark Filter		None		
Hyatt Mechanical Filter (with coag.)	Somerville NJ 1882	Newport RI 1882, 2nd in US	Greenwich CT 1887 (with pre-aeration)	
Warren Filter	Cumberland Mills ME 1884	Cumberland Mills ME 1884	Augusta ME1887, 2nd in US	Brunswick ME 1887, 3rd in US
National Filter	Chattanooga TN 1887	Exeter NH 1887, 3rd in US		
American Filter	Elgin Ill 1888	None		
Blessing Filter	Athol MA 1887	Athol MA 1887		
Jewell Filter	Rock Island IL 1891	None		
Continental Filter	Atlantic Highlands NJ 1893	None		
Filter variations				
Rapid Sand	Louisville KY 1897			
Upward filtration	Richmond VA 1832	New Milford CT , 1874, 2nd in US	St Johnsbury VT 1876	Lewiston ME 1880
Multiple Filtration	Atlantic Highlands NJ 1893	S. Norwalk CT 1908	Lawrence MA 1938	
Coagulation	Somerville NJ 1885			
Other Treatment				
Chlorine (electrolytic hypochlorite)	Jersey City NJ 1908	Newport RI 1910	Stamford CT 1913	
Ozonation	NYC pilot test 1906			
UV	Henderson KY 1916	Taunton MA 2004		
Aeration	Elmira NY 1860	Lawrence MA 1875, 2nd in US	Nantucket MA 1891	Greenwich CT 1887
Iron removal by aeration/filtration	Atlantic Highlands NJ 1893	Reading MA 1896, 3rd in US		
algae/CUSO4	Ludlow 1904	Ludlow 1904		
Softening	Oberlin OH 1903			
Chloramination	Greenville TN 1926			
Activated Carbon	Bay City, Mich 1930			
Iodization	Rochester NY 1923			
Fluoride	Newburgh NY 1945 (pilot)			

Where are we now? - Current Stats on treatment

As a recent snapshot of the current state of water treatment around New England, the following summary was presented by NEWWA's 1993 survey of New England water treatment practices:

Of the 139 Water Treatment Plants surveyed in 1993, the following was found:

Process	No. of WTPs	Details
Aeration	16	
Preoxidation	89	47 use chlorine, 30 use potassium permanganate, 5 use chlorine dioxide, 1 other
Coagulation	120	101 use aluminum sulfate or sodium aluminate, 29 use polymers
Rapid mix	125	63 use mechanical, the rest use static or in line
Flocculation	90	Most use vertical, many horizontal paddles, some baffles
Clarification	107	Most are conventional, some tube settlers, some upflow clarification, a few plate settlers, some dissolved air flotation
Filtration	139	124 rapid filters, 12 slow sand filters, 3 diatomaceous earth, 38 have GAC somewhere, 31 package plants
Disinfection	139	94 use chlorine gas, 45 use hypochlorite, 3 use chlorine dioxide, 1 ozone
Sludge disposal		60 lagoons, 32 sewer discharge
Taste & Odor control		30 use copper sulfate, 40 powdered activated carbon, 25 granular activated carbon
Corrosion Control		116 use pH adjustment, 56 phosphates

Bear in mind that this is surely out of date as the continuing emergence of regulations is causing much updating and reconstruction of treatment plants in the past decade.

The following is a recent snapshot of fluoridation status as a % of population served by public water systems:

State	1992	2000	2002
MA	57%	56%	61%
RI	100%	85%	89%
CT	86%	89%	88%
NH	24%	43%	43%
VT	57%	54%	56%
ME	56%	75%	74%

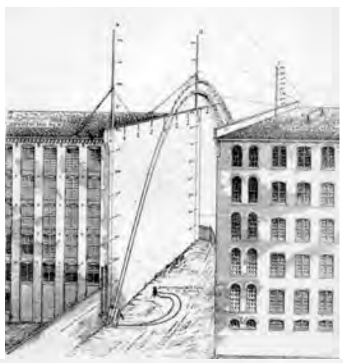
Are we ever going to get ahead of emerging threats?

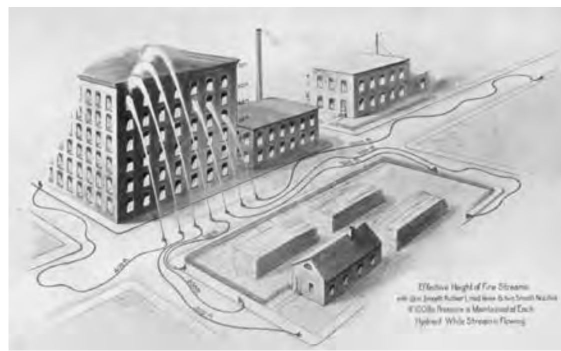
The future of water treatment is still going to be dictated by public health risk which is in turn driven by detection technology and new threats being released into the environment. Most water systems take the step necessary to protect against known threats but no more than that. Minimizing impact on the ratepayer makes it necessary to be sure that the next protective step is truly necessary. Chances are that the cycle of learning and improvement will continue.

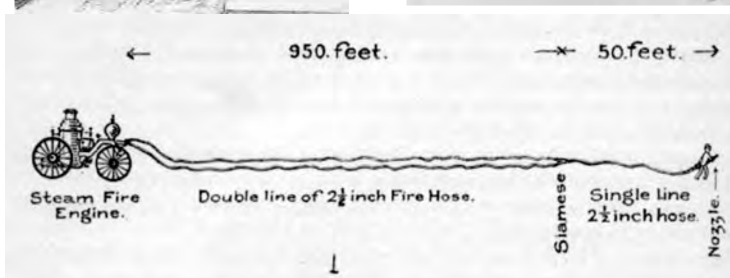
Chapter 4 Water Distribution Systems and Water Efficiency

In the early colonial days, water supply technology wasn't very complex. If you wanted water run to your house, you bored out your own wooden logs. If you wanted water for your town, large scale systems of bored-out logs were needed. Incidentally, pipe laying work was as unpopular back then as it is now because it ruined the roads. Such simple questions as proper depth, means of connecting services and fire taps arose almost immediately. Soon after the initial pipes were laid, the real fun began, as the leaks, outages, water quality complaints and other facts of life for the water supplier became apparent. As with any other emerging technology, the methods and materials weren't always up to the challenge. As systems expanded, NEWWA was to be of enormous help, providing a forum where water suppliers could rub elbows with engineers and equipment manufacturers to learn what the latest developments had to offer.

Distribution System Standards







Examples of test apparatus from early fire flow testing

Design of early distribution systems was driven by two things, first connecting the paying customers and then providing fire protection requirements where necessary, which in turn were driven by the nature and height of buildings. In the early 1800's, most communities had fairly low wood frame housing with unpaved streets and the risk of a conflagration was great. A wooden pipe "fireplug" could at least fill a bucket to be thrown or hand pumped onto a fire. The ability to pump directly from a hydrant on a water main didn't happen until the mid 1800's when fire-fighting technology had evolved to steam powered pumps. The idea of high flow volume being applied directly to fires from a pressurized hydrant was only made possible by the mid 1800's availability of metal pipe and better joint design for high pressure use. If properly designed, such pipes would be capable of pressures needed to direct a nozzle stream up at least six or so stories to protect increasing building heights in urban areas.

The height of buildings also forced improvements with time. In the mid 1800's, cities had mostly timber framed brick faced structures and were usually limited to 4-5 stories because of the timber construction. Early systems had problems delivering water from the street mains to an upper story fire simply because the hydrants and hose nozzles were still non-standard and not well designed to direct a flow in a consistent arc to a great height. By the 1880's, most distribution systems became capable of delivering at least 50-100 PSI pressure to the hydrant. During the early days of NEWWA, much study went into optimum nozzle design to direct an effective fire stream, as well as hydrant spacing to deliver enough fire streams to a large blaze. Minimum pipe sizing was also adopted after considering the results of such major conflagrations as the Great Boston Fire of 1872. Water engineers also began to use distribution storage to supplement flow from sources during peak fire flows.

Odd fire protection strategies
In ancient Rome, fire companies were often entrepreneurs that would race to the scene of a fire to negotiate with the owners for a price to either save or purchase the ruins of their structure.

One such story was noted in a late 1800's NEWWA journal which referred to a Canadian community served by a private water company that would not allow the local fire department to use its hydrants unless a hefty fee was paid.

The early 1900's changed urban area fire protection planning again when steel construction allowed taller buildings, culminating in a period of skyscraper construction that was well beyond the ability of normal water supply pressures to protect. This led to tall building designs that incorporated internal pumping and storage and also led to special high pressure fire districts, examples being the Boston and Providence systems which had dedicated fire service mains and fire pumping stations in their downtown areas.

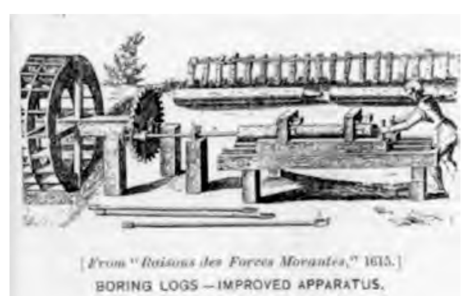
Another major factor in distribution system design was suburbanization as the affordable automobile and better roads resulted in very rapid suburban growth and construction of housing in more remote and higher elevation areas. Extension of the distribution system to serve such area became a greater issue in the second half of the 1900's. The need for new pressure zones, booster pumping, and additional tanks grew steadily with sprawl.

Age and condition of the distribution system infrastructure has also always been an issue beginning in the days of the first wooden pipes. What other expensive asset do you go out and bury in the ground and expect to last over a hundred years? Water engineers have struggled with the inability to find the perfect material for the job even to this day. How best to balance cost, durability, corrosion resistance, installation ease, workability and, most importantly, water quality protection, have occupied the industry since NEWWA began. Every material has its drawbacks and every structure has maintenance needs of some sort.

The following sections examine the evolution of common distribution system components.

History of Pipes

Wood was the available material in New England for any use including pipe manufacturing. Pitch pine was preferred for its resistance to splitting and rot. Joints were usually made by tapering and driving together fitted sections using some pitch for waterproofing. Occasionally, sheets of lead were used as a gasketing between sections or a rolled iron plate tube was inserted to make the joint. Tapping for services and "fireplugs" was done by hand drilling and driving a lead service line or a smaller wood pipe into the hole.



Wood pipe production

Custom fittings could be creatively made by carving larger wood pieces to shape as was done in the piece of the original 1652 Boston "Conduit" that is on display in NEWWA's offices. Other creative solutions include the use of a fork in the tree to make a "Y" or a crooked tree as a bend. Wrought iron bands could be used for reinforcing where needed.

As you can imagine, leaks were common given the poor jointing and splitting of the wood under pressure. Further, even the best wood would have a very short life due to rot, tree root damage and insects.


Wood pipes from 1796 Jamaica Pond Aqueduct

Later wood pipes were manufactured similar to barrels in that staves would be beveled to shape and joined with metal reinforcing bands to allow larger pipe sizes and improved working pressures. This allowed low cost, locally produced pipe that continued to be used in rural systems well into the 1900's.


1916 14" wood stave pipe and valve, Pembroke NH

The next logical advance was metal pipe. Of the available metals of the time, lead was too soft to form a pipe larger than a few inches so it was typically limited to use for service lines. Plate iron was available in the early 1800's and could be heated and rolled into a pipe shape, riveted and joined by using sleeves packed with cement. This was the early wrought iron pipe, sometimes called cement lined pipe or "kalomein" pipe. The metal thickness was not standardized and would be relatively thin for workability. It also had the brittleness of cast iron so it was subject to fracturing under force rather than yielding like later steel pipes. Natural waters in most areas were fairly corrosive and this meant rapid buildup of corrosion deposits unless lined with cement. After some experience in the field, an external cement layer was added for longevity against soil contact corrosion. With the thin metal layer, it was tappable but barely. It was commercially available but some communities developed pipe manufacturing shops and made their own. Even after cast iron pipe was available, the cost of early cast iron pipe production forced such a high price that wrought iron was more often than not chosen by smaller systems as a cost effective substitute. In 1882, when NEWWA was formed, about half the pipe in place was wrought iron. By the late 1800's improved cast iron production methods made the cost more competitive and cast iron became the material of choice for most systems from that point forward.

Catastrophic breaks on wrought iron pipe were common due to the brittleness of the iron. Most of those in the field of water supply were emphatic in their dislike for the material. Towards the end of the first meeting held in 1882 to form NEWWA, the discussion went from organizational matters to technical matters, at which point Mr. Charles K. Walker of Manchester NH let loose a rant on the unsuitableness of that "@&$#*^ cement lined pipe". This was one of the first recorded technical issues among the men, having just met and sizing up their peers for the first time, and the topic broke the ice for spirited future discussions. An interesting counterargument was offered in an 1890 paper which defended wrought iron pipe to the assembled water works men, based on the author's experience. As was the practice at the time, a discussion followed the reading of the paper, apparently going badly for the author. The word "laughter" is recorded in the minutes no less than seven times in the post-discussion and the general consensus was that the author was definitely in the minority.


Example of wrought iron pipe, New Haven CT Water Interpretive Center

The workhorse pipe for the next century was next, that being cast iron. Nationally, Philadelphia installed the first cast iron pipe in 1817. In New England, the first cast iron pipe is believed to be a 1833 North Conway NH cast iron pipe serving its Artist's Brook supply. Peabody MA utilized cast iron pipe as early as 1834 as well. Many more New England communities started using cast iron as their standard from this period forward. NEWWA was a player in this effort in that one of the organization's earliest tasks was to develop standard specifications. The committee for this effort included Dexter Brackett of Boston MA, Freeman C. Coffin (later to start Coffin & Richardson, Inc) and F. F. Forbes of Brookline MA, the most respected distribution system engineers of their age. NEWWA adopted a Cast Iron Pipe Standard in 1902, then AWWA followed suit six years later in 1908 largely based on the NEWWA work.

The early casting of pipes was done by standing a mold on its bell end and casting the pipe vertically. This resulted in considerable non-uniformity of both the thickness (the thickness tended to increase from the weight of the molten iron towards the bell end) and in the variability of wall thicknesses around the circumference if the center mold was a bit off-line. The amount of material used was generous to create conservatively thick walls, helping with longevity of this age of pipe. The fact that pipe was sold by weight probably helped with this conservatism. Before the first American cast iron foundry was started in New Jersey in 1834, cast iron pipe was imported from European foundries. Although some very early versions of cast iron pipe used flanges and lead sheet gasketing for jointing, the mid-1800's version that was adopted by most water supplies was bell and spigot pipe with poured lead joints, a reasonably certain method of leak control for its time. The pipe was very tappable and workable and its only real drawback was the poor internal corrosion protections of the time. Various concoctions of pitch, coal tar, lead paint and other field applied coatings were tried with limited success. Cement lining was developed in the 1920's to resolve this, with the first cement lined cast iron pipe in New England being installed in Dedham MA in 1924. The lengthy roster of Cast Iron Pipe Reasearch Association's (now DIPRA after ductile iron replaced cast) Century Club demonstrates that those choosing cast iron pipe in the 1800's were rewarded with a quite reasonable life span, unlike some other materials.

Pit casting continued until 1922, after which, later generations of cast iron were made by centrifugally casting the pipe, thus resolving the uniformity of pipe wall issues. This continued to be the most common material until it was replaced with ductile iron in 1948.

Pipe Oddities - *Don't like your pipe the way it came? Change it.*

A 1913 NEWWA paper described bending of cast iron in lieu of fittings for gradual curves. The technique required heating the pipe on a bed of coals and applying force.

1942 unrolling pipe in Springfield MA – With the steel shortages experienced during WWII, 30" & 26" steel pipe was recycled by unrolling it and welding 2 halves together into a homemade 58" pipe.

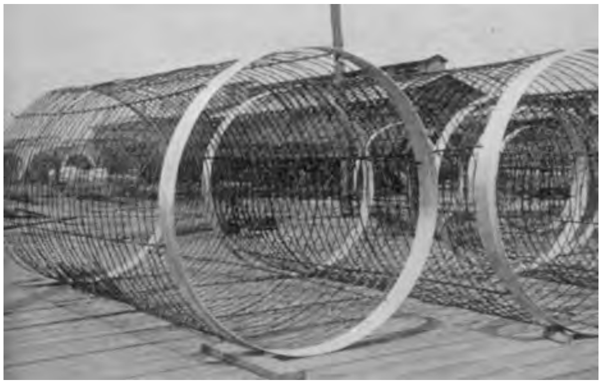
One drawback of cast iron was that larger pipe sizes were difficult to cast and handle. Steel pipe offered a solution when it became commonly available around the early 1900's. The initial steel pipes were formed similar to wrought iron in that the steel plate was rolled, overlapped, drilled and riveted. Joints were also overlapped and riveted in the early days since field welding methods weren't available. Corrosion protection was no more effective than on cast iron, consisting mainly of coal tar coatings.

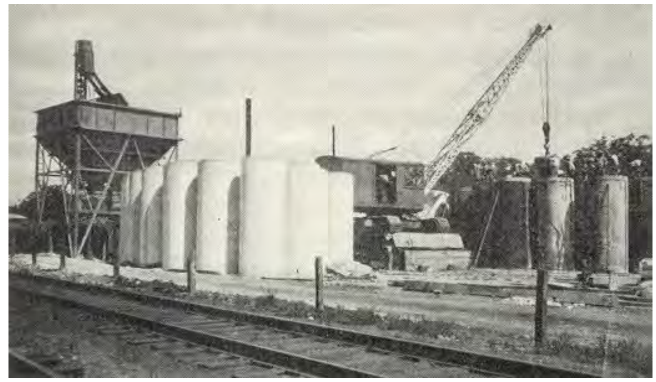
1924 caulking lockbar pipe

1927 welding steel pipe

One variant on the steel pipe manufacturing was the 1905 Lockbar pipe that had a unique method of joining the rolled plates using an interlocking tongue and groove mechanism. A further improvement was available in the 1930's when spiral welded pipe was made available. Welding science had at this point made field welding the preferred method of joining pipes. Steel is still commonly used for very large pipe and special transitions.

Reinforced concrete pipe was developed as early as 1842 for use in sewers, performing well in corrosive conditions. It was in 1905 that reinforced concrete was first available for water supply use. It was cast using an internal steel cylinder for watertightness and an external reinforcing


1924 reinforcing cage


1935 Vertical casting in pipe yard


1935 Cage set over cylinder


1946 laying Hultman Aq 138" RCP

cage for structural strength. This method did not have structural uniformity and was not commonly used. In the 1930's, the first prestressed wire wound pipes were developed which greatly increased strength in all directions. The use of steel cylinder prestressed concrete pipe became popular during the 1940's as steel shortages made metal pipes much more scarce. The only blemish on record for this type of pipe was a period of manufacture dating to the 1970's and 1980's during which prestressing wire experimentation led to occasional wire embrittlement and the possible catastrophic loss of pipe wall strength if wires failed. This was since corrected and PCCP continues to be popular for larger transmission mains.


1937 Asbestos cement transite pipe laying, Note ease of handling.

Since smaller rural and suburban systems needed to lay a considerable amount of pipe mileage at low cost, the apparent benefits of asbestos cement (AC) pipe came as a blessing. Although it was only available in smaller diameters, it could be layed simply by hand placement using relatively unskilled crews. It was inexpensive, light, had no internal corrosion issues and featured a fairly simple push-on joint (the first common use of rubber gaskets in pipe joints). It first appeared in the 1930's during the heyday of WPA programs that were intended to put unskilled labor to work. The federal government funded entire distribution systems to be built for needy communities using AC pipe and local labor. It was also a favorite during the metal shortages of World War II.

Asbestos wasn't understood to be a health hazard back in the 1930's so the material was in fairly common household use. The release of fibers to the water was prevented first by a bitumastic coating, then later by an internal vinyl coating which was applied suing a mixture of vinyl with a tetrachloroethylene solvent. Proper installation of this coating was crucial, partly to allow the vinyl to cure to the point that volatile solvent release was stabilized. Pipes installed too rapidly began to have continuing solvent release aesthetic issues. By the 1970's, when organics detection technology made it possible, the release of the tetrachloroethylene was discovered where the internal coating was found to be breaking down in some areas. Further, the asbestos cement pipe itself has been reputed to lose its strength over time under some corrosive soil conditions, making leak repairs a challenge. With these limitations, AC pipe no longer enjoys the popularity it did in the mid-1900's.

Ductile iron came along in 1948 and essentially became the industry standard by 1955, remaining so to this day. It too has changed in the interest of efficiency, with the pipe wall thickness being reduced over the years to the point that it barely resembles its cast iron ancestor.

In looking at all the pipe material choices made by our predecessors to this day, the thing that is clear is that, for the most part, our forefathers did pretty well, with most distribution piping providing a century or more of service. However, not all choices were effective in the long haul, often for reasons unimagined by the designers. New materials become available from time to time, for example, many plastic pipes have been approved for water use by NSF. In addition to plastic service pipes, high density polyethylene has recently become an alternative for some applications, such as sliplining. Other new techniques like pipe bursting have also helped improve the range of options for urban rehabilitation projects. Hopefully, our choices today continue to fare as well as some of our forward thinking predecessors.

Special Pipe Issues – Special Solutions

1904 Mobile boiler for pipe thawing, Manchester NH

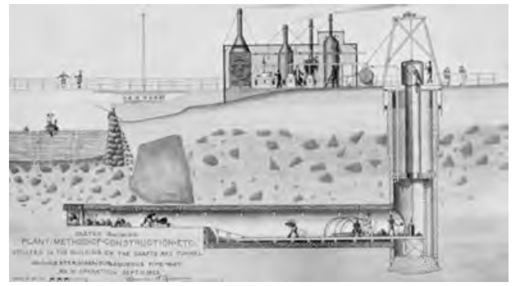
1920 pipe thawing truck using a portable generator for electric current, Dedham MA

While discussing pipes, certain New England solutions to problems are worth noting. The relatively cold climate is one such problem. As pipe systems grew, freezing of pipes forced some creative solutions. Experience taught that depth of cover in southern New England needed to be at least 3-4 feet and, in northern New England, it needed to be about 5-6 feet. However, when the cold snaps were longer than normal, service pipes or smaller mains occasionally froze. The unfreezing of pipes produced some interesting devices.

The advent of electricity produced electrical pipe thawing using contraptions such as the one shown in the adjacent figure.

In the category of firsts, Boston has the first documented subaqueous river crossing in 1848 using a cast iron pipe. The crossing was one of several built to connect Boston proper to Charlestown, Chelsea, East Boston and South Boston. The pipe trench was dredged and the pipe placed by divers. Other communities faced with river crossings occasionally chose the above water approach. Some tried self supporting arches but not always successfully, as was the case in Nashua N.H. when a local man's design for the initial self-supporting crossing wound up on the bottom of the river (see below right for a successful example, an 84" pipe arch was built by Boston's MDC in its 1903 Weston Aqueduct crossing of the Sudbury River). A truss support bridge was also a common solution or the pipe was often added to the roadway bridge superstructure.


1895 Burlington VT diver, placing the intake pipe further in the lake.


1908 Gloucester MA subaqueous pipe tunnel


1923 Portland ME Harbor crossing


1908 Gloucester MA pipe tunnel – men working in pressurized tunnel

Subaqueous pipelines were also needed for coastal situations to serve islands or portions of the community on the far side of the bay, such as Portland's connections to South Portland and its harbor islands. Many other coastal communities had to develop such mains.

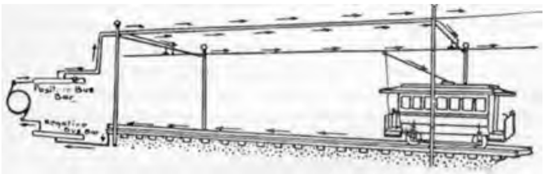
Trolleys came on the scene in the late 1800's bringing a new threat to metal pipes: electrolysis. The direct currents used to power the trolleys became pipe killers, causing extensive pipe pitting to the point of causing holes in inch thick cast iron in a matter of months. This led to new pipe design standards for insulation joints.

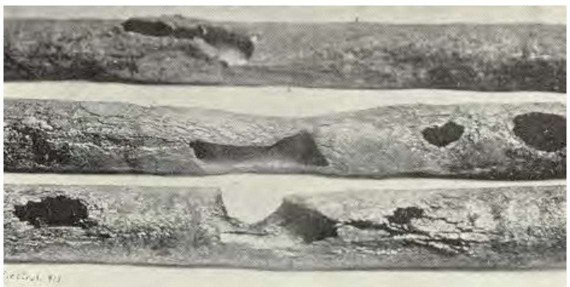
In a fairly recent development, pipe bursting and slip lining have become more popular as rehabilitation techniques for old pipes.


1903 Weston Aqueduct 84" steel self-supporting pipe bridge

Service Pipes

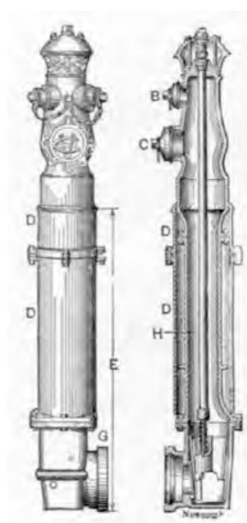
Small pipes sometimes create big problems. As with street mains, experience has taught some hard lessons in the history in making the last connection to the user's tap.



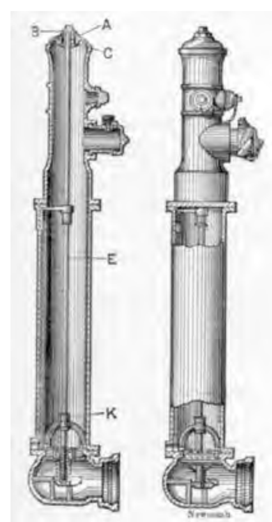


From the beginning of trolleys in the late 1800's, the DC currents associated with the trolley motors would jump off onto pipe surfaces and cause erosion of pipe material. Pipes less than 10 years old needed to be replaced in key locations.

Wood obviously was never going to work as a service line material leaving lead as the most practical early solution. Even the Romans had relied on lead for services some 1,800 years before. The health issues with lead were reasonably well understood but, in the absence of hard science to the contrary, there was a long held belief by many water supply and even public health officials that the internal corrosion layer blocked dissolution of the pipe metal effectively enough to not be a problem. This lasted well into the 1900's and may have been partly a rationalization to defend the use of lead since it was clearly the best material in terms of workability and durability. Even as it was being accepted as a standard by many, empirical evidence of the effects of lead exposure caused many water suppliers to try aggressively to find workable alternatives to lead for services.

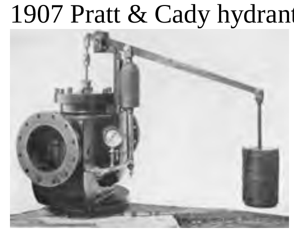


1907 Chapman hydrant



1907 Pratt & Cady hydrant

1936 Dresser coupling



1906 Counterweighted pressure regulating valve

In the late 1800's, wrought iron was tried with the result that internal corrosion in the small diameter service pipes choked off the pipe within a matter of a few years of use. Alternatives were sought, such as dipping in coal tar, coating with zinc or other less reactive metals, and so on. But, even with all these efforts, the best case was extending the useful life of the pipe by a matter of years. Hartford claims the first use of galvanized iron for its services in 1855. Wrought iron also presented a workability issue for use as a house connection so many plumbers used a lead transition piece at the house wall to take up any stress from differential settlement. The use of brass pipe was tried with more or less the same conclusion; the joints were weakened by corrosion and breaks were common. The poor service life of other materials meant a commitment to frequent replacement or a return to the use of lead, with many water systems choosing the latter.

Lead was still heavily used up until it was banned in 1986. By this time, copper pipe had become the preferred solution. Thin wall copper tubing became available in the 1930's and worked well for connecting the service into the house. Within the house, copper tubing soldered with lead was still used up until lead solder was also banned in 1986. As lead testing results so often show, poorly soldered copper pipe can produce problematic lead levels in standing water as well. Nowadays, brass faucets are still a source of lead dissolution to the tap. The use of lead-free solders and plastic service pipes have ameliorated the risk of lead in the water but lead control is far from solved (more on this in the treatment chapter).

History of Pumps and Motors

New England started with only wind and water for its natural energy sources. If pumping was needed, these were the early options but, of course, gravity supply was always the preferred power source for the early water system.

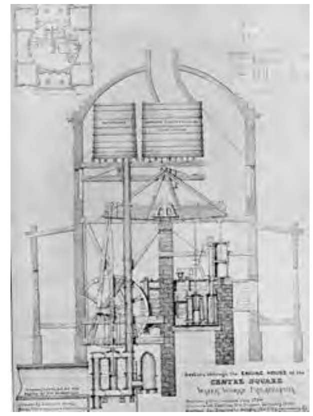
The first pumped municipal water supply in the colonies was in 1755 and was built by a Moravian sect in Bethlehem PA. It featured waterwheel powered pumps to lift water to a 70' tower for distribution to users. The 5" pumps were made of lignum vitae wood and were positive displacement type similar to early hand fire pumps.

Steam engines for water pumping became possible in the early 1700's. Thomas Savery is generally credited with developing the first steam engine in 1698 for mine dewatering. This was followed by Thomas Newcomen's engine in 1712 and James Watt's rotary crank engine in 1769, each step being a huge improvement in practical application or fuel efficiency. Given the wide variety of ways to make steam and use it for force, patenting did not limit the further development of steam engines. The complexity and precision machining necessary to make a successful engine kept the idea from being widely available until well into the 1800's.

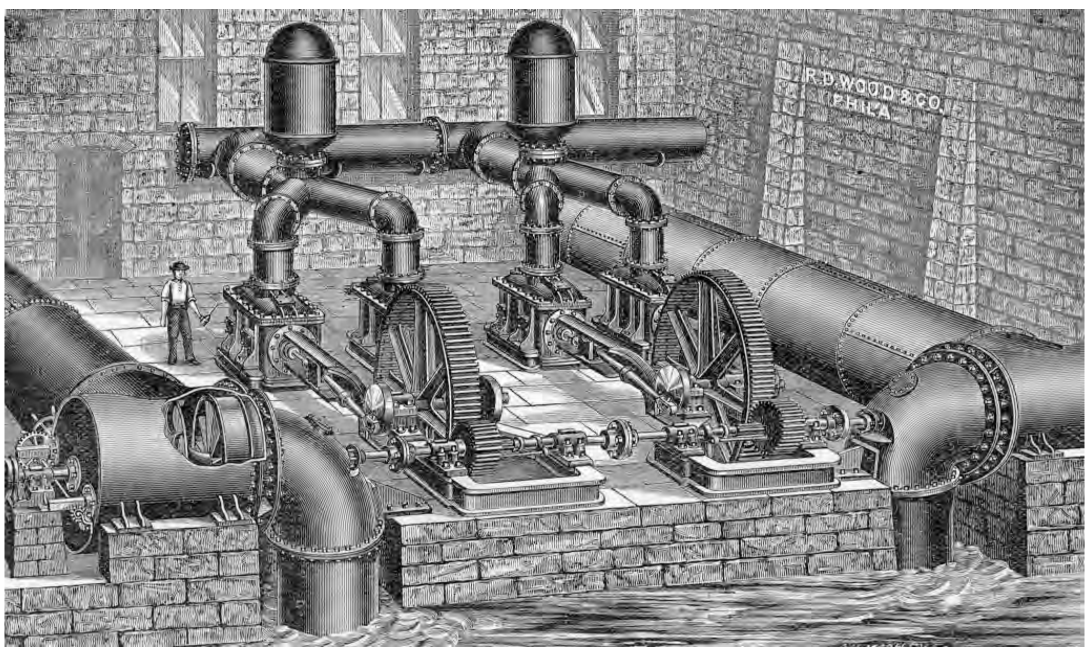
New York actually had the first attempt at steam pumping by an entrepeneur/civil engineer, Cristopher Colles, who was contracted in 1744 to build a steam engine to pump from a well to an above ground tank. After some aborted attempts, the engine was built and appeared to function during trials, at least long enough for the designer to claim his payment. However, the Revolutionary War broke out at that point and the actual use of the engine for water supply never happened.

The first successful use of steam pumping for a municipal system was in Philadelphia in 1815 when Benjamin Latrobe (the noted civil engineer, not the brewer) designed steam pumps to deliver Schuylkill River water to a tank for distribution to a wood and cast iron pipe system. This pump was moderately successful and established a national reputation for the Philadelphia water supply as the finest of its era.

Philadelphia's 1815 Centre Square pump station, the first municipal water supply steam pump in the US



Interestingly, the expense and mechanical problems of the pump (not to mention a fatal boiler explosion) eventually discouraged the city and in 1822, they rebuilt the Schuylkill supply source to be powered by hydraulic pumps.



1885 Hydraulic pumps at Willimantic CT

This same hydraulic pumping approach was successfully used by a number of New England communities such as Nashua NH in 1854, New Haven CT in 1860, Bangor ME in 1875, and Manchester NH in 1872. This required the supply to be on a river of sufficient flow to power the turbines that would then drive the positive displacement pistons to move a portion of the water to a higher elevation.

Most used rotating flywheels to power a piston driven positive displacement pump. Some systems used pump chambers and special valving that would allow water to be pumped on both strokes of the piston. A large surge arresting pressure vessel usually accompanied this pumping to smooth the transition between strokes.

An interesting variant on hydraulic pumping was the use of hydraulic ram pumps. In our time, hydraulic transients are avoided at all costs but these early pumps actually used the water hammer to lift the water. As shown in the accompanying figure, the fast acting valve would be closed to force a pressure build-up in the surge chamber which would then force some water up and out the smaller discharge pipe. This could pump as much as 1 gallon in ten that passed through the hydraulic ram but only to a modest height. These pumps have been around since the early 1800's and were used by some communities adjacent to rivers. They have been more suited to smaller applications like farming given the need for so much flow release, making them impractical for most municipal applications.

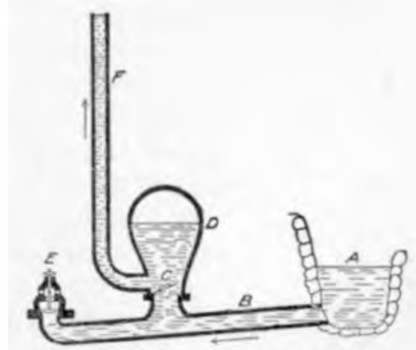


Fig. 64. Illustrating Principles of the Hydraulic Ram.

Hydraulic Ram pump – Valve E is rapidly closed to force water up pipe F

The ability to pump water without fuel was a wonderful thing but the limiting thing for these older supplies was the need for enough water to power the turbine or wheel. Droughts were problematic and growing demands often dictated that the turbine water was needed for supply purposes as well. Old hydraulic pumping stations are notable for their proximity to a dam or channel, their internal hydraulic machinery, and the absence of chimneys.

By the mid 1800's, practical windmill pumps had been developed for smaller applications like farming. Some New England communities, examples being Sanford ME, Winchester MA and Hyde Park VT, actually applied windmills for pumping to a remote high area. These were unusual and probably fairly unreliable, leading eventually to abandonment in favor of mechanical systems. Wind powered pumps did go on to be hugely successful in other parts of the country, especially for farming applications in the mid-west and plains states, where groundwater was the only water supply option. Daniel Halladay, a Connecticut man, is credited with the 1854 development of the most successful windmill design.

Unusual Pumping Energy Sources – A One Horse Power Pump?

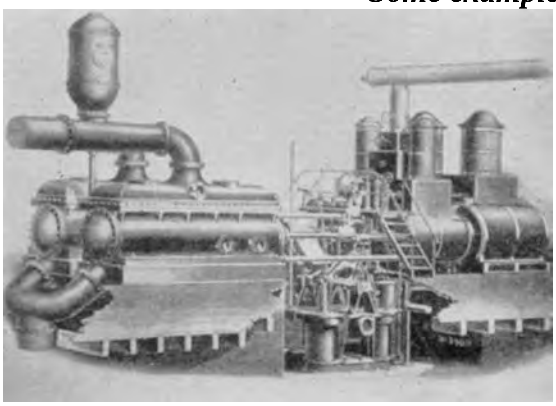
After its start in 1852, the **Pennichuck Water Co**. which serves Nashua, NH used hydraulic pumping to move its water. This worked well until a combination of water use growth and drought meant that a supplemental solution was necessary. The answer? A horse was harnessed to the wheel to power the hydraulic pumps in slack flow times.

A touch of Yankee ingenuity was added later in the form of a motivational paddle (known as "French's Spanker" after its inventor). It would automatically slap the horse's rear every few revolutions to "urge old Dobbin to greater effort".

Human powered pumps for firefighting were available well before settlement of New England. These were simple positive displacement type pumps that could at least get a small stream of water up onto a roof. They would be fed from a bucket filled from wherever water was available, often a cistern or rain barrel. Later human powered fire pumpers featured a larger volume stream and better pressure by making the unit bigger, putting wheels on it and adding a rocking arm so both sides could be manned by several firemen. Boston purchased such a "fire engine" in 1654. When steam engines became available, they took the place of the human power. As soon as municipal water systems developed better pressure, all of these became obsolete and the pipe pressure could power a nozzle that could reach most buildings. The use of fire pumping engines to boost the hydrant pressure emerged again as gasoline and diesel engines allowed smaller, more powerful engines.

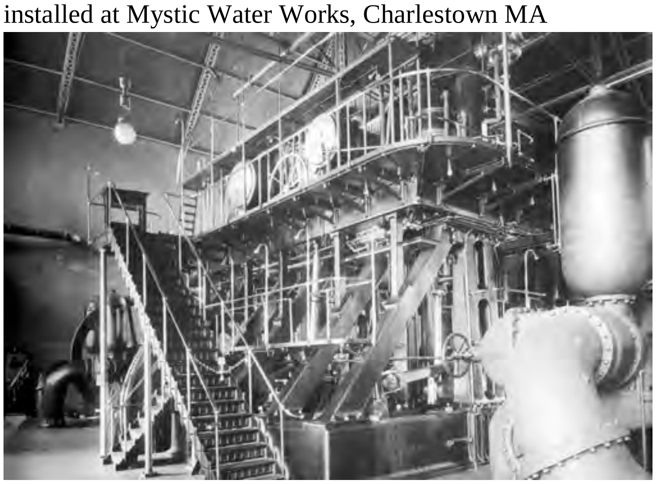
Steam pumps reached their peak in the latter half of the 1800's as a number of designers produced very effective but unique solutions. The principles were roughly the same but some designers began to use multiple expansion chambers and different mechanisms for transferring energy to the flywheel to move the displacement pistons. The engines were often named for their designers and occasionally had names in the same way as car models.

Some examples of early pumps and motors

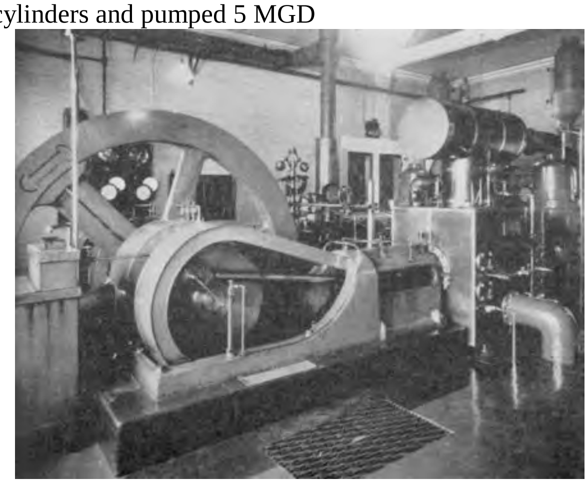


1864 First Worthington Duplex pump in the country installed at Mystic Water Works, Charlestown MA

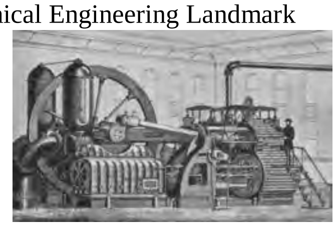
Corliss Spider – Installed in 1873 at Hope Pump Station, Providence RI, it had 5 steam cylinders, 5 pump cylinders and pumped 5 MGD



1894 Leavitt Engine at Boston MA's Chestnut Hill High Service Pump Station– Triple expansion engine, ASME designated it as a Mechanical Engineering Landmark



Later generation of active steam pumps – 1939 engine at Falmouth MA



Holly Quadraplex and Holly Compound – two of many steam models offered in the late 1800's

1920 Early electric pump motor, Putnam CT

1902 Early gasoline engine, Nantucket MA

The first municipal steam water pump in New England was built in Hartford CT in 1851. It took water from the Connecticut River and delivered it to an 8 MG reservoir on Asylum Hill. Designed by Wm. Wright and built by Woodruff & Beach, the steam station operated until 1865 when it became an emergency backup as Hartford brought in a new gravity supply. Cambridge MA and Plymouth MA followed suit in 1855, both using Worthington steam pumps in their stations. The old Mystic Water Works pumping station in Somerville MA had the first Worthington Duplex steam pump in the country installed in 1864. Providence RI began steam pumping in 1870 and became the largest pumped supply in New England by the 1882 start of NEWWA.

At the formation of NEWWA in 1882, the New England leaders of steam pump design were men like Erasmus Leavitt of Massachusetts, George Corliss of Rhode Island and Henry Worthington of New York. Corliss' finest achievement was felt to be the Corliss Spider, installed at Providence's Hope Pumping Station. He had many models and had equipment installed through much of southern New England. Henry Worthington, a designer and fabricator, had probably the most steam engines installed throughout the country in 1882, with 62 of the 182 known steam pumps in New England using Worthington equipment. Erasmus Leavitt was more of a designer, leaving the building of his pumps to contractors. He was known more for larger installations and he designed engines for Boston's Chestnut Hill Pumping Station and several other communities like Cambridge, New Bedford and Lynn MA. The Leavitt Engine at Chestnut Hill Pump Station was designated as an American Mechanical Engineering Landmark. It stands an impressive 2 stories above the operating floor and the flywheels and pistons occupy about the same space in the lower pipe gallery. It took a gang of operators to control the engine while crews of shovelers fed the boiler its ration of the 660 pounds of coal needed per hour to move the 20 mgd. A railroad siding was needed in the back to deliver coal by the train car load.

By 1882, of the 258 works in New England, 130 were supplied by gravity, 50 pumped to an open reservoir, 21 pumped to a tank, 31 used standpipes and 21 pumped directly to service with no storage. This last category required the operators to monitor discharge pressure and constantly throttle the engine.

Steam pumping stations began to pop up in many communities after the 1880's, recognizable by their chimneys and coal rooms. NEWWA began to keep statistics on "duty", the forerunner of modern "wire to water" efficiency, in which the amount of coal needed to do standard units of work was calculated and engines could be compared, often to the great pride of some designers.

The steam age peaked in the late 1800's with most observers noting that the triple expansion engines were the pinnacle of steam powered pumping technology.

Some examples of early pump station architecture

Hope Pump Station, Providence RI

Quitticas Pump Station, New Bedford MA, AWWA Historical Landmark

Branch Street Pump Station, Pawtucket RI, AWWA Historical Landmark

Snow Pump Station, Nashua NH, AWWA Historical Landmark

Manchester NH Low Service Pump Station, AWWA Historical Landmark

Great Sandy Pond Pump Station, Pembroke MA, AWWA Historical Landmark

Stoughton Pump Station, MA

Burlington Pump Station, VT, AWWA Historical Landmark

Chestnut Hill High Service Pump Station, Boston MA

Pawtucket Pump Station, Pawtucket RI

North Easton Pump Station, MA, AWWA Historical Landmark

Oak Bluffs Pump Station, Martha's Vinyard MA

The need for a less complicated and labor intensive method brought the next advance, namely petroleum fuel engines. Up to this point, coal powered virtually everything in New England. In the 1890's, Rudolph Diesel invented his engine, which caught on in water pumping in the early 1900's. In the late 1800's, several inventors developed gasoline engines which were initially of more interest to car developers but which were used in some water works applications. In support of this, the oil industry was just becoming a viable alternative to coal and the refinement of oil to produce the necessary grades of diesel and gasoline made it a commercially available commodity.

This advance in liquid fueled motors allowed the next step to be taken by pump manufacturers. Up until this time, the use of centrifugal pumps was known but low RPM steam pumps required extensive gearing to get the RPMs up to the levels necessary to power a centrifugal pump. Diesel and gasoline motors had the torque to spin a smaller pump shaft and had no problems developing the required RPMs. Many steam pumps were converted to the new power source by simply connecting the old positive displacement setup to the new engine via drive belts. However, in new facilities, centrifugal pumps began to dominate. The other advantage of fuel engines was that they could be throttled similar to the old steam engines so a variable output was possible but with much less labor than a coal fired steam pump.

One footnote to the early 1900’s attempts to find better pumping power sources was the use of gas producer plants for pump stations. Up to this point, coal gas had been produced starting in the early 1800’s at municipal plants and used for municipal gas lighting systems and industrial uses. Some water supplies tried this technology so that they could still use coal for fuel while powering more modern pumps. In 1908 and 1911 respectively, Hingham and Manchester MA installed gas producer plants and used the coal gas to power a motor that spun its centrifugal pumps. Apparently, such stations were plagued with a smell of gas in the plant and also in the surrounding neighborhood while running. Gas producers and gasoline motors eventually faded out of water supply use because diesel engines were more reliable and economical.

The last truly big step in pumping was the development of the electric motor. While the original idea is credited to Michael Faraday in the 1830’s, the development of a practical water pumping motor took until the early 1900’s. Obviously, the power developed in such a small footprint was an extraordinary advance. Cleanliness, convenience, controllability and reliability were additional benefits. This did not mean an immediate conversion for all water pumping since the extension of municipal electric power took some time, but, in each successive pump station rehabilitation, electrical pumping was usually the mainstay. Diesel power still had a major role in providing backup for electrical power failure so it continued to be heavily used if this was a main concern. Other types of pumps, e.g. turbines, were developed to handle particular situations but the core concept was still a water power from a spinning shaft of some sort.

Of course, the inconvenience of early electric motors was the single speed nature. This led to interesting decisions in sizing pump stations and much more focus on water storage tanks as a companion to the pumping station. Eventually, around the 1960’s, the variable speed motor became commonly available and helped ease some situations that require tight water level control, but the pumping workhorse is still the electric powered pump.

History of Distribution Water Storage

The first distribution water storage was, of course, part of the first water works, that being the 1652 Boston “Conduit”. The wooden pipes led to a below grade 12’ by 12’ chamber from which water buckets could be filled. This mimicked the Roman practice of having terminal reservoirs for their aqueducts. In Boston's later 1796 Jamaica Pond system, there was also a terminal chamber built on Fort Hill to allow for off peak flows to accumulate for later.

The first true municipal systems required distribution storage as a result of uncertainty of flow from the source. When Hartford CT built the first steam pump station, they also built an open earth embankment reservoir on Asylum Hill that could provide water for a matter of days while the pumps were down for repairs. Boston MA built its Brookline Reservoir as part of its 1848 Lake Cochituate supply to allow for daily adjustment of aqueduct flows.

The form of these early reservoirs was usually rectangular, formed by earthen dike walls that used the "puddle" method of construction to get an impervious core. Some had earthen bottoms and had to be relined with concrete at a later date. Covering the reservoir didn't seem to be necessary in the beginning, so virtually all early distribution reservoirs were open. This led to a realization around the turn of the century that such structures were beset by algae growths even in carefully filtered supplies. Much of the early discussion of such structures in the NEWWA journal focuses on this, particularly the findings of Mr. F. Forbes of Brookline MA, who was probably the first to not only study the problem but also correct his system with a cover. So it wasn't birds, regulations or the possibility of intentional contamination that drove many communities to cover their reservoirs, it was algae. Of course, not everyone did so right away, in fact, many larger systems still had uncovered distribution storage well after the Safe Drinking Water Act was passed and states began to regulate open storage out of existence. Of course, this is easier said than done, with cities like New York and Portland OR still utilizing open distribution reservoirs to this day.

Entrance to Boston's Chestnut Hill Reservoir grounds, landscaping designed by F. Olmsted, notable as an example of the ornate style of many early water facilities

Covering the open reservoirs in the early days usually meant columns, a concrete deck and an earthen grassed surface dotted with vents and hatches. In the 1970's, fabric covers became available and became a viable alternative to structural covers. Either way, many systems continue to rely heavily on these larger volume storage reservoirs and have continued to upgrade them to meet today's more rigorous security requirements.

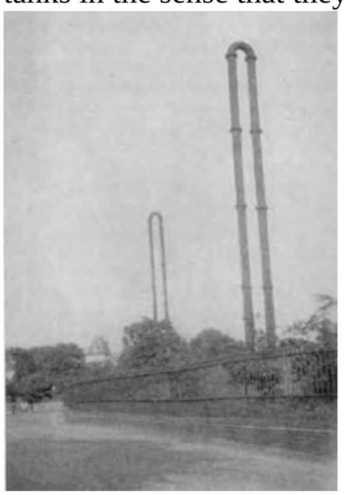

1896 Construction


1927 Relining bottom with gunite


Modern day covered reservoir

The life of an early distribution reservoir: Payson Park, Cambridge MA– Early puddled earth construction lead to concerns over leakage, the bottom is relined, then later columns and a deck are added to cover the water surface.

The original purpose of a standpipe was strictly as a pressure control device. Its English origins intended it to be a vertical pipe that allowed overflow during surges. In 1800's New England, the term standpipe originally referred to fairly narrow tanks that were built close to the pump stations allowing pressure relief as well as water level readings for pump control. These were tanks in the sense that they were above ground, held water, provided fire flows while the pumps were ramping up and generally allowed the pumping to react to demand changes. Notable local examples include Cambridge MA's iron standpipe (now demolished) associated with its 1855 Fresh Pond supply. Cambridge had built an open reservoir at a hilltop location, but also added this standpipe adjacent to the reservoir to supply high areas and act as a pressure relief. The structure had a 5' riveted boiler iron structure surrounded by a granite, brick and wood structure with an internal spiral staircase to a landing on top.


English Standpipe for pressure relief

In 1870, Boston built its Fort Hill tank, which also had a 5' riveted boiler iron tank structure but, in this case was enclosed in a brick structure decorated with an ornate superstructure. This tank served the vicinity of Beacon Hill and the Statehouse for about 15 years before being replaced by another reservoir. In 1872, Fall River also built a standpipe structure housing two 40" pipes in a granite block structure that has the appearance of a lighthouse. In each case, the standpipes served the original steam pump station well but were eventually replaced by other larger, higher storage tanks. Tank placement strategy went on to dictate locations more distant in the distribution system since it wasn't necessary to keep the standpipe close for control purposes. The term "standpipe" went on however to refer to any tank having a uniform diameter from the ground up.

Above ground tanks went on to include elevated tanks (the tank volume being up on legs) and those with non-uniform diameters.

In the world of storage tanks, the earliest material in the late 1800's was iron boiler plate. Plates were rolled to the proper curvature and riveted together on all sides. Roofs were optional for many older tanks. Of course, absence of a roof led to weakness against wind stress leading to an occasional failure. The other major concern of many utilities was freezing of these early tanks which, in a riveted tank, could be hard on the rivet heads as the ice layer rides up and down.

Many utilities chose to enclose their early metal tanks for this reason. An ornamental facade also helped with neighborhood complaints and a viewing platform at the top usually afforded a commanding view of the city for public occasions. Some prime examples of such enclosed tanks are found among the AWWA Historic Landmarks including the Bangor ME Standpipe, the Lawrence MA Tower and the Lawson Tower in Scituate MA. Both the Lawson Tower and the Lawrence Tower were even equipped with bells to allow an occasional concert.


1870 Fort Hill Standpipe, Roxbury MA


1902 Forbes Hill Standpipe, Quincy MA


1897 Thomas Hill Standpipe, Bangor ME, AWWA Hist.Landmark


1855 Cambridge MA standpipe, 1st in NE, demolished in late 1800's


1895 Lawrence Tower, MA, AWWA Historical Landmark


1884 Fall River MA Standpipe, contains two 42" riser pipes


1901 Lawson Tower, Scituate MA, AWWA Historical Landmark


1921 Park Circle Standpipe, Arlington MA


1905 East Providence RI Cast iron tank

After this early period of architecturally interesting structures, tanks became much more utilitarian. When steel became available in the early 1900's, it was riveted in place similar to the old iron plate. Once field welding was possible in the 1930's, the plates were welded to make the smoother looking tank structure that is ubiquitous around New England.

Elevated steel tanks evolved somewhat in shape over the years. Early iron plate tanks features a hemispherical bottom, plate sides and a conical top, occasionally with some ornamentation. As steel tanks came into vogue, the shape flattened a bit in a progression shown in the adjacent figure. Ellipsoids became fashionable in the 1960’s. The spheroid tank was developed in the 1930’s and became an interesting alternative to the multi-legged versions. Most recently, the pillar shape with either a steel or reinforced concrete base became popular.

The down side of any metal tank, of course, is the need to recoat the tank at regular intervals as protection against corrosion. The glass coated steel tank is an interesting variant that was developed in the past 15 years to avoid this recoating. The sections are shop coated and the rings are bolted to the desired height. This type of tank has become popular in parts of New England.


1881 Oldest steel standpipe, Dedham MA (now demolished)

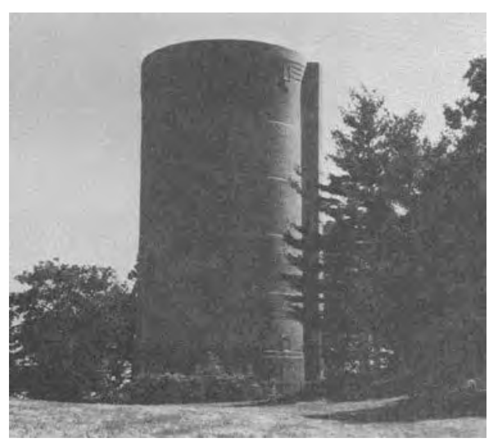

1938 Brookline MA – First spheroid tank in New England, it was chosen to protect against wind damage

The use of concrete for tanks began in 1903 when the first reinforced concrete tank was built for Hull MA. The structure, named for its location in Fort Revere, has been designated an AWWA Historic Landmark and was constructed using forms and reinforcing steel set in 8” lifts until the desired height was reached. It was also enclosed in a brick and concrete structure with a public landing that overlooks Boston Harbor. Other reinforced concrete tanks were built in the early 1900’s using similar techniques but the lifespan of these tanks was short. It was difficult to get these early tanks watertight since the water pressure on the structure pushed outward and caused


1963 Stamford CT standpipe featuring pillars


1961 Bellevue Tank, West Roxbury MA featuring ribs for the access ladders


1903 Fort Revere Water Tower, Hull MA, was the first reinforced concrete standpipe in the US, AWWA Historical Landmark


1936 First prestressed concrete tank in NE, New Britain CT, the tank was prestressed by the cable and turnbuckle method

cracks, then the resulting spalling of exterior tank walls kept exposing reinforcing and requiring repairs. In the 1930's, the first prestressed concrete tanks were developed. New Britain CT was the site of the earliest prestressed design tank in 1936. In this case, the prestressing was done using cables and turnbuckles that were added after casting the walls in place. The down side of this was that the stresses weren't uniform around the whole tank circumference. While this was better than the earlier designs, it was still lacking. The issue was resolved in the 1960's with the prestressing wire winding techniques that mimicked PCCP manufacturing. In this case, panels could be cast with a watertight layer, then effectively joined in position by using a wire tensioning system that wound continuously around the entire tank circumference. Tank roofs were occasionally domes cast of thin lightweight concrete or, in larger diameters, columns and a cast flat roof were used.

These modern prestressed reinforced concrete tanks have been the preferred solution to larger diameter tank construction since the latter part of the 1900's.

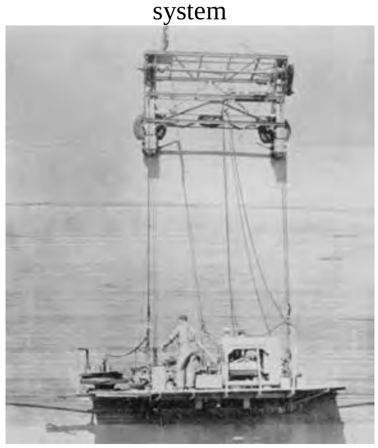
1906 Casting in place in lifts of several feet

1906 Attleboro Standpipe completed

1942 cable winding

1942 turnbuckle prestressing system

1959 Precast wall sections with integral waterproof core



1959 Continuous wire wrapping for uniform stress, gunite coating

Protecting water quality in the distribution system

One topic that started early and continues to this day was the control of cross connections. NEWWA spent considerable time examining the issue of cross connections even in the early days. It was not uncommon to have industrial facilities that had fire protection from non-potable sources or other hazards connected to their plumbing.

There have been numerous cross connection incidents over the years in New England, the most famous of which was in 1969 when 83 members of a local college football team were stricken by infectious hepatitis by drinking water contaminated by a back-siphonage incident involving the irrigation system of its newly fertilized playing field.

Nationally, there have been hundreds of significant cases that have caused illness and even death. Backsiphonage from irrigation systems is a recurring theme and the resulting risk has gone from the usual biological threats to exposure to herbicides and pesticides. Numerous incidents have been found to have exposed customers to such chemicals as Chlordane, DDT, Malathion, Sevin, Diazanon, Heptachlor, Paraquat, and 2,4-D, all associated with irrigation works in an area that was being treated with these substances.

Another fairly frequent offender is a cross-connection with cooling or HVAC systems. Conditioning chemicals like hexavalent chromium have been blamed in many incidents. One of the more ironic events of this type was in 1974 when a chromium compound from chiller water in the air conditioning system was accidentally released through a cross-connection in Boston's Hynes Auditorium which, at the time, was hosting the AWWA conference.

Other more oddball cross-connections recorded in national experience have managed to introduce gasoline, hydraulic oil, propane from tank purging, and caustic soda from an industry (causing customer burns). Odder still was a cross connection with a compressed air system in 1989 that caused 2 dozen toilets and urinals in a Seattle WA courthouse to "explode" when they were flushed. In a 1980 incident in Texas, the municipal water turned blue when a commode tank being flushed reversed flow during a main break.

Who says all backflows are bad?
In 1970, an Ohio wine producer had a backflow when an open valve resulted in a backflow of sparkling Burgundy wine into the city's water main. There was no evidence of consumer complaints.

In 2006, a Norwegian pub cross connected its beer tap to its water supply line, sending product to an upstairs apartment. The complaint in this case was that the beer was flat.

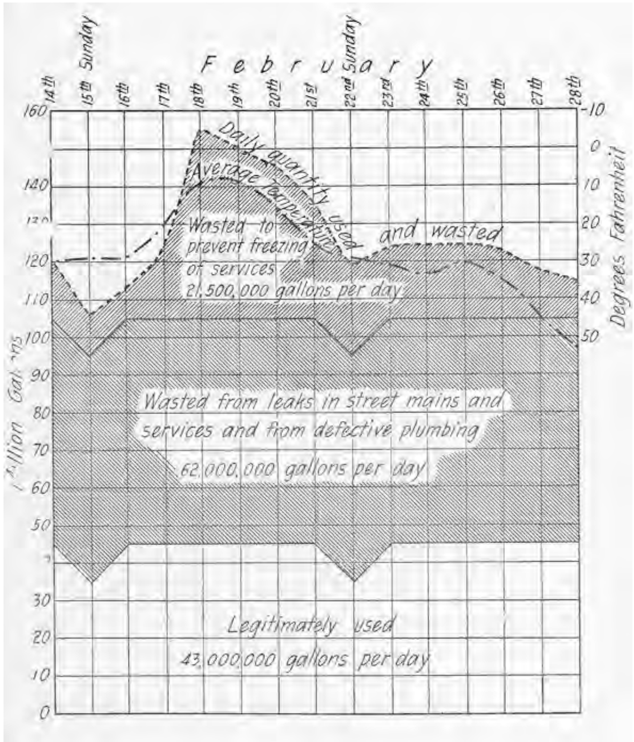
The lesson continues to be learned. NEWWA created a committee to adopt standards in 1928. The work of this committee helped with the development of backflow prevention programs within the industry.

The control of red water in the distribution system has also been a long term topic. Sediment accumulation from iron corrosion products, algae or other detritus has always plagued distribution systems, particularly during hydraulic events like breaks and fires. In recent years, more proactive programs like directional flushing have been popularized to help minimize this problem.

Distribution System Waste

One of the earliest and most frequent distribution system topics of the NEWWA Journal was waste. Dexter Brackett of Boston published the earliest and most definitive paper on the subject in 1886. He described the causes and response strategies for all to follow and, to be sure, they did. Today's most effective leak detection and unaccounted for water reduction strategies generally follow his principles. These included the application of metering to identify wasteful users, night flow determination, district measurement to identify high leakage areas, listening for leak sounds at night when it is quiet, and other strategies.

Prior to universal metering, early estimates of waste were up to 50% of that supplied from the source. This may be partly attributable to the experience with early wood pipe systems that were so unreliable that customers often left the tap on so they wouldn't miss the water while it was available between shutdowns. In the late 1800's, meters were available but were costly. At the 1882 start of NEWWA, there were already many meter manufacturers (the first associate member of the organization was a meter manufacturer). An 1886 survey showed a grand total of 37,913 meters serving 1.7 million people in 286 communities, not a high number. Barrington RI was noted as the only community to have 100% metering but then they only had 30 taps. Woonsocket RI had 88% of its taps metered and Worcester MA had 84% of its 8110 taps metered. Once metering was universally installed, there was an obvious and dramatic reduction in usage.



From Dexter Brackett's 1886 Paper on Water Waste; Note the relative amounts of leakage and intentional waste

Top - Late 1800's Deacon Waste meter
Bottom - 1906 Cole pitometer

In the absence of metering, there was no incentive to turn off the tap short of being threatened by water department staff. Water suppliers assigned staff to identify running services by listening at night for just this reason. District measurement was done by using temporary meters. The earliest of these was a Deacon meter, an English invention, which had to be mounted so that pipe flow was physically directed through it. Later in 1903, the Cole pitometer rod was developed to simplify this task by inserting the measuring device into the pipe through a tap. A photo recorder powered by an oil lamp was added in 1908 to provide a means of recording overnight flows. Tracking of unaccounted-for water has remained a significant control measure for determining when to trigger leak surveys.

Leak detection techniques have progressed since NEWWA started. In the early days, field staff would hold a screwdriver to their ear and touch a valve or hydrant to get sound. The use of geophones came in the early 1900's and allowed better detection due to the sensitivity of the resonance chambers. The stereo sensor arrangement allowed the leak detector to get a sense of direction as to which way the leak was located. Geophones gave way to electronic sensors in the 1970s and to leak correlators in the 1980s. Now some water systems are deploying permanent leak sensors with a data collection system that automatically reports developing leakage.

Infrastructure issues at the current time

The looming crisis for many New England water suppliers is the advancing age of facilities.

1912 pipe relocation for Boston subway, the original "Big Dig" for Boston

Since most community systems have now been in existence for well over a hundred years, the original assets like pipes, tanks and dams are now aged beyond reasonable life expectancy and are often in need of renewal or rehabilitation. Many systems have already developed capital expenditure strategies as certain types of pipe required early replacement or hydraulic capacity needed to be restored in pipes choked by internal corrosion. Systemic problems like tuberculation of cast iron pipes or aging equipment have created a significant capital need for the industry as a whole. Many systems with limited resources will have a very difficult time catching up with deferred capital system renewal.

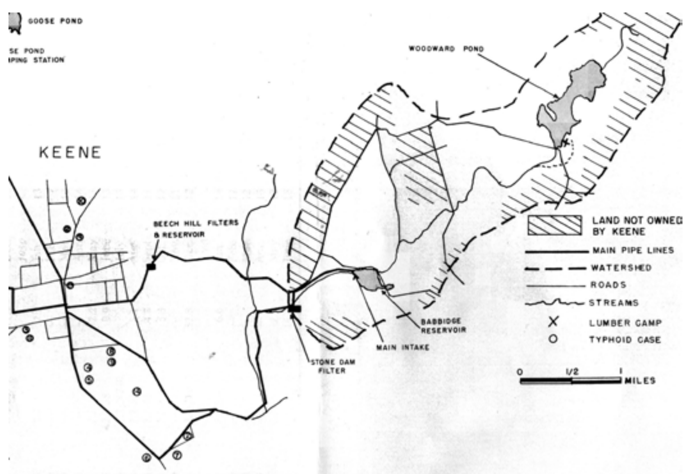
Chapter 5 – Disasters, War and Emergency Planning

As hard as we all work on building and operating good water supplies, as good as our skills and experience make us, we can only control the situation so much until something bigger than we can handle comes along. These times help define our history.

There are four types of extraordinary events that are discussed fairly frequently in the history of the NEWWA Journal: public health incidents, water supply failures, natural disasters and social disasters such as wars.

Public Health Incidents

The early years of the Journal record a significant number of waterborne disease investigations that found some source of typhoid contribution from within the source watershed. The absence of effective treatment in the early days was the real culprit and once disinfection was widely practiced, the incidence of waterborne disease dropped off to near nothing. There was still an occasional problem, one notable one being the 1959 Keene NH outbreak which had hundreds of cases of gastroenteritis but, most notably, 14 cases of typhoid, one of which was fatal. This was traced back to an infected person at a logging camp in the watershed and was made possible by the absence of residual disinfection, something that was immediately rectified after the incident. The supply was actually filtered but the event came during heavy rains while a filter was being cleaned. Other relatively minor incidents included a 1978 Campylobacter outbreak in Vermont with 3,000 cases, a 1976 Giardia outbreak in Berlin NH with 750 cases, a 1985 Giardia outbreak in Pittsfield MA with 700 cases and a 2002 Norovirus outbreak in Connecticut with 142 cases. New England has been relatively well off compared to other regions of the country.



1959 Keene typhoid incident, note logging camp near pond

The focus on public health incidents in the past several decades has been more on breakdowns of the protection barriers. With the advent of effective treatment, complacency can be a problem where there are high risk sources, examples being the Milwaukee WI and Walkerton Ontario sources that often had runoff from cattle grazing. The lessons here were learned elsewhere but were significant for the entire industry. In both the 1993 Milwaukee cryptosporidium incident and the 2000 Walkerton *E coli* incident, the real issue was failure of the treatment process. The Milwaukee incident is believed to be the result of improper filtration backwashing combined with the intake being susceptible to high cryptosporidium loadings during storm events. It is clearly the largest waterborne disease incident in modern times with over a hundred deaths and 400,000 cases of illness. It is also an example of how effective a biological agent can be and why we need to be vigilant in securing water systems. In a historical footnote, this was not a first large waterborne health incident for Milwaukee. In 1916, there was an incident involving a night-time operator that did an unauthorized shutdown of their chlorination after receiving a complaint of chlorine taste, leading to 60,000 cases of gastroenteritis, 400-500 cases of typhoid and 40-50 deaths. This speaks volumes for selection of a well protected source to minimize reliance on the treatment barriers always being 100% effective.

The Walkerton incident that caused seven deaths and up to 2,000 illnesses was an example of operator inattention and, worse, operator dishonesty. The loss of chlorination that caused the incident to occur was unreported and water quality tests were falsified to hide the lapse. Fortunately this is rare within the industry and serves as a reminder of the importance of our actions in protecting the public.

The occurrence of other health disasters is worth noting. The 1918 pandemic, commonly called the "Spanish Flu", was an example of a viral epidemic with enormous impact. It hit New England hard, starting in Boston's military hospital that was treating cases of the flu in returning World War I soldiers and then expanding out to the general public through person to person transmission. In a matter of months, this flu passed through the entire country causing infected persons to be severely ill at best and causing death in a relatively high percentage of cases. The epidemic was so virulent and the strain of flu so deadly that otherwise healthy people died very rapidly. Since the only possible response was to limit contact to avoid infection, this pretty much cleared the streets and affected society at all levels. The lesson from this for water suppliers is important and the current Avian Flu and SARS scares make this a timely issue. Water suppliers will need to be prepared to operate through pandemic conditions someday where a significant percentage of staff is unavailable and other businesses that provide critical services like chemicals, materials or services may be equally unable to fulfill needs.

3 Unreal Biological Infestations

Fiction is stranger than truth when it comes to some reservoir stories:

1. "**Champie**" is the name for the sea serpent that roams Lake Champlain, Burlington VT's water supply. Sightings are attested to by many residents.

2. **Stephen King** wrote his book "*Dreamcatcher*" after visiting Quabbin Reservoir. The Intake is featured in the climactic final scene where an intelligent space fungus tries to infect Boston's water supply. Stephen King also featured Bangor's 1875 Water Works and Thomas Hill Standpipe in other stories.

3. Providence's Scituate Reservoir, when it was being constructed in the 1920's, was the inspiration for **H. P. Lovecraft**'s short story "*The Colour Out of Space*". Lovecraft tells of a strange growth that arrived on a meteorite, possessing people in the final days before the area was inundated by reservoir filling.

No word on regulation of alien growths or sea serpents in SDWA amendments.

Water supply disasters – Things just break sometimes

Many water supply problems came early in the development of water supply technologies and were the result of a sometimes painful learning curve. For example, soils engineering really didn't come of age until the early 1900's, which meant engineering specialties like dam design in the 1800's were done more through lore handed down from mentor engineer to student engineer rather than through sound understanding of principles. Hydrology and hydraulics were still young fields in the 1800's and the absence of reliable records of floods and drought meant there was an inadequate understanding of nature's extremes.

Catastrophic failure of water facilities occasionally caused problems beyond the interruption of the water supply. Collapse of water containing facilities was a significant hazard to the downhill areas.

Dam failures

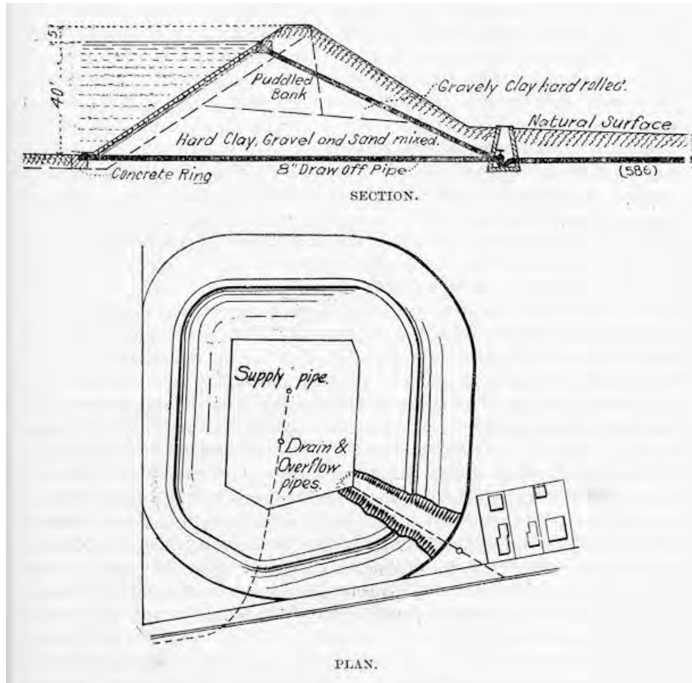
Most early colonial dams had been built privately for mills and failure was not unknown. The first major dam failure in the US was in 1874 in Williamsburg MA, killing 144 people and causing $1 million in damages. Many early timber dams, such as the original Holyoke Dam on the Connecticut River had failed but with lesser consequences. As late as 1889, the Johnstown, PA dam failed, taking 2,200 lives, still the largest US loss of life due to a dam failure. The Johnstown failure in particular, was clearly the result of inadequate understanding of proper maintenance and flood management by the non-technical owners.

In the water supply world, there had been an 1842 failure of New York's Croton dam during construction. Within New England, there had been several failures of water supply dams including the 1848 failure of Boston's original Lake Cochituate stone dam during filling, the 1867 failure of Hartford's Dam No. 1 on Trout Brook during a flood event while under construction and the 1876 failure of Worcester's original Lynde Brook dam. The Worcester event was clearly the most destructive. Failure was preceded by substantial leakage from the old earthen structure and gradual undermining of the dam. The flood swept away the gatehouses, leaving a hole 150' wide by 20' deep and causing a water level drop of 16' in an hour and a half. Owing to the warning, no lives were lost but downstream mills, houses and railroad embankments were washed away causing $750,000 in damages. Worcester rebuilt the dam and continues to use this source to this day. In each of these older incidents, the underlying cause was a lack of engineering knowledge, be it an underlying soils issue as in Lake Cochituate or Lynde Brook or inadequate flooding protection as on Trout Brook.

As with all dams, water suppliers have been subject to monitoring requirements regarding physical condition of the dam and follow-up remediation steps to assure safety. During the 1936 and 1955 hurricanes, non-water supply dam collapses in New England caused extensive damage to downstream communities. Nationally, following some particularly catastrophic dam failures in the 1970's, federal regulation came in the form of the 1972 National Dam Inspection Act which directed states to assume primary responsibility for dam condition and directed the Corps of Engineers to inspect all high hazard dams. This continues to be a timely issue with 2 national examples of privately owned dam failures (Hawaii and Missouri) with resulting fatalities in 2006.

Examples of distribution storage failures

- Portland ME distribution reservoir – In 1882, one of the city's open reservoirs breached and in 30 minutes discharged 6 million gallons into the streets of the city, causing some damage but injuring no one.
- Fairhaven MA tank – In 1901, the city's new steel elevated tank collapsed one night in high wind. As with many other early tanks, the wind stresses were not adequately addressed.
- Other early uncovered tanks, such as an early steel tank in Bath ME, had such little reinforcing in the top ring that they were buckled by wind forces.



1882 Portland ME Distribution Reservoir breach

1901 Fairhaven MA Tank

1901 Fairhaven MA Tank after the failure

1921 Bath ME Failure of open top tank

- Saugus MA Tank – On September 22, 1987, a 40 year old steel elevated tank in Saugus MA ruptured. The escaping water crushed several cars and damaged an adjacent cable television building but, fortunately, did not cause any deaths or extensive property damage.

- New London CT Tanks – In 1943, New London had constructed three new 1.2 MG prestressed reinforced concrete tanks in a cluster. In 1960, there was a catastrophic breach and flooding from 2 of the three tanks. The cause was later determined to be soil settlement and failure of the piping in the space between the tanks and subsequent undermining and collapse of 2 of the tank floors. The event caused no loss of life and minimal damage but resulted in a review of all similar reinforced concrete tanks.

New London CT prestressed concrete tanks, failure occurred at pipe manifold in center

1988 Holden MA dome failure

Water Supply Irony – Part 1

Water tanks help provide fire protection, right? How about a water tank that burns down? This happened in Boston during the early 1900's to an early iron plate tank in the Orient Heights neighborhood of East Boston. The tank had a wood framed and shingled enclosure with an internal stairway to a public viewing platform. It caught fire and burned to the ground, causing significant damage to the iron tank. Other historic wooden enclosed tanks such as those in Bangor ME and Scituate, MA now have internal sprinkler systems.

East Boston Tank

Water Supply Irony – Part 2

How about when the Water Department offices burn down? This happened in 1925 to Fairhaven MA. In a 1940 paper, they declared themselves as being the most hard luck Water Department in NEWWA, having had 4 recent major disasters - the others being the 1938 hurricane, a 1901 elevated tank collapse and a 1933 lightning strike that collapsed their pump station chimney.

Breaks

1916 Pumping out a basement after a 48" pipe break in Boston MA

Every water system superintendent has been woken up in the night to control flooding from some ruptured pipe, often with resulting flooding of homes or sensitive facilities. Every community could tell stories about "the big break" in their system but only one can claim the largest pipe break in New England. That dubious honor apparently goes to Providence, RI which had a rupture in its 102" prestressed concrete aqueduct in a Cranston neighborhood on 11/17/1996. A rather large chunk of wall blew out in a section that had experienced reinforcing wire failure from corrosion. An 80 acre area of Cranston was flooded and the pressure loss affected 600,000 customers. Fortunately, there was a backup pipe, smaller but large enough to provide supply during the 2 month repair.

Power failures

While most water systems have taken care to develop backup power for critical facilities, recent national experience is worth noting. The 2003 power failure that affected most of the northeastern and mid-western states demonstrated that not everyone was ready. Both Cleveland and Detroit suffered service outages when their large source water pumping systems couldn't operate. Only the far western parts of New England were directly affected and there were no significant water supply problems. The great Northeast blackout of 1965 had similarly affected the entire New England area but the outage was much briefer, so any water systems that couldn't pump probably were able to continue service on storage. These incidents are ample reinforcement to consider maintaining strong backup power readiness.

Natural disasters

In the 125 year history of the organization, there have been many significant natural destructive events, such as floods, hurricanes, blizzards and earthquakes. Some examples of these events are described below.

1936 flood in Hartford CT

Spring Floods

The most notable floods in New England were the following:

- 1927 Vermont flood (84 dead, $28M damages) – This flood caused extensive flooding of riverfront villages and washing out of mains on bridges and streets near the rivers.
- 1936 Storm and rapid snowmelt (24 dead, $113M damages, Merrimack River valley cities very hard hit, 77,000 homeless, Hooksett NH 18-20' under water). Noted among the stories after this incident was the flooding of the Lawrence Experiment Station up to the lab benches. The Lawrence engineering staff also disconnected and pulled their electric motors up to the second floor to avoid flood damage.

In both these cases, water supply facilities along the rivers were flooded and significantly damaged causing extended loss of service in many communities.

Hurricanes and High Wind Events

In general, hurricane damage to water supplies is due to several factors. In addition to the expected damages due to high winds and falling tree limbs, power failures affect everyone. Coastal storm surges cause salt water fouling of coastal groundwater and low lying water reservoirs. River flooding can cause washouts of roads and bridges and, with them, the pipes. Any water facilities, like intakes or pump stations, in the coastal storm surge areas or river flood plains can experience extensive flooding damage. The most significant storms included the following:

1954 Hurricane – Bristol RI staff closing a valve during the storm

1954 Tidal surge ocean water pouring into Kickemuit Res., Bristol RI

- Unnamed Category 3 1938 hurricane (700 killed, 400M damages) – This storm caused extensive wind damage to facilities and knocked down most of the trees in central New England. In addition to the building damages, this storm had significant lasting effects on water quality and watershed runoff of many surface sources. A follow-up review in Massachusetts noted that 24 communities had lost mains and 14 had sources flooded out. 10 additional communities lost power and 2 had standpipes damaged, including East Brookfield which had their standpipe overturned completely.
- Carol 1954 (66 dead, $500M damages) - This storm produced a devastating storm surge in Connecticut, Rhode Island and the Buzzard Bay area of Massachusetts, destroying 5,000 buildings. Coastal supplies were especially hard hit with water quality problems from salinity and wind blown debris.
- Diane 1955 (90 dead, 1500 homes damaged) - This storm dumped up to 20" of rain and caused the Blackstone River to go 17' over flood stage at Woonsocket RI. Roads and bridges were washed out with loss of water supply pipes.
- Donna 1960 (50 deaths, $387M in damages) - This storm crossed Long Island and hit Connecticut with extensive storm surge damage along the coast and up to 130 mph winds in Rhode Island.

Blizzards

The Great blizzard of 1978, a storm with 24" to 38" of snow, followed an earlier 20" snowfall causing near complete paralysis of most of southern New England. This was an interesting challenge for most operators with many staff having to bunk in at their facilities for lack of relief shift operators.

Earthquakes

New England has the potential for substantial earthquake events but they are much less frequent than those of the west coast, where the need to harden piping across fault areas and to have substantial response resources in place has been deemed necessary. Northern New England is much closer to the more active Quebec earthquake area but southern New England has more vulnerable construction in its older communities. Either way, the risk of damage from a repeat of some of the earlier recorded earthquakes is substantial and lessons could be learned from west coast experience. The following are some of the region's bigger events:

- 1638 in NH - Estimated at 6.5-7 magnitude, damage was limited due to very simple construction in early colonial days.
- 1755 in Cape Ann, MA - Estimated at 6.0 magnitude, many buildings fell as far away as Boston.
- 1940 in Tamworth NH –Estimated at 5.5, apparently caused a Chicopee MA pipe failure.

Social Conflicts and War

Nature's fury is at least fairly short-lived. War can go on for years and the after effects last longer. Several such major events dominated the history of water supply and were documented by many NEWWA Journal papers.

Earlier wars

Prior to World War I, wars didn't have too much direct impact on New England water supplies mainly because they were elsewhere. It is notable that medical men were as unfamiliar with germ theory as the water suppliers at the time. The result was that these wars were extremely deadly to the participants from the lack of proper sanitation, with more men dying from typhoid in remote war zones than from flying bullets.

World War I

New England men went to fight this war with at least some understanding of sanitation but were faced with new threats such as chemical warfare. Even the water supplier's new friend, chlorine gas, was used a chemical weapon on the battlefield.

World War I water wagon

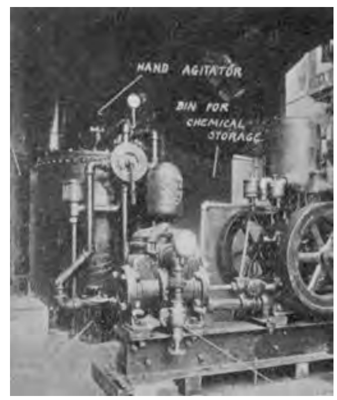
One subject discussed at some length in the NEWWA Journal was the water supply issues associated with the Allied Expeditionary Force (AEF). Bacteria testing and water treatment via disinfection were now practiced in the field. A noteworthy paper in 1919 by Col. Francis Longley, a member of NEWWA who had served in the AEF, documents the experiences of his 26th Engineers, a U.S. Army Regiment whose special purpose was the water supply for the Allied Forces in their zone. They supplied safe water to not only the men but also the horses being used by the troops. They performed water quality testing and treatment in a live war where chemical weapons were used in combat for the first time and sanitary conditions were horrendous. As was common in wars of this period, more casualties in this unit were from disease (21) than from battle wounds (5).

The war was clearly limited to Europe but the US had declared war on countries from which many people had emigrated to the US. The idea that enemy sympathizers in the US could sabotage critical infrastructure was a novel one that caused some amount of concern for the security of water supplies at home.


“Hardened” pump station at St. Jacques

The other notable impact on water supplies in this period was in the lack of resources at home. Coal was in short supply to the point that the steam stations struggled to maintain operation. Gasoline and diesel fuel were in similar short supply. Metal for pipes was scarce so distribution system expansion was limited and new pipe materials like reinforced concrete were looked at more seriously.

1919 - 26th Engineers mobile water treatment truck



Mobile chemical feed

1919 Boston Police Strike

Shortly after World War I, the increase in union activity led to strikes in many industries. The most disruptive was a 1919 strike by Boston policemen which led to rioting in the downtown neighborhoods. As was the case during the World Wars, key water facilities required full time guards.

MA National Guard protecting Chestnut Hill Reservoir in Brighton MA during 1919 Police Strike

World War II

The concerns during WWII were similar to those of World War I but now improved airplane technology meant that bombs could conceivably be delivered over the US mainland. This caused much consternation in the water supply world since it was apparent from the extensive bombing in Europe that water utilities were suffering great damage. Contingency plans were called for to contain pipe ruptures due to bombing and to build redundant facilities for critical aqueducts or pump stations. One common technique was to add hydrants to suction and discharge piping of pump stations to allow a fire engine pump to serve as a backup.

WW II Bomb crater in England, water leaking from broken main

Many more chemical and biological agents were now available as weapons. In fact, active testing and/or use of such had occurred in some theaters of the war. Experts now began to be concerned over the use of such materials away from the battlefield, with US water supplies being considered a likely target to demoralize the US public. Briefings were provided to water suppliers regarding these agents and their likely effects in drinking water. Response measures focused on the use of higher chlorine doses and delivery of extra chlorine at additional points in the distribution system.

The idea of saboteurs now included both enemy sympathizers (a.k.a. Fifth Columnists) and also the possibility of spies being landed on our shores by submarines. Arrests of such infiltrators were apparently made by the FBI in separate incidents on Long Island NY and Jacksonville FL, according to one NEWWA paper. The reaction in the water supply world, as one of the critical infrastructures, was to fortify facilities and guard them with armed troops in some cases. This is not unlike the reaction to today's threat of terrorism.

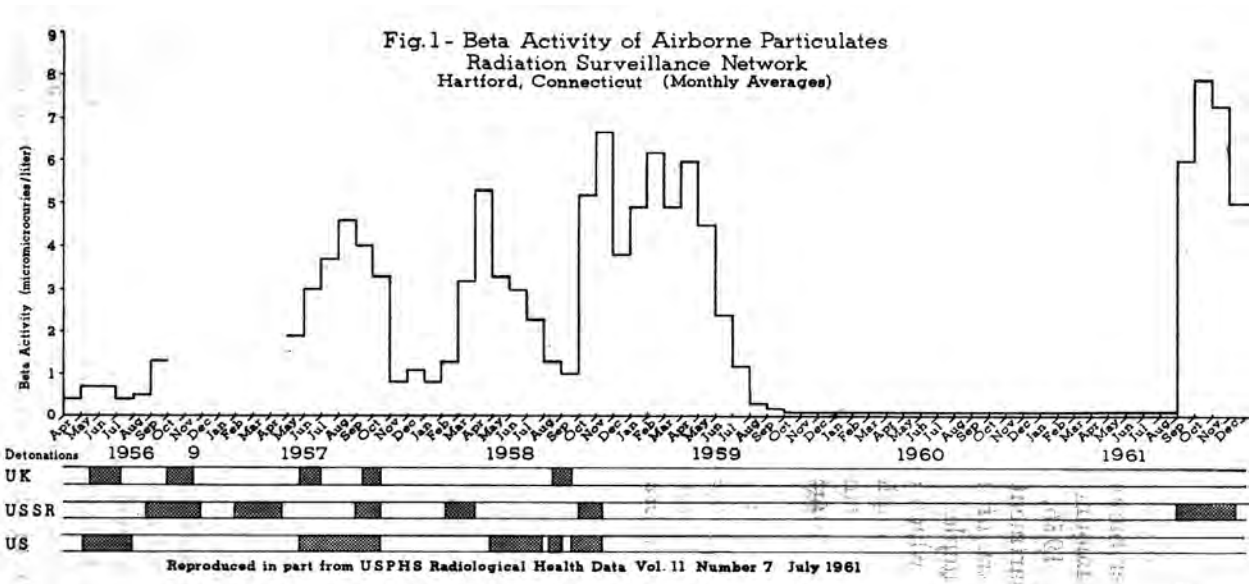
Shortages in many materials essential to the war effort such as iron, steel and rubber affected the water supply industry. Vendors of many new materials like asbestos cement pipe and reinforced concrete pipes and tanks took the sales approach that it was patriotic to use less metal by using their product. With the draft taking many New England men, labor for system improvements or even just maintenance was in short supply as well.

Ads run by a prestressed concrete pipe manufacturer emphasizing the metal saved by using their product

The Cold War

The end of World War II, brought about by the use of the atom bomb, began the Cold War era. During this period, other nations developed not just nuclear capabilities, but also the ability to deliver many nuclear missiles or bombs to target cities in the US. This raised anxiety among water suppliers in the same way that the public began to fear the bomb. NEWWA Journal articles quoted briefings of the probable deaths within a certain radius of cities like Boston and counseled that water suppliers needed to come up with response plans for post nuclear attack scenarios.

The threat of radiation from fallout turned to reality in a limited way as a result of the open air H-bomb testing done in the early days of nuclear escalation. With Russia, the US and others conducting bomb testing, fallout became a worldwide problem which, for a time, produced measurable radioactivity in surface waters.



1962 chart of beta radiation measures in airborne particulates after worldwide H bomb test detonations

The 9/11/01 World Trade Center Attack and Terrorism

The events of 9/11/01 and the days that followed reinvigorated concerns over attacks on water supplies by terrorists. With large stockpiles of chemical and biological agents in the hands of foreign governments around the world, the idea that a terrorist group could procure such materials was a major concern. The 9/11/01 attacks also demonstrated a clear intent to cause maximum casualties and a level of planning and resources that made the future threats very credible. Up to this time, security at most water utilities had been focused on vandalism and theft, but now the idea of defending many vulnerable locations in a far-flung water system against a motivated, well financed, technically astute enemy was an entirely new situation. Other recent incidents like the Oklahoma Federal Building bombing and terrorist bomb attacks worldwide also raised concerns that explosive attacks could occur on any critical infrastructure and that water supply should protect itself from such threats as well.

DHS Orange level - Guarding key water supply facilities

Post 9/11 Welding hatch covers

The threat of water supply poisoning is not a new one, but there are relatively few contamination incidents in the past. The possibility of an unknown contaminant being injected at any point and any time in the distribution system is a difficult problem to monitor and defend against, leading to much research and the development of new distribution system water quality monitoring strategies aimed especially for this issue.

After 9/11/01, the 2002 Bioterrorism Act required all water suppliers serving 3,300 people or more, to conduct vulnerability assessments and update emergency plans accordingly. Much effort has since gone into the protection of New England water systems and the development of response measures against the terrorist threat.

The intentional contamination aspects of terrorism will likely have far reaching effects. Already much research funding has been allocated by the federal government. Some version of minimum water security standards and broader contamination monitoring may eventually become regulated at the state or federal level as a preventative measure.

Chapter 6 – Managing the Water System

Take away the science and politics and you still have an enterprise to run. This section reviews some of the changes in water system management over the years.

The people who built and ran the systems

The original water systems were private enterprises and were managed for a profit. There were privately run water companies among the early members of NEWWA but the organization became dominated more by staff from the larger public utilities and by consultants and academics. Perhaps this is because the public utilities had a greater need to learn from the organization since many of the newer water works staff were recruited from other municipal areas and didn't have the luxury of being apprenticed into the field. Private water companies at least had the resources to pay for support from experts. Many consulting engineers of the day, on the other hand, studied the more interesting technical problems and shared expertise more freely to help establish the reputation needed to develop more business. Even in the early days, vendors offered much technical help in exchange for a chance to market their product.

> ***Famous Water Supply Managers***
>
> Did you know that **P. T. Barnum** once managed the Bridgeport Hydraulic Company? So he did for 15 years, then, of course, he ran off to the circus.
>
> Also, did you know that **Eli Whitney**, the man who invented the Cotton Gin, the machine that began the Industrial Revolution by enabling New England mills to be supplied by ample southern cotton, was the man who developed New Haven's supply? Lake Whitney bears his name and his son Eli Whitney II went

By the late 1800's, many more water supplies were being built and run by public agencies. Systems were usually headed up by either an engineer or someone who had come up through the ranks. While consultants were most often used for the large system improvements, many public service employees became leaders in NEWWA since they very often worked out the solutions to problems that plagued the industry. Field staff were much like today, people who could deal with the hours, the physical nature and underlying complexity of the work.

People/staff/salaries


1896 – Some of New England's finest working on pipe pressure testing using a hand pump

In 1882, a worker's pay was on the order of 20 cents per hour and life expectancy was 47 years. The work week was 6 days per week for a total of about 53 hours. Minimum wage didn't come into play until the 1930's and was only $0.25 per hour at that. There weren't many grades of workers, simply skilled and unskilled laborers, in most communities with a foreman or two and a manager that directed the effort. Operations staffing included many strong backs for shoveling coal and an occasional boiler operator.

By 1960, minimum wage was all the way up to $1.00 per hour and the work week had come down to around 40 hours.

Labor organization

There had been some unions in New England in the early 1800's, the need being driven by the oppressive conditions in some mills. Unions did not get truly strong or forceful enough to strike until the late 1800's and did so more in the manufacturing industries. By the early 1900's, strikes were not uncommon and labor unions began to develop true political power. By the early 1900's, unionization had reached most public service agencies including water supplies. There has never been a strike in a New England water supply.

Another significant event in labor/management arrangements was the adoption of Civil Service by the states. The Federal Civil Service Commission was established in 1871. New England States followed with their state Civil Service rules around the end of the 1800's. This had positive effects on employee job security but it also created a significant difference from private industry, in that there was no quick solution to non-performing or problem employees. Some would argue that employee performance in Civil Service situations was never the same. Within Civil Service, the process of testing and being granted status was onerous and the narrowing of job descriptions also took away some of the flexibility that private industry enjoyed.

With the threat of privatization hanging over most municipally operated water supplies, most public utilities have trimmed staffing in recent years. Financial pressures on communities, due to such measures as Proposition 2 ½ in Massachusetts, also forced staff reductions in the water supply as in all public service sectors, even public safety. Tools like automation of operating facilities and improved maintenance planning have allowed for some efficiency in staff utilization. As a result, today's water system employee has broader responsibilities and is generally better trained and qualified than ever.

Training & certification

Operator skill development was always a NEWWA goal but the process was more informal than formal until well into the 1900's. As the level of complexity of treatment systems increased, there was a growing need to address this issue.

The establishment of Water Works schools was first suggested by Robert Spurr Weston during his NEWWA presidency in 1930. The first was held on June 6-11, 1932 at Harvard and MIT with 19 men completing the course. The course was repeated but the thrust of the effort was more purely educational than to support certification.

The next big step was in 1961, when NEWWA appointed a committee on Certification of Water Works Personnel. A Model Plan for voluntary certification was developed by the committee in 1961. The goal of adoption of mandatory certification via state regulations came next. Despite much lobbying by NEWWA, progress on implementation was slow with the states beginning mandatory certification almost a decade later. Maine was first to adopt mandatory operator certification in 1970, followed by Connecticut later in the same year. Vermont and Massachusetts followed in 1971 and New Hampshire in 1979.

Some safety milestones

1800's First use of canaries for gas detection
1814 First particulate removing filter
1854 First use of GAC for vapors
1911 American Society of Safety Engineers
1913 National Safety Council
1918 ANSI
1930's Mouth pipetting in labs, fume hoods
1940's First safety glasses
1970 OSHA standards for chemical safety

The first certification courses were taught at Worcester Polytechnic Institute in 1969. In the following years, courses were given in colleges or high schools throughout New England, including early sessions in New Hampshire, Connecticut and Massachusetts. By 1973, 426 individuals had been certified in this first round. Theses efforts continued, eventually supporting the system of certification that exists today.

NEWWA Introduced Practices

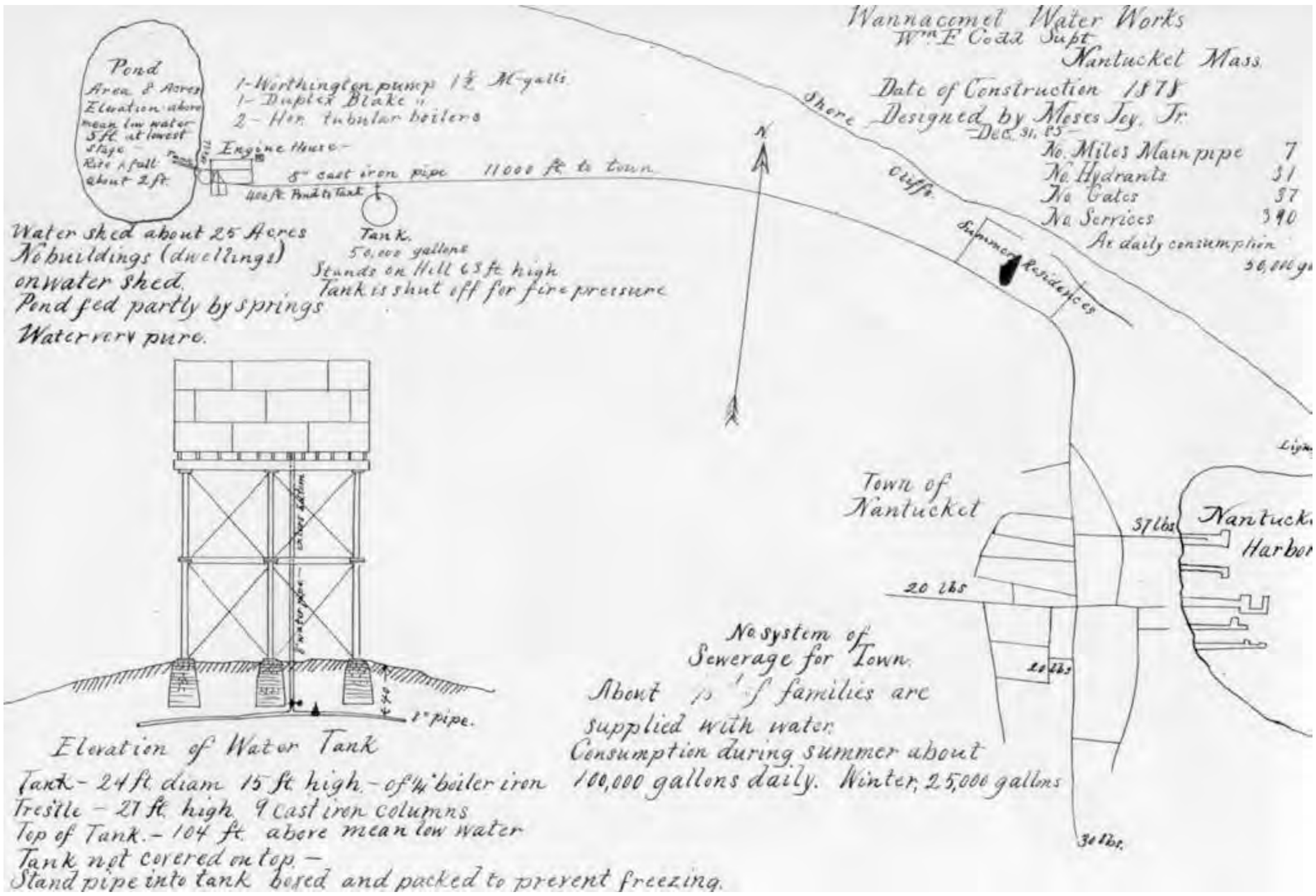
Since so many water supply systems were just starting out in 1882, NEWWA created committees to provide some examples of proper practices for use by all. This was desperately needed at the time and gave the newcomers a chance to learn and measure themselves against their peers. The following were some of the important early initiatives:

- Annual reports – NEWWA published a standardized format for reporting everything from water sold to fuel used and other statistics.

- Operating statistics – Summaries of such data as "duty" of pumps were published to give some perspective to what reasonable efficiency should be. Since all water suppliers were weather watchers but few could take comprehensive measurements, the publishing of hydrologic data was also a service to smaller systems. Occasional surveys of treatment practices and water quality were done by state public health boards, the predecessors of today's regulators.

- Record-keeping - Distribution system record keeping was described and installation practices (e.g. depth, methods, materials) were noted to help guide smaller systems.

- System maps – An 1887 committee assembled a collection of 27 system maps documenting the member's systems. Since there were other cities outside New England represented on the committee, there were a few nationally prominent systems represented as well (e.g. New Orleans, Louisville).



From NEWWA's 1887 collection of distribution system maps, 27 communities contributed hand drawn sketches of their works, Nantucket's notes a steam pump station, an open top plate iron tank and seven miles of mains.

- Specifications – Given the wide variety of manufacturers for important equipment and the lack of compatibility between different manufacturers, it was essential to get some standardization. Early efforts targeted such items as meter testing and pipe specifications.

- Materials and tricks of the trade – Early Journals occasionally talked about techniques for problem solving, similar to AWWA's Opflow. For example, during the initial 1882 meeting, one savvy tip for keeping eels from clogging service lines was noted (a bit of coiled wire inserted in the main end of the service). The usual topics included such things as effective coatings for preventing corrosion, pipe freezing problems, or whatever the issue of the day may have been.

- Vendor presentations - Industry representatives would come in and describe how some materials were manufactured. This could be a pipe casting representative, a chemical manufacturer or other specialist.

Tools and technology available to the water industry

It's hard to imagine a world without beepers, cell phones, cars and other conveniences that are useful for immediate response to an emergency, but that was the world of the old water supply operator. Some major milestones are noted below:

<u>*Communications*</u>

1951 Portable radio

In the 1800's, messages were sent by horse and rider. This was well illustrated when an early washout of Boston's Sudbury Aqueduct was reported by an operator's heroic ride to the intake to alert operators to shut off the flow. When telegraph came along in 1844, at least a message could be sent to the distant end of the wire, but stations were limited. Telephone came along in the 1870's and was the standard for office and field communication until fairly recently. Telephone worked for facility to facility communications but still limited field crew communications to the occasional pay phone call. Car mounted two way radios were invented in the 1930's primarily for police and fire use but most water utilities did not move to two way radio communications until the 1970's or thereafter. Similarly, handheld two way radios were around from the 1940's but finding one that didn't cause a hernia took until the 1970's or so. Pagers became available as early as the late 1950's but were really popularized in the 1970's much to the annoyance of the spouses of water supply workers. Wide area paging is a 1990's phenomenon. Cellular phones came along in the 1980's, but even then, the early generation required a battery pack the size of a briefcase. Today's tools make accessibility a simple matter to the point that many water operations staff occasionally long for the "good old days".

<u>*Travel*</u>

1929 Portland ME's new emergency truck and lights

In the 1800's, you were pretty much looking at an extended journey if you wanted to go from the city out to the sources. With this in mind, many systems provided housing adjacent to the water works for their operators or managers just to ensure their presence. The Water Superintendent of the 1800's typically had a horse and buggy available for his use. The first cars were developed in the 1880's but cars really weren't commonly available until after 1908 when Ford began making the Model T. At around this time, many larger water utilities began use of automobiles for managers and emergency crews. Some early NEWWA papers discuss the cost of maintaining automobiles and the benefits there from, concluding that they were much more cost effective than horses. Roads were significantly improved in 1920's and 1930's removing some early constraints on travel. Most major highways like Interstates were added after 1956. The availability of small and reliable communication equipment and the ease of travel has made responding to problems much quicker and easier today.

<u>*Engineer's tools*</u>

Early calculations were done by hand, usually recorded in careful handwriting in some ledger and verified by a second person's recalculation. Slide rules (invented in the 1700's) were the preferred tool of the engineer until well into the 1970's when electronic calculators became available. Then, for a mere $250 or so, you could get a 4 function calculator, or if you wanted log functions you would fork over an extra $100 or so. Of course, your alternative was to access a mainframe but computer programs in those days involved punch cards and very crude program languages. Personal computers were introduced in the 1980's and have essentially now taken over most forms of calculations and data management in the water supply field. The Internet with all of its resources was conceived in 1970s, then the infrastructure was put in place by late 1980's, allowing it to become widely used by 1990's. The amount of readily available reference material on the internet was a real boon to engineers and water system managers everywhere.

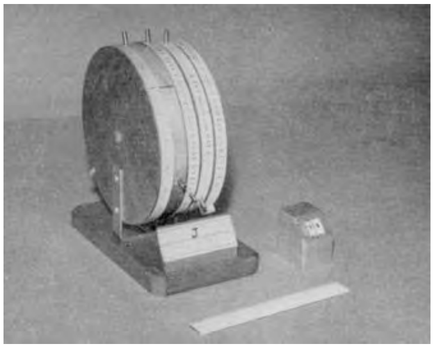
Strangest Hydraulic Test

When the New England Patriot's old Schaefer Stadium was built in 1971, the concern was whether the new water supply system could handle the halftime flush volume. The owner at the time, Billy Sullivan, stationed all of his employees at bathrooms and taps throughout the stadium to conduct what became memorialized in the press as "Superflush". The current Gillette Stadium water supply was featured in a 2004 NEWWA article that noted many well engineered improvements but much less testing drama.

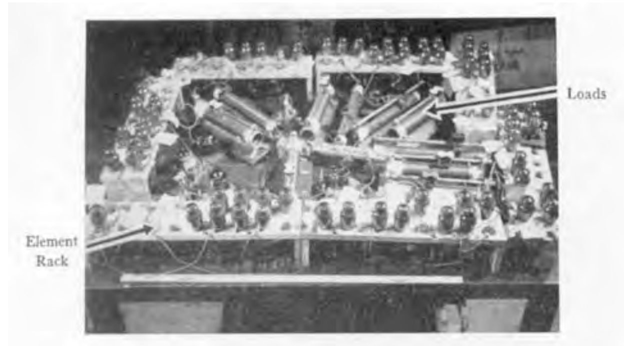
Hydraulic calculations

Flow analysis of pipe networks was always a difficult thing. The Darcy-Weisbach equation had become the standard for pressure pipe hydraulics in 1845 but it was cumbersome to use. In the early days of the organization, Allen Hazen played a role in simplifying the work for the hydraulic engineer by working with G. S. Williams to develop a more empirical approach, the Hazen-Williams equation. This allowed the development of flow/head loss monographs which allowed rapid calculations. This was a huge advance but flow calculations in networks could still only be done by use of simplifying techniques like equivalent pipes. As a result, pipes were more likely to be generously sized.

Slide rule calculators were tried without much acceptance. In 1935, Hardy Cross developed the first practical analysis tool for pipe networks using a balancing error technique. Doing this by hand was a challenge, often involving a plan size sheet to record the iterative calculations, a cumbersome and tedious process. The computer programs designed to do this calculation quickly weren't developed until the 1970's when programming languages had advanced significantly. In the interim, there was much research on practical tools for distribution system designers. Some researchers like the team of H. L. Hazen of MIT and Thomas Camp tried electric analogs as early as the 1930's, using resistance to simulate pipe head loss and current for flows. Another advance was the McIlroy analyzer, developed at Cornell University, which was able to be more easily configured but still required an entire room of hardware. Many New England systems were modeled by the McIlroy analyzer at Tufts University. With the advent of computers, early network analyzing software required fairly powerful minicomputers to operate. Today, a variety of software is available down to even the personal computer level and the analysis software is capable of such features as dynamic simulations, GIS output and water quality modeling.

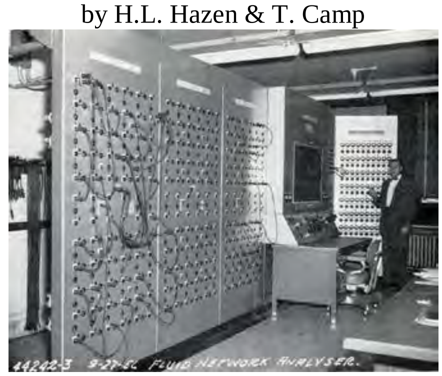


1956 rotary hydraulic calculator



1943 Vacuum tube hydraulic analog calculator developed by H.L. Hazen & T. Camp

1951 early version of McIroy Pipe network analyzer



1957 McIroy Network analyzer built for Philadelphia PA, a similar one was built at Tufts Univ.

Building Things

In case you thought police details were a modern phenomenon

Most structures in the water system require civil site work and heavy construction. In the 1800's, the old tried and true method was hand excavation with picks and shovels. Rock work for dams was typically done by masons, often Italian immigrants. Trenching and pipelaying was either done by hand or occasionally by using a trenching machine, a wood frame apparatus that could pass excavated material from the front of the machine to the rear for backfill. Horses were used for work that required more power than men could handle. By necessity, construction staff became expert in rigging and hoisting using block and tackle, masts and booms and other manual methods. Tunneling was done by hand using drill and blast methods. Explosives were limited to black powder until the invention of dynamite in 1865.

Early earth moving

Horse drawn scrapers for grading

Dam excavation with a steam shovel

Early Pipe Laying

Breaking rock the old way, with a pneumatic jack hammer

Early trenching machine

Early support equipment

1939 Air compressor

1938 Early gunite gun

Kerosene fired lead melter for making pipe joints

Portable gasoline powered dewatering pump

Early Rigging

Trans-loading cast iron pipe from rail to horse drawn carriage for delivery

Pipe rigging at the site using chainfalls

1925 Self propelled crane

Moving a 50,000 lb steam pump base plate from railcar to site

Shipping of pipe, engine parts, or any other weighty pieces was done by rail and then by horse drawn wagons. Steam power was applied to cranes for heavy lifts, bulldozers, and some types of excavators in the late 1800's, but this was cumbersome since the equipment wasn't easily self-propelled. Steam powered equipment was common well into the 1900's

1919 MDC Emergency truck with valve operator mounted beside driver's door

Development of construction equipment paralleled vehicles. Around 1893, the diesel engine opened the door for developing what we consider modern equipment. The engine could easily provide for movement of the machine as well as powering the excavating function. In the 1910's, gasoline powered equipment became much more common, replacing the horse as the prime mover, but the bigger advance was the development of pneumatic tires in 1911. This allowed much more maneuverability in equipment and allowed deployment over roads.

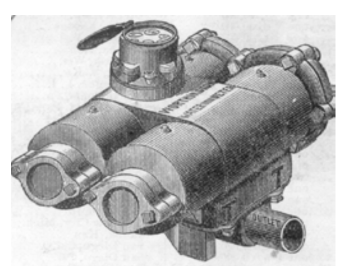
The business of building water works for municipalities has been closely controlled by state laws that normally separate design and construction and ensure competitive bidding. Recent trends in construction practices have included more use of design/build ventures where allowed by legislative permission. Just as with the trend towards more privatization and contract operations in recent years, the design and construction roles may see more untraditional solutions in the future.

Selling the water

Water measurement at the point of sale became very important for control of waste in the latter half of the 1800's when high pressure distribution systems came into play.

Mechanical meters

The first US patent for a water meter appeared around 1850 and relied on measurement using physical displacement, at first using reciprocating pistons. As can be imagined, this made for a fairly large device, as demonstrated by an early Worthington meter that weighed 57 lbs for a 5/8" pipe size. This was not put into wide use due to the expense and inconvenience of such a large device.


1888 Worthington Meter

Disk meters, the true fore-runner of today's residential meters, solved this problem when they came onto the scene around 1880. In the years following formation of NEWWA, there were about 5 or 6 companies with some type of meter available. Locally, one of these was the Hersey Meter Co. who patented a rotary displacement meter in 1885 in Hyde Park MA. Nutating disk type meters came on the scene around 1890. The cast iron frost bottom was added in 1896 to solve cold weather issues. The first major effort at standardization culminated in 1921 as NEWWA, AWWA and the manufacturers agreed on the Cold Water Meter Standard Specification. This was reviewed again in 1930 and 1940 with minor revisions.

Early disk meter ad

Early meter ad – the closest NEWWA came to a “cheesecake” ad

1905 Hersey Compound

1903 Meter testing lab, Burlington VT

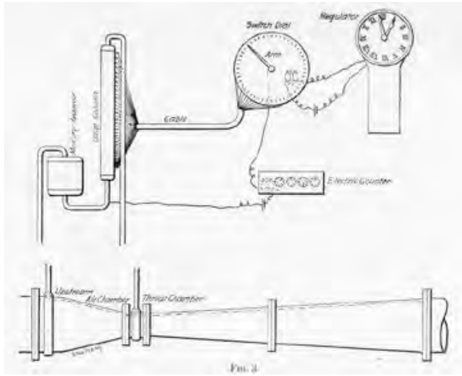
The next big advance was in the early 1920’s when oil encased intermediate gear trains replaced open water lubrication to avoid corrosive water problems. The development of magnetic drives in the 1950’s allowed complete separation of the gearing from the watertight enclosure. A problem remained: meter readers unable to enter homes when no one was home. This problem was solved in 1964, with the introduction of the mechanical encoder register that allowed remote readouts. Various versions of remote registers outside of the house then became available to simplify the task of collecting readings.

In the past 10-20 years, the advances in Automated Meter Reading systems has been remarkable, progressing from plug-in data dumping devices to radio collection via roving vehicles to stationary radio systems that can collect all meter data in a community via strategically placed antennas. This allows water demands to be reviewed very quickly for problem diagnosis. It also solved the billing frequency problem for communities that needed to go from semi-annual or quarterly bills to a more frequent cycle due to steeply rising operating costs.

Other large meters

The quest for a larger meter for industrial usage led to development of the first turbine meter (known then as a “torrent” meter) that could be used in a pressure pipe in 1896 and, subsequently, the compound meter in 1903 to widen the available flow range. The compound is still the workhorse of the industry for larger service connections like industries and institutions.

Measuring very large flows, such as for the master meter serving the entire community was an issue in the early days. In the late 1800's, there was no practical metering device that could pass a large but variable flow through its body without creating such a large head loss as to create a fire protection problem. This changed in 1891 when Clemens Herschel, one of NEWWA's most respected water works experts, developed the first venturi tube. Being a humble man, he named his newly created device after Giovanni Venturi, the author of the principle of pressure drop at a constriction. Herschel tested prototypes in his Holyoke Water Power Co. lab, then gave a paper on his design in 1887. He then allied with Builder's Iron Foundry in Rhode Island to make the first tube for East Jersey Water Co, the system he was managing at the time. The first New England application was in Worcester MA in the 1890's. Venturis are still the mainstay of large flow measurement.


Early venturi layout, note the mercury manometer


BIF's first venturi tube


Herschel Clemens, inventor of the venturi meter and authority on all aspects of water supply, he later translated the works of Frontinius on the Water Supply of the City of Rome for NEWWA's publication


One of Herschel Clemens lesser known civil engineering projects was the design of the small suspension bridge in Boston's Public Gardens, an ASCE Landmark

It should be noted that Clemens was not the only inventor. Frederick Stearns and Alphonse Fteley had jointly patented a current flow meter for use in the Boston aqueducts, but it didn't have the lasting impact of the venturi which continues to be productive over 100 years later.

Other new technologies for large meter flows came later in the mid-1900's, including magnetic and sonic technologies. These were more suited for specialty applications like water treatment plant flow controls.


1957 Mag Meter in Medfield MA

One of the side effects of reduced consumption in recent years has been that many larger size meters had now become over-sized for their service flow. Some communities have been very successful in recapturing under-registration and reducing unaccounted-for water by “right sizing” these overly large meters.

Controls and Efficiency


1921Motor operated valve


1923 Pump control panel


1957 Foxboro telemetry

Control of water operations was very manual to begin. Steam pumps and treatment plants needed to be attended by operators. The development of electric motors and telephone communication in the early 1900’s led to creative use of both technologies in combination to remotely start a function. Frequently positioned control valves were one of the first targets. The use of a water tank elevation signal to start pumps was also a major advance. Circuits were crude and unreliable for much of the early 1900’s so only limited remote control was attempted.

Beginning in the post-World War II period, plant automation techniques in manufacturing, and communication advances like microwave transmission, began to bring new possibilities to water system control. Controls began to be based on electrical relays and had to be very physically complex to operate a sophisticated function like those of a water treatment plant. The idea of Supervisory Control and Data Acquisition (SCADA) was tried first by electric and gas utilities, while the water supply industry was cautious. By the 1980’s, improvements in the controllers themselves began to allow the complex decision making to be embedded in controller programming rather than hard wired relays. SCADA eventually became the preferred means to perform complex function control and remote control to the point that virtually all new water facilities now feature SCADA controls.

The related benefit of modern control systems has been the shift to unstaffed operation of most operating facilities. This allowed operators to be more centralized and responsive to emergencies while the control systems attend to the boring routine of watching setpoints and starting and stopping functions.

Finances - Follow the money

Rate structures

Before meters, water was traditionally sold by the size of the connection. This led to many issues with water waste as there was no penalty for leaving the water running or allowing leakage to continue. Meters were implemented on the largest users first and most communities eventually managed to get to 100% metering. At this point, most communities adopted rate structures that established a usage based fixed rate but with a minimum charge to cover the cost of managing the account.

As large water users, like manufacturing industries, became dominant political forces in their communities, declining block rates began to appear in the mid 1900's. An argument could be made for this in terms of the cost to the utility being proportionally smaller to serve a large single user but it created a disincentive for controlling usage. By the 1970's, the increasing pressure to conserve water made these declining block rate deals unacceptable. In fact, some communities went directly to increasing block rates. The bottom line was that the price elasticity effect of expensive water and sewer charges in some communities had a dramatic effect on wet industries and helped defer water supply shortfalls. The other related rate topic that received much discussion was the collection of water bills, an age old issue. NEWWA's Journal had many papers on rates in the early days to help newly formed or expanding community systems. Through the years, papers also examined trends in such areas as bonding, enterprise accounting and other financial practices.

External financing

Who paid for the billions of dollars worth of water system projects in New England? For the most part, it was the ratepayers in the communities. However, there were some notable periods where the federal government supported this expense.

The early systems were usually started by a private company, which meant a state charter to operate and funds raised by selling shares in the water system. Eventually, this was replaced by municipalities raising funds through bonding. As long as the economy stayed strong, this continued to be a workable solution, lasting all the way to the Great Depression. Starting in 1929 and lasting through the 1930's, the devastating impact of the Stock Market crash and closing of businesses was most felt by the up to 10 million people that became unemployed. During the Franklin D. Roosevelt's administration, the government's reaction was to spend money to jump start the economy, as well as to try to hire the unemployed to at least a "make work" job. The spending was targeted towards public works, with water supply being one of the main beneficiaries. There were actually a series of initiatives, the largest of which included:

- The Public Works Act of 1933 authorized $3.3 Billion for large projects, including water. This was spread around the country with many New England projects receiving funding, as documented on plaques at many water facilities of the era.
- The Works Progress Administration was created in 1935 and was more targeted to the unemployment issue. Projects again targeted public works but tended to focus on work that could be done by unskilled laborers, such as digging ditches for pipe laying. Many rural water systems were built or improved at this time.

Both the PWA and WPA were completed by about 1939. The next major federal funding mechanism followed on their heels but was specifically targeted to another need of the times, that being war preparations in view of the escalating conflict in Europe. This included:

- In 1940, the Lanham Act created the Defense Public Works program which helped fund works in towns with defense plants. Water supply was considered an important element in supporting the war effort, resulting in the funding of 24 projects in 18 New England communities (7 MA, 6 CT, 2 ME, 1 VT, 1 NH, 1 RI). Communities like Newport RI received funding for dams, pipes, pump stations, filter plants, or covered storage. Title V of the War Mobilization and Reconversion Act continued this funding through to the end of World War II.

After these efforts, the only other significant federal funding provided was for the cleanup of rivers and sources of pollution through such vehicles as the Clean Water Act and Superfund. These were beneficial but did not directly improve water supply infrastructure. The 1974 Safe Drinking Water Act and its subsequent amendments were notable for the absence of any significant funding for expensive compliance projects. The recent Bioterrorism Act of 2002 also had very limited funding for communities despite the significant capital costs of system protection. The aging of water infrastructure is another looming financial issue that may need governmental support at some point.

Future issues for consideration - Public/private

What is the optimum organizational structure and staffing level for a water system? Is cost control the over-riding concern? Is the traditional separation of design, construction and operations the optimum strategy for the future? All good questions that generate strong opinions but that have no definitive answers.

One thing that can be said is that there are emerging trends in the past decade or so:

- Many smaller municipally owned systems continue to struggle with resources.
- Larger municipally owned systems have long struggled with issues like over-specialization of staff and higher staff count than private companies.
- Some publicly owned water systems have been privatized successfully and, conversely, some communities have attempted to withdraw from privatization commitments because of dissatisfaction.
- The larger private water companies, especially the well financed European companies, have been acquiring smaller New England companies.

Where will it end? Stay tuned because the issue will continue to evolve over time.

Chapter 7 – NEWWA – the people, the forums, the difference they made

Beginnings – The idea of a water works organization

The original idea of forming a national water works organization is credited to James W. Lyons of Salem MA. As early as 1877, he bounced this idea off of several of his water works associates who agreed to help pursue the matter. With the encouragement of his peers, he sent 400 letters in 1879 to all of the existing water supplies in the country. He received 70 replies, most of them supportive. However, he dropped his pursuit, noting later that the low response discouraged him. Others would later look at the written responses to his original letter and comment that there was sincere interest in many of them. The seed that he planted took hold and grew, because on March 21, 1881, the American Water Works Association was formed, a tribute to both Mr. Lyons' initiative and to the Water Works professionals that saw merit in the idea and wouldn't let it drop.

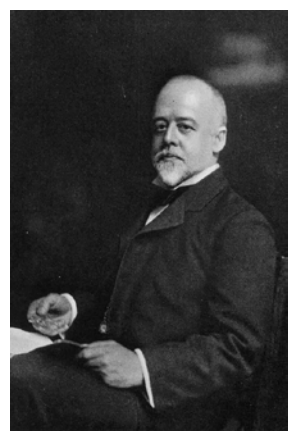
The Founding Fathers of NEWWA

The next steps were taken by an inspired group of supporters of the original Lyons proposal. In an informal meeting between Horace G. Holden, Superintendent of the Lowell MA works, Frank E. Hall, the Worcester Superintendent and Robert C. P. Coggeshall, the New Bedford Superintendent, a decision was made to pursue the idea of a New England organization. The fact that they were informally meeting in Lowell to compare experiences suggests their strong interest in sharing knowledge, especially in light of the difficulties of making a journey across the state in those days. That same day, they visited with and enlisted Henry Rogers, Superintendent of nearby Lawrence MA into their group and began the process of soliciting interest from others.


Horace G. Holden
Lowell MA


Henry Rogers
Lawrence MA

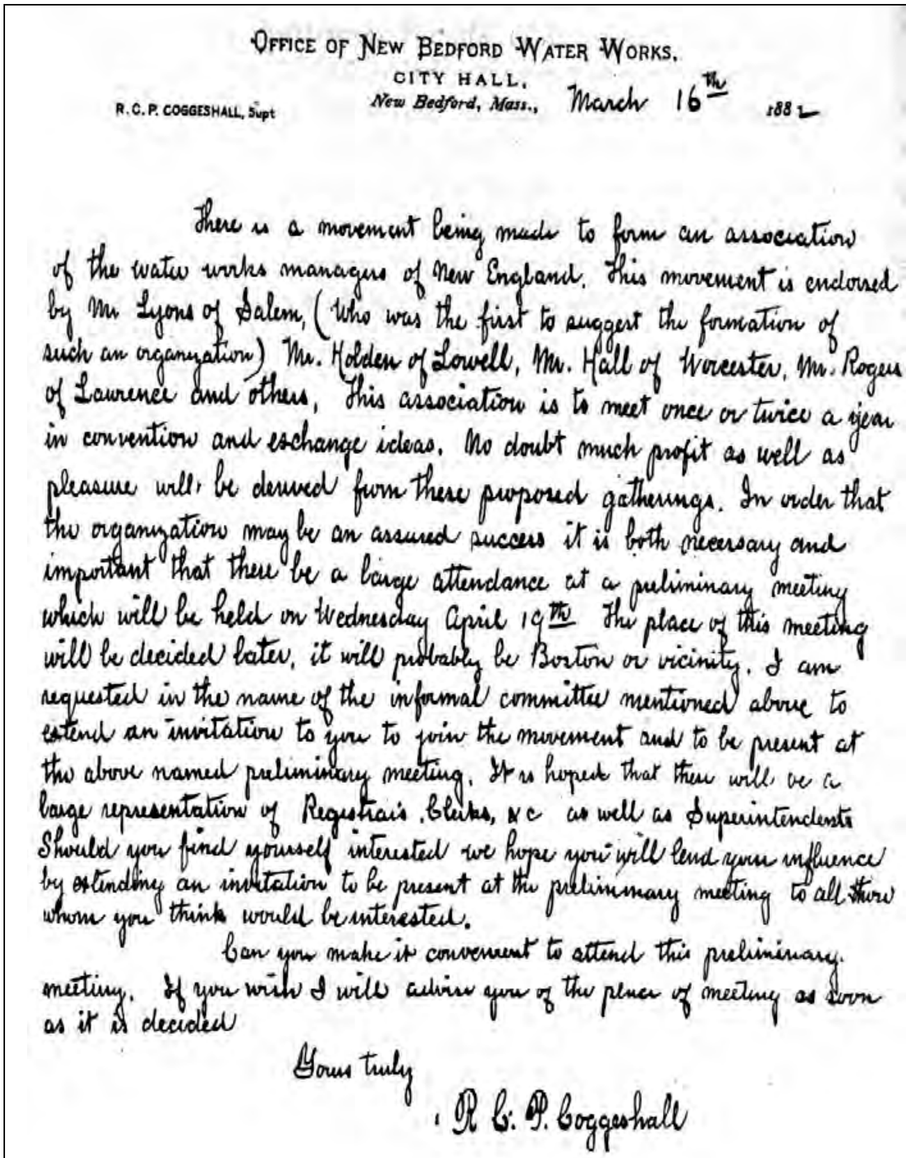

Frank E. Hall
Worcester MA


Robert C. P. Coggeshall
New Bedford MA

The original 4 men later enlisted James W. Lyons to their cause and broke down New England into 5 areas. Each directed a letter soliciting interest to all of the known water supplies in their respective area.

The Charter Members

The first meeting was held at Young's Hotel in Boston on April 19, 1882. Attending were representatives from the following communities:



OFFICE OF NEW BEDFORD WATER WORKS,
CITY HALL,
R. C. P. COGGESHALL, Supt New Bedford, Mass., March 16th 1882

There is a movement being made to form an association of the water works managers of New England. This movement is endorsed by Mr Lyons of Salem, (Who was the first to suggest the formation of such an organization) Mr. Holden of Lowell, Mr. Hall of Worcester, Mr. Rogers of Lawrence and others, This association is to meet once or twice a year in convention and exchange ideas. No doubt much profit as well as pleasure will be derived from these proposed gatherings. In order that the organization may be an assured success it is both necessary and important that there be a large attendance at a preliminary meeting which will be held on Wednesday April 19th The place of this meeting will be decided later, it will probably be Boston or vicinity. I am requested in the name of the informal committee mentioned above to extend an invitation to you to join the movement and to be present at the above named preliminary meeting. It is hoped that there will be a large representation of Registrars, Clerks, &c as well as Superintendents Should you find yourself interested we hope you will lend your influence by extending an invitation to be present at the preliminary meeting to all those whom you think would be interested.

Can you make it convenient to attend this preliminary meeting. If you wish I will advise you of the place of meeting as soon as it is decided

Yours truly

R. C. P. Coggeshall

Example of letter of invitation to join NEWWA

The Charter Members:
From Massachusetts
Fitchburg
Springfield
Worcester
Fall River
Brockton
Plymouth
Lawrence
Cambridge
Lowell
Leominster
Malden
Medford
Salem
New Bedford

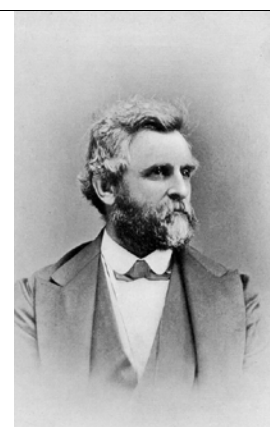
From Connecticut
New Haven

From Rhode Island
Pawtucket

From New Hampshire
Manchester

Notably absent were Boston, Hartford, Providence and anyone from Maine or Vermont.

Also present were two meter vendors, one steam pump vendor, and one former governor of New Hampshire (a friend of the Manchester NH representative and an advocate of water supply).

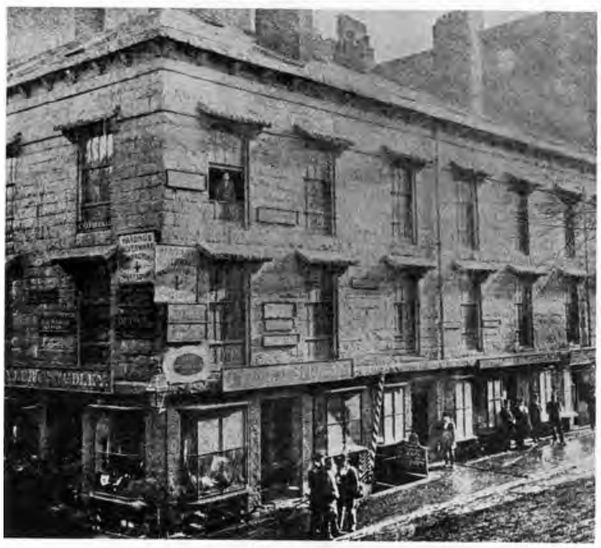


James W. Lyons, Salem MA
The First President of NEWWA

As the first business of the new organization, they appointed staff to develop a Constitution and chose Boston as the site of the next meeting in June.

There is some brief record of water discussions on topics such as wrought iron pipe, fish becoming stuck in service lines, eels in pipes and growth of sponge, algae and clams in reservoirs and pipes, all normal issues for the day. They then adjourned for a hearty dinner and lighter conversation.

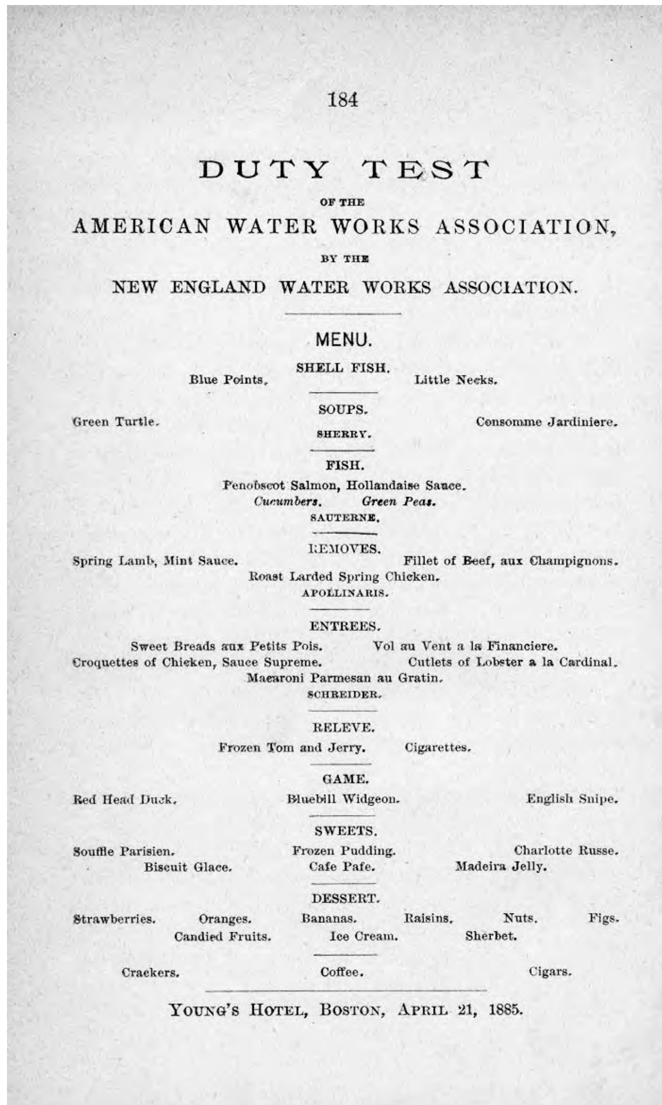
At the second meeting in Boston on June 21, 1882, the draft Constitution was adopted and a vote was taken for officers of the new organization. At this point, James W. Lyons was voted to be the first president of the organization. Other officers were named, the most important of which was the appointment of Robert C. P. Coggeshall of New Bedford to be Secretary. He became the institutional memory of the organization, not only producing the records of the early years, but also the reminiscences of his later days provided many insights to the personalities of the early members and the workings of NEWWA business. He was later elected President and then made Editor of the Journal, important and influential roles.



Young's Hotel

Young's Hotel in Boston– Site of the original conference

1883 NEWWA Annual Conference in Rhode Island



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DUTY TEST

OF THE

AMERICAN WATER WORKS ASSOCIATION,

BY THE

NEW ENGLAND WATER WORKS ASSOCIATION.

MENU.

SHELL FISH.

Blue Points. Little Necks.

SOUPS.

Green Turtle. Consomme Jardiniere.

SHERRY.

FISH.

Penobscot Salmon, Hollandaise Sauce.

Cucumbers. Green Peas.

SAUTERNE.

REMOVES.

Spring Lamb, Mint Sauce. Fillet of Beef, aux Champignons.

Roast Larded Spring Chicken.

APOLLINARIS.

ENTREES.

Sweet Breads aux Petits Pois. Vol au Vent a la Financiere.

Croquettes of Chicken, Sauce Supreme. Cutlets of Lobster a la Cardinal.

Macaroni Parmesan au Gratin.

SCHREIDER.

RELEVE.

Frozen Tom and Jerry. Cigarettes.

GAME.

Red Head Duck. Bluebill Widgeon. English Snipe.

SWEETS.

Souffle Parisien. Frozen Pudding. Charlotte Russe.

Biscuit Glace. Cafe Pafe. Madeira Jelly.

DESSERT.

Strawberries. Oranges. Bananas. Raisins. Nuts. Figs.

Candied Fruits. Ice Cream. Sherbet.

Crackers. Coffee. Cigars.

YOUNG'S HOTEL, BOSTON, APRIL 21, 1885.

Menu from the 1885 joint dinner with AWWA
Note that "Duty Test" was the term for determining fuel efficiency of steam engines in their day

A few new communities came to the June meeting including Waltham, Winchester, Dedham, Newton, and Melrose from Massachusetts and Meriden Connecticut. Together with the previous list from the April meeting, these communities were the charter members of the first year of the organization.

Growth in the early years
In the coming years, membership grew rapidly as word of the organization spread and as meetings were held in areas more convenient to other states. More vendors became regulars at meetings as well. But the core of this young organization was clearly water suppliers, the men who ran operations and personally directed the building of systems for their communities. As the years progressed, more consulting engineers began to join, as well as scientists and public health officials. Water suppliers from distant states also became interested and joined despite the difficulties of travel. Some of the more progressive systems in the country, e.g. Louisville and Richmond with their early filtration studies, were taking part in the organization to take advantage of the collective expertise in the east. The New York City engineers and water works men were also drawn to the organization and offered a wealth of experience in construction of large works. The organization rivaled the AWWA in terms of technical programs and respected participants. Membership grew rapidly to about 600 members by the turn of the century, then continued a more gradual growth to the present day total of over 2,800.

The first joint meeting with AWWA was held in April, 1885 in Boston MA and was a much anticipated event. The Mayor of Boston and Governor of Massachusetts spoke to the assemblage that included other local mayors. The program included several days of papers on a variety of technical matters. The excursion was a visit to Boston's water supply including a tour of the Sudbury River works by train and carriage. Other excursions included a tour of Cambridge's works, a tour of the old Mystic River supply and a tour of the Chestnut Hill area with Newton's filters, distribution reservoirs, Boston's aqueducts, water quality labs and reservoirs. A high point of the tour, for those brave souls that wished to partake, had to be the "sail" by boat through the active Sudbury Aqueduct from Echo Bridge to Chestnut Hill, a stretch of about 4 miles through a roughly 9 foot diameter underground conduit illuminated only by lantern light. The banquet was described as being impeccably elegant. NEWWA's reputation as host was certainly enhanced through this early effort.

The Early Meetings
How do today's NEWWA meetings compare to the early days? Some observations are offered on the nature of meetings in the late 1800's:

- On many occasions, the assemblage was led in song by some of the more vocally talented members.
- Papers were "read" literally and supporting documents like full plan sheets and drawings were prepared in advance to be distributed to participants.
- Presentations were sometimes accompanied by "lantern slides", the early equivalent of Powerpoint.
- Jokes that would now be considered politically incorrect were occasionally recorded into meeting minutes.
- Papers were read in three sessions during the day, morning, afternoon and evening. Demonstrations were held early in the morning or between reading sessions.
- Each paper was verbally dissected by an expert panel after the conclusion of the author's presentation, with agreement not being a foregone conclusion and discussions

being respectful but spirited at times. One can read some tension into some of these discussions.
- The Journal records these discussions fairly literally, noting "laughter" whenever it occurred.

One of the most useful parts of the conferences was the excursion to view local works. The conference locations were established with an eye to having a host system provide comprehensive tours of its facilities, often being chosen to highlight a major project like a new water treatment plant or dam. In so doing, NEWWA members could "kick the tires" of other system facilities and see first hand solutions to the problems of the day. This extended regionally to larger systems like New York and Philadelphia that hosted visits by NEWWA.

This 1906 photo shows a tour of Wachusett Dam construction being conducted for the Consulting Engineers of the Panama Canal. Frederick Stearns and Caleb M. Saville of NEWWA both worked as consultants to the Panama Canal project, the premier civil engineering project in the world at the time.

The early conferences were also a major honor for the hosting community and each strived to make the event unique. There was a determined effort to outdo the previous host community in terms of diversions for the guests and interesting displays. Tours wouldn't necessarily be limited to the water supply, often traveling to local tourist sites and visiting theater performances. An interesting diversion for the host water supply was to show off its pressure by an exhibition of fire streams in a public spectacle, one such example being an early canal tour of Providence during which fire streams were arched over the canal under which the touring member's boats would pass. Meals would often be banquets befitting the important visitors. Remember that early public works were highly regarded and water supply managers were viewed as men worthy of great respect for the complexity and importance of what they did.

Guests from other parts of the country would present papers at NEWWA conferences, thus sharing important advances elsewhere. International guests would also contribute with experiences from Canada, Latin America, Europe, Asia or other places of interest. A close relationship was formed with the British Institute of Water Engineers for this purpose, resulting in reciprocal papers being offered on important topics.

Officers

The organization has always run on volunteerism with literally hundreds of people contributing part of their time to the success of the overall effort. The various Boards and Committees take considerable effort and have little recognition in return.

In 125 years, there have been hundreds of people that have served as officers of the organization. A listing of past presidents is available with the annual NEWWA membership list so it will not be repeated here.

Awards

Recognition of member's efforts has always been a strong focus of the organization. The following lists the current awards granted by the organization:

Dexter Brackett

The longest running and most prestigious award is the Dexter Brackett Memorial Medal. Its namesake was Dexter Brackett, the superintendent of Boston's distribution system, a "salt of the earth" water works man who worked hard on necessary advances like control of water waste and standard pipe specifications. These things were less glamorous than water treatment technology advances and scientific issues but they were desperately needed by water system managers. His drive and attention to detail exemplified the association's roots in being helpful to the system operators.

Current NEWWA Awards	
Dexter Brackett Memorial Medal, given since 1917	John H. Chafee Distinguished Public Servant award
Past President's Award, given since 1949	Younger Member award
Award of Merit, given since 1967	Employer Recognition for Younger Member award
George Warren Fuller award	Utility of the Year award
Kenneth O. Hodgson award	Utility Service award
Operator Meritorious Service award	Legislator of the Year award
Distinguished Public Service award	Volunteer of the Year award
Scholarship award, given since 1956	Most Innovative Program award
Historical Landmark award	

The lists of recipients are published annually with membership lists so they will not be repeated here. Suffice it to say that the list of the awardees reads like a Who's Who of New England water supply.

AWWA Recognition of NEWWA

Many NEWWA members have also contributed to the national organization and received recognition. The following are awards earned by these members:

AWWA Water Industry Hall of Fame

Induction date	Name
1971	George Warren Fuller
1971	Allen Hazen
1971	Clemens Herschel
1973	George C. Whipple
1974	Moses N. Baker
1976	William W. Brush
1976	Gordon M. Fair
1978	Thomas R. Camp
1978	Malcolm Pirnie
1983	Robert S. Weston
1988	George E. Symons
1989	Joseph C. Lawler
1992	Leonard Metcalf

AWWA Past Presidents from NE

1913	Robert J Thomas
1916	Leonard Metcalf
1935	Frank A. Barbour
1990	Fred H Elwell

William N. MacKenzie
Richard P. McHugh
James S. McInerney, Jr.
Clarence L. Ahlgren
Stephen L. Bishop
Richard C. Drake
R. Patrick Grady
Alice I. Hathaway
David B. Paris
Raymond J. Raposa
John P. Sullivan
Floyd B. Taylor
Leonard H. White

A. P. Black Research Award

Year	Awardee
1977	Richard L. Woodward
1990	Charles R. O'Melia
2004	James K. Edzwald

Distinguished Public Service

Year	Awardee
1952	Abel Wolman
1984	Fred H. Elwell

Honorary AWWA Members

Kenneth O. Hodgson
Donald E. Jackson

The Journal

The Journal is the record of the organization and its issues. The Editor plays a significant role, especially in the early days when papers were followed by a discussion that was captured and included in the printed record. Several luminaries would comment on the paper and ask follow-up questions of the author, sometimes more in the manner of a cross-examination if the paper was controversial. Over the years, the Editor has been responsible for cajoling papers out of the presenters, editing for quality and propriety, handling the logistics of production and maintaining the professionalism of the overall product. The Editor position has always been a long term member that has a depth of water supply knowledge and who enjoyed the respect of peers within the organization. A full listing of past Editors is offered annually with the membership directory so it will not be repeated here.

> **Most prolific author -** Charles W. Sherman published 24 papers between 1913 and 1940. He was an engineer at M&E and expert on a variety of topics. Given his skills, he also served as the Editor of the Journal.
>
> **Most esoteric name of paper –** Multielemental and Hydrochemical Study of Holy ZamZam water

The Journal itself contains several thousand papers and the bound books occupy about 12 linear feet of bookshelf. There is a wealth of useful information on these shelves.

Offices

The organization had no permanent offices from 1882 until 1896. Business was conducted by NEWWA officers at their normal water supply offices. A home for NEWWA and its documents was found in 1896 at Boston Society of Civil Engineers' offices at Tremont Temple in Boston MA. This sufficed until 1935 when NEWWA moved to the Statler Office Building in Boston. In 1948, the office was moved again to 73 Tremont Street, Boston, then in 1968 back to Statler Office Building.


Tremont Street

With the expanding training program that was needed to support operator certification and other needs, a larger office was needed. Milford Water offered space at its facilities in what was felt to be a good central location for members throughout New England. NEWWA moved to Milford in 1988 which allowed much better training facilities and office space but, once again, growth of the organization's needs outpaced the space available.

Milford

The most recent move was to a newly constructed office in Holliston in 2004, once again to gain elbow room for NEWWA activities. Over the years, the role of the Building Committee has been critical and the membership, especially the corporate members, have risen to the challenge each time.

Holliston

Early important people

Prior to NEWWA, there were some significant water supply figures that are worthy of note. They paved the way for the early water suppliers and the 1882 birth of the organization

Significant Water Supply Figures – Pre-NEWWA	
Name	**Significance**
Laommi Baldwin	Built Middlesex Canal, consulted on Boston's Cochituate supply, "Father of Civil Engineering" in US
E.S. Chesborough	Worked on New York's Croton system, built part of Boston's Cochituate works, built Chicago's sewers and water supply, built Boston's Main SewerDrainage works
Charles S. Storrow	Wrote first treatise on waterworks engineering in 1835
John Jervis	Worked on Erie Canal, built New York Croton system, planned Boston's Cochituate Works, went on to build railroads
J. T. Fanning	Wrote 1876 *Practical Treatise on Hydraulics and Water Supply Engineering*
James P Kirkwood	First American engineer to build a filtration plant for water purification, studied European filtration methods, producing detailed design information and

	sketches
Lemuel Shattuck	Wrote *Report of the Sanitary Commission of MA*, followed the sanitary reform model set by Chadwick in England and laid the groundwork for public health
Joseph P Davis,	Chief Engineer for Boston Water, became chief engineer for ATT
James B Francis	Published "*Lowell Hydraulic Experiments*" in 1855, invented a successful turbine, one of incorporators of MIT

There are many important NEWWA members and the following only attempts to recognize some of the most important early figures.

Early water quality experts	
Name	**Significance**
Hiram Mills	The patriarch of LES, he ran the Lawrence MA canals, was the first chair of the MA Board of Health committee on water supply, worked with Kirkwood and Storrow, and trained John R. Freeman and others in his charge.
Allen Hazen	Graduated MIT in 1888 (the first graduate), was made Director of LES, his specialty was filters and sand media, hydraulics of treatment, wrote several books on water treatment, designed filters for many cities nationally and internationally, consulted for dozens of New England supplies, later formed Hazen & Whipple
William Ripley Nichols	MIT professor, joined MA BOH before LES and helped develop "Chlorine Map" to assess sanitary state of MA water bodies.
Thomas M. Drown	The original chemistry expert on the LES team, became President of Lehigh
William T. Sedgewick,	Graduated from MIT, he was the preeminent biologist on the LES team, taught at Harvard, became President of APHA
George W. Fuller	The 3rd graduate of MIT, he succeeded Hazen as Director of LES, then moved to Louisville to conduct landmark rapid sand filter studies
Robert Spurr Weston	Started as chemist working in water supply, worked with Fuller at Louisville, founded W&S, coauthored the *Waterworks Handbook*
Harry W. Clark,	Was Director of LES after Fuller, prolific author and chemistry expert
Stephen Gage	Started as chemist at LES, went on to RI Board of Health as its Chief Engineer
George C. Whipple	2nd grad of MIT, ran first biological lab at Boston's Chestnut Hill lab, early algae work, wrote *The Microscopy of Drinking Water*, formed consulting engineering company with Hazen
M. C. Whipple,	An assistant to Desmond Fitzgerald, he became professor of chemistry at Harvard, consulted on many water issues
M. N. Baker	Editor of Engineering News Record, wrote *Quest for Pure Water*, the most comprehensive treatise on early water purification
J. Herbert Shed	Wrote the 1874 report for Sewerage of the City of Providence
X. Henry Goodnough	Succeeded Stearns to run MA BOH, expert on reservoirs and sanitary protection, expert in sewerage systems, helped get Quabbin supply developed
Harrison P. Eddy	Sewerage expert, started at Worcester, consulted on many water supply issues, with L. Metcalf, wrote *Wastewater Engineering*, the bible of sewer design for many years, formed Metcalf & Eddy
Leonard Metcalf	Similar background to H. Eddy, also consulted on many water projects and NEWWA committees
Gordon M. Fair	Water quality expert, professor at Harvard, wrote *Water and Wastewater Engineering*, a text used by most Civil Engineering courses

Thomas Camp	Hydraulics and water treatment expert, wrote definitive papers on many filtration techniques, helped form Camp, Dresser & McKee

Early hydraulics & hydrology experts	
Name	**Significance**
Clemens Herschel	Expert on mill hydraulics at Holyoke Power Co, ran the Jersey City water system, invented the venturi, expert on power
John R. Freeman	Started at LES under Hiram Mills, did early work on fire protection and related hydraulics, member of Boston Metropolitan Water Board, helped NYC, Baltimore, LA, San Francisco, Panama Canal, Grand Canal in China, expert on sewer hydraulics, MIT hosts an annual lecture series in his name.
Gardner Williams and Allen Hazen	Developed the Hazen-Williams equation, hydraulic tables and the hydraulic slide rule, still the standard for distribution pipe analysis.
Dexter Brackett	Ran the Boston distribution system, early expert on pipes, led the development of the first cast iron pipe spec., expert on water waste, one of the Boston's Sudbury system reservoirs bears his name.
Frank E. Winsor	Started in Metr. Boston Sewerage Commission, worked on Wachusett, Weston Aq., New York's system, Boston's Charles River dam, built Catskill reservoirs, Kensico, Hillview, Scituate reservoir in RI, Quabbin Reservoir (the main dam bears his name).
Frederick P Stearns	He was the first Chief Engineer of MA Board of Health, he went to the Boston Metropolitan Water District and helped build the Wachusett works, he consulted on the Panama Canal and for other large sities including the LA Owens River project, a Boston reservoir bears his name.
Caleb M Saville,	Started in Boston's system, built part of Wachusett, worked as a consultant on the Panama Canal, returned to run the Hartford system through its expansion of sources to Nepaug and Barkhamstead Res.
Desmond Fitzgerald,	He managed the supply sources for Boston, published pan evaporation data that is the definitive data to this day, published hydrologic data to support safe yield standardization, oversaw the first water quality lab
J Waldo Smith	From Lincoln MA, worked with Lawrence Experiment Station, worked at New Jersey with Herschel, Chief Engineer of NYC water system, consulted on the MDC Quabbin/Ware, Providence Hartford, many other cities

The above list is very brief and is meant to honor the NEWWA members who put the organization on the path it is on today. Assembling the biographies of all of the award winners, honorary members and others deserving recognition over the 125 year history of the organization would be a worthy task but beyond the scope of this paper.

Making a difference

What has NEWWA accomplished? In the 125 years of existence, some significant water supply improvement has occurred through the efforts of NEWWA's membership:

- Municipal water supply is available throughout the region. There are over a thousand water systems in the New England states running safely, efficiently and without interruption. Compared to other parts of the world, this is an underappreciated achievement.

- Billions of dollars of water works construction has been put in place with very few unexpected results. The competence of the designers and builders has been clearly demonstrated.

- Most systems have developed capacity to survive drought with minimal impacts on consumers.

- Waterborne disease has been virtually eliminated.

- The chronic pollution of water sources has been reversed and treatment strategies have addressed risks of environmental contaminants.

- Fire protection has advanced to properly supply fire protection and eliminate conflagrations.

- Cross connections have been regulated and controlled.

- Like peeling an onion, a number of subtle but dangerous public health hazards became known through research and controlled through water treatment improvements.

- Wars, natural disasters and other catastrophes have come and gone, causing trouble but also teaching lessons about being adequately prepared.

- Water operator training and certification has reached all systems and NEWWA has been particularly good at delivering this service as documented by AWWA recognition awards.

- Public confidence in water supply is good, ranging from people who take their water for granted (a sign that they have no problems) to sincere appreciation by people who have traveled to other regions or countries that have poorer aesthetics than New England water.

While there is always room for improvement, things are looking good. The NEWWA organization has been invaluable to the continuing education of its members and the betterment of water supply performance throughout the region. NEWWA's mission is being met.

works challenge.

- In 2070, above ground hydrants will be displayed as historical oddities. *Remains to be seen.*

Now, 25 years later, we see some truth in these. Not to be outdone – I offer some things that I predict will happen:

<u>*Water supply adequacy*</u>:
Trend – Regulatory philosophy has swung to more aggressive protection of the environment, squeezing water supplies for the sake of relieving stressed river basins. The regulatory rationale is targeting excessive per capita water use with the idea that the river benefits when elective uses like lawn watering are minimized.

Prediction – Some communities may actually have diminished rights to historic supplies or lose them altogether. Regionalization may be pushed to reduce water withdrawals in sensitive areas.

<u>*Emerging health threats*</u>:
Trend - New threats loose in the environment include things like endocrine disrupters, pharmaceutical compounds, personal care products and the like. Existing organisms may develop treatment resistance or change properties.

Prediction –Water suppliers will struggle with a new genetically engineered or mutated biological threat that either slips past treatment or becomes resident in biofilms in pipe.

Prediction – A long trusted plumbing material (like copper? plastic? brass?) will turn out to have health impact to the point that it will need to be replaced.

<u>*Water quality monitoring*</u>:
Trend - Policing distribution system water quality in the post-9/11/01 era requires more than just source monitoring and backflow awareness.

Prediction – DNA based tests of specific pathogens will eventually replace TCR Rule coliform tests, both to widen the net for unusual pathogens and secondly to speed up the time necessary for results.

<u>*Treatment chemicals:*</u>
Trend – Some of the things that we add (e.g. chlorine, fluoride, aluminum salts, copper sulfate, carbonates) are known to cause health problems at higher doses but we use them based on the idea that, like aspirin in pain management, a small dose solves the problem at hand.

Prediction – Some of the chemicals currently used in common water treatment applications will be found to be a problem and will need to be phased out.

Prediction – Treatment will eventually become more physical (e.g. membranes, UV,) and less chemical.

Prediction – Source water treatment requirements will someday be tightened to produce ultrapure water, then consumer connections will be equipped with polishing treatment (to address distribution system issues like iron particulates, biofilm bacteria).

<u>Infrastructure</u>
Trend – With the huge amount of aging cast iron pipe, most communities have focused on larger mains first to improve hydraulics, leaving a large backlog of small diameter tuburculated laterals.

Prediction – A more practical chemical treatment/relining method will be developed to rehabilitate smaller laterals.

Computers

Trend – Customer metering has already seen the emergence of Automatic Meter Reading systems. SCADA and process control have evolved to allow more on-line analyzers. Near real-time data collection is now possible from a variety of home devices.

Prediction – Someone will produce a multipurpose metering device for each service connection that will read flow, pressure and leak sounds as well as water quality parameters to allow alarms and real time management of the entire distribution system.

The business of water

Trend – The rising cost of water, aging of water systems and lack of financial resources for many communities has made contract operations an attractive option. Public utilities face more competition with privatizers and are tending to trim down on staff and resources.

Prediction – More communities will seek contract operations and there will be fewer but larger private water companies remaining to fill the need.

Prediction – Design/build projects will become more common but traditional separation of design and construction will continue to provide the bulk of projects in New England.

<u>NEWWA's future</u>

Trend – NEWWA's management team and award winning training program will continue to offer timely programs on emerging issues while helping mentor the next generation of water works people in the basics of water supply.

Prediction - One thing that can be predicted with complete confidence is that NEWWA activities will produce better educated and experienced water professionals.

Chapter 8 - Where will the future go?

We study the past to foretell the future. Taking inspiration from the 100th anniversary of NEWWA, the noted prognosticator Don Burford, a.k.a. "The Water Wizard" left us a time capsule in the form of some tongue in cheek predictions at the 1982 Centennial conference, including the following:

1982 Predictions (paraphrased a bit for brevity)	***2006 Accuracy***
• Dual systems will not catch on.	*True.*
• By 1987, every well-run water system will have a computer and every home above the poverty line will have a computer.	*True, albeit a bit later than 1987.*
• By 1990, deferred maintenance will be the exception because our systems will be failing catastrophically with consumers accepting doubling and tripling rates.	*Maybe not quite as dire but true as far as rates.*
• By 1990 widespread use of aeration, GAC and resin adsorption will meet the challenge of contaminated groundwater.	*True.*
• By 1992, "point of use" treatment will increase dramatically.	*Not true yet.*
• By 1992, MDC will finally complete the Northfield diversion.	*Not true.*
• By 1993, it will at last be understood that New England is short of cheap water but rich in water needing a little treatment and a little movement.	*Still not the popular view.*
• By 1995, internal corrosion will be licked.	*Methods known but a slow path to solution.*
• By 1997, most utilities will use self propelled "torpedoes" to conduct surveillance of their distribution systems.	*Not true yet some devices come close.*
• By 1997 waldos (gloves that transmit movement to mechanical hands) will compete with robots for work in hazardous areas.	*Not true yet.*
• A 1998 survey will show that water works personnel are at last being well paid	*Arguably not true.*
• By 1999, a "new wave" of "responsibility taking" will sweep the nation.	*Not yet.*
• By 2000, Metro New York will have 22 million people and New England will grow by 1.5 million people.	*Not true.*
• In 2000, SDWA will be looked upon as being far sighted for its famous section regulating anything that "may have an adverse effect on health".	*More true than not.*
• In 2002, gold will no longer be a monetary standard but money will be based on control of energy, land and water.	*Not true but water is a more political issue*
• By 2015, plans will be complete for the Long Island Sound Fresh Water Reservoir but the project will be delayed and dropped.	*Pretty unlikely.*
• By 2020, inexpensive solar energy will fuel the return of industry to the "Sun Belt" due to plentiful water from desalination. Brine disposal will remain a problem.	*Has an element of truth as membranes improve.*
• By 2030, there will be expanded development of modular communities using package energy and water plants.	*Remains to be seen.*
• In 2032, at the 150th Anniversary of NEWWA, it will be noted that large waterborne outbreaks will be eliminated throughout the world. However, cross-connections will continue to be a problem	*Remains to be seen.*
• In 2050, treatment for radioactive material will be the biggest water	*Remains to be seen.*

A Closing Thought – Appreciating History

In the day to day world, we don't think much about our heritage. Yet we live in a historic part of the country and some of our facilities are nationally significant examples of our industry. NEWWA has a historic recognition program, as does AWWA, mostly for designation of a particular facility as a historical landmark. This is to be encouraged but I urge you to also consider the history, the stories and the people who came before you and make an effort to document what you have learned about your system for those who follow. This is a small return for the education that you have been given by people who shared with you. A good water system history also helps immensely with public education and community pride in its achievements. There can be incidental benefits such as getting support for needed improvements or just cooperation in such areas as source protection.

NEWWA's offices have some interesting historical resources but space is limited and a more comprehensive and publicly accessible museum could be a regional resource. Some other local specialty museums like the MA Museum of Public Health and the RI Museum of Steam Pumping are examples of smaller museums that fit a niche. Nationally, Philadelphia has a water works museum that celebrates their status as an important early system. It is housed in the Greek temple-like buildings of their early Schuylkill supply and has a well developed interpretive history center. Baltimore has a sewerage museum near its Inner Harbor area (I will have to admit that you can smell it well before you get close to it). New Haven CT has created a small interpretive center focusing on water supply.

Locally, there are historical exhibits at many utility offices and consultant offices but little continuity between them. Upcoming possibilities for improved water works exhibits include the former MWRA Chestnut Hill Pumping Station, a MA Historic Landmark, which was recently surplused with the stipulation that redevelopment include museum use of the engine room that houses the ASME Historic Landmark Leavitt Engine. This presents an interesting opportunity to present water supply history in an impressive backdrop. Public interest regarding major public works is not unusual, especially something like water supply that touches everyone's lives, so perhaps a successful museum can be leveraged to generate interest in the other intriguing water facilities found throughout New England.

The last suggestion is to keep recognizing the people. Personally, I think a New England Water Works Hall of Fame could be an interesting thing, but the list of Honorary NEWWA members and award winners is a great start.

Thanks

Thanks to a couple of my old mentors, Jim Matera and Russ Babcock, who had such infectious enthusiasm for water supply history that it sparked my lifelong interest in the subject. I thank Ray Raposa for suggesting this history for the 125th Anniversary and trusting me with the treasures of the NEWWA library. I thank all the people who helped me collect material, especially Rebecca Kenney and Mary Lydon at the MWRA Library. I thank the volunteers that helped review the draft paper, especially Pat Grady, Bernie Lucey, Denise Breiteneicher, Chuck Larsen, Jim Powers, Kirsten King and Peter Karalekas. I thank my wife Martha and all of my *various bosses, past and present, for their patience with my ever growing collection of historical material.*

Bibliography

Most of the information for this paper was derived from a review of the entire New England Water Works Journal. For brevity, the specific papers reviewed will not be listed here since there are several thousand. For further information on any topic area, the Journal Index is the best starting reference.

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Ductile Iron Pipe Research Association – development of pipes, Cast Iron Century Club
American Institute of Steel Constructors – Historic tank listings, Century Club
New England State Government sites – Information on history, firsts, Public Health history
National Register of Historic Places – Listings of historic structures by state including water supply facilities
Municipal web sites – Many water systems provide on line histories.
Many local landmark sites have a local committee that has posted historical information.

The NEWWA library also has many reports from member systems with detailed historic and engineering information.

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19	Cambridge Standpipe	Reservoir and standpipe at Reservoir Street, Photo 1896-1897. House is 29 Reservoir Street, C.H. Wright Collection, Cambridge Historical Society Album, Cambridge Historical Commission
19	Lawrence Tower	M. Kempe photo
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3	1883 conference	NEWWA Journal, Centennial Committee, A Remarkable Hundred Years V96, No 3, Sep 1982, P187
3	AWWA/NEWWA Dinner menu	NEWWA Journal, Centennial Committee, A Remarkable Hundred Years V96, No 3, Sep 1982, P183
5	Panama Canal engineers	NEWWA Journal, Centennial Committee, A Remarkable Hundred Years V96, No 3, Sep 1982, P189
6	Dexter Brackett	NEWWA Journal, R. Coggeshall, Some reminisces, V18, 1904, p312
8	NEWWA Tremont St office	NEWWA Journal, V11, 1896, p276
8	NEWWA Milford office	NEWWA Journal, Cover V102, No 3, Sep 1992
8	NEWWA Holliston office	NEWWA Journal, Cover, V116, No 1, Mar 2002
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1	Water Wizard	MWRA school education sketch