Hidden Waterways of the Lowell Canal System
Hidden Waterways of the Lowell Canal System

Al Lorenzo

2007
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Acknowledgements</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to the Subterranean.</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>The Role of the PL&amp;C and the Corporations.</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>The Hidden Waterways.</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>The Moody Street Feeder.</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Two Other Underground Schemes that were abandoned.</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>The Merrimack Feeder.</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Mechanic Street Feeder.</td>
<td>26</td>
</tr>
<tr>
<td>4</td>
<td>The Boott Penstock.</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Chronology of the Penstock</td>
<td>34</td>
</tr>
<tr>
<td>5</td>
<td>The Subterranean Powerhouses.</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Merrimack Manufacturing Company.</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Lowell Machine Shop.</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Hamilton Manufacturing Company.</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Appleton Manufacturing Company.</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Middlesex Company.</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Massachusetts/Prescott Manufacturing Companies.</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>The Prescott Mills.</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>The Massachusetts Mills.</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Boott Cotton Mills.</td>
<td>78</td>
</tr>
<tr>
<td>6</td>
<td>Tremont and Suffolk Mills and the Lawrence Manufacturing Company</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>The Western Group of Manufactories.</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>The Role of the Western Canal in the Western Group.</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>The Role of the Northern Canal.</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td>The Suffolk Manufacturing Company.</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>Motive Power of the Suffolk Manufacturing Company.</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>Proprietors of the Tremont Mills.</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>Lawrence Manufacturing Company.</td>
<td>129</td>
</tr>
</tbody>
</table>

Bibliography -
Acknowledgements

By now we have reached six years of research and writing in an effort to bring the history of the Lowell Canal system to interested readers. This is the fourth book and it promises to be the most difficult because no one actually addressed this aspect of the system fully in print to date, at least that has been uncovered.

Photographs and illustrations will be scarce for the simple reason there are not many in the files. The Proprietors of the Locks and Canals on Merrimack River (from here on PL&C) kept records of much of their own work for the Company and many photographs when the camera became available, When James B. Francis became the head engineer for the PL&C in 1837, his daily work books make many mentions of work done for the mill corporations under the blanket of the PL&C.

The fact is the PL&C built many of the mills and produced the mill machinery in their machine shops and records of the work appear in those workbooks as in earlier records from newspapers and other sources. So does mention of construction of the wheelpits that contained the water wheels and turbines. Of the waterways that made it all work? It seems they were treated as a sideline. Within the research, enough text and sketches can be provided to give some substance to the story to create an interest and provide a background of history for the reader. It is quite possible this small volume will perk up the reader’s interest enough so they’ll want to see what they missed in the other three books. It takes them all to complete the story and well worth reading.

This work was made possible by the generous efforts of several people who were of the greatest help in putting the finished product together. The order of the listings takes away nothing for my appreciation to all.

The National Park Library was a prime source for much of the research material and Jack Herlihy did his best to help out. Dan Walsh was more than willing and able to contribute his expertise and he did to his utmost.

The Center for Lowell History, UML, as usual was a great source of information and Martha Mayo is an exceptional editor. The support of Janet Pohl is one of the main reasons why the finish work exists.

Bud Paquin was instrumental in producing the finished product that you are reading and his workmanship added greatly to the author’s endeavors, and in fact made it possible.

Thank you all.
Chapter One
Introduction to the Subterranean

The entire Lowell Canal System is certainly an object of beauty when full to the brim and the waters serenely flowing between granite stone banks on its journey from the Merrimack River through the canals and returning to the river when its job was done. This observation by any viewer would send him on his way perfectly content that he had experienced all that there was to experience. He had come; seen and understood all there was to understand.

In reality he was as the blind men describing the elephant they had touched or the person who appreciates the classical lines of the cruise ship from the beach as it steams by in the distance. Neither has any real comprehension of what they are feeling or looking at except for the picture their senses are providing. The blind men come away with impressions of the trunk, ears, belly, tail, etc. and are satisfied that each knows the true shape. The observer from the beach is satisfied with the beauty of the ship’s form sailing majestically on the sea, never giving a thought to the enormous engines in its bowel that propel it and turn the electric generators that supply the power to every commodity needed for the good life aboard.

Likewise, the water viewed in the canals in all its serenity is deceptive. The pleasant view of its calm surface a contradiction. The power contained between these walls of the canal banks is unbelievable to all except those who were exposed to the results of the work done day after day without letup at the mill complexes that tapped this power to run the cotton looms inside.

Even if the reader has toured and examined the entire five and one half miles of canals that comprise the Lowell Canal System, at least another several thousand feet of waterways exist underground and out of sight. These can be designated as penstocks, raceways, head and tail races, and at least in one instance as a feeder and all will be more fully described as they are introduced in the text. Except for the feeder, all serve the same purposes, supplying water to the wheelpits from the canals or providing a path from the wheelpits for the water to return to the canal system to be reused, or to the Merrimack and Concord Rivers. As the reader will in no way understand any of what he reads without at least some idea what the terms above are describing, a short description will be given here.

Feeder is referring to a waterway of a design to move a large amount of water from point ‘A’ where it is to point ‘B’ where it is needed. There is only one discussed here and that is the Moody Street Feeder that runs from the Western Canal to the Merrimack.

Penstock parallels the feeder in operation but on a smaller scale as far as volume and usually supplies water to a specific destination.

Flume is a channel usually inclined somewhat to carry water for power.

Wheelpit is the underground chamber constructed for the exclusive purpose of containing the water wheel or turbine on its mounts.

Raceway is usually the term applied to any waterway involved in the supply or exit chain of the water without a specific purpose designated.
Headrace is the term given to the channel designed to supply the wheel or turbine with waterpower.

Tailrace provides an exit path to remove the water from the wheelpit.

Forebay is simply an enlarged area in the channel where the water could collect before entering the wheelpit.

Millpower (sometimes referred to as mill privilege) is the measurement of the waterpower that the individual mill complexes purchased from the PL&C.

Backwater is the term used to describe high water in the tailraces that impeded the operation of the waterwheel by flooding the wheel pit.

It is doubtful if this book would be of any interest unless some knowledge of the canal system and its operation were experienced by the reader. It could be said that it would be like starting in the middle but this is what the system is all about. Providing the waterpower to the mills and the looms. It is the only reason that the power canals were built in the first place. And hopefully this book will provide if not a working knowledge of the operation, at least a fairly comprehensive overlay of these waterways that furnished the waterpower that was the lifeblood of the industrial empire called Lowell.

For the sake of understanding, best we start at the beginning in case this is the reader’s first foray into the world of working canals. Presumably the reader has at least viewed a canal somewhere along the line but let’s start with a layout of the canal system and the mill complexes that they feed waterpower with this map.
The Role of the PL&C and the Corporations

It was the obligation of the owners of the canals, the Proprietors of the Locks and Canals on Merrimack River (from hereon the PL&C), to supply the necessary waterpower in the canal system and to keep the canals free of any debris that would impede the mill operations. Moving the water from the canals and into the mills was the responsibility of the individual mill corporations but these waterways were usually built and maintained by the PL&C under contract as well. The corporations didn’t have the expertise and the waterways would still have to be built to specifications drawn up by the PL&C to maintain continuous integrity of the system. The work force and material already existed at the beck and call of the PL&C so why look any further.

The PL&C also wrote the rules and regulations for the construction and operation of these underground raceways. Where they left the canal proper, a set of gates had to be installed and maintained at the top of the headrace in order to control the volume (millpowers) and to enable PL&C to shut off the flow of water for necessary repairs. They even maintained the right to be able to hold back the flow by shutting these gates if for any reason the corporation fell into arrears. It was fairly difficult to measure the amount of water flowing into any single headrace but the PL&C retained the right to measure the volume as it exited the tailrace after leaving the wheelpit. Only so much water was contracted for and it was only good business practice to check what each corporation’s actual use was.

Usage probably balanced out pretty well in the long run. At times of low water in the river, the mills always complained about the decreased amounts of water flowing through the wheels or turbines, and thus the mills were running slow so they would open the head gates all the way to feed maximum water into the headraces. They only paid for the mill powers contracted. When the river was running high, it was pay back time and if the PL&C didn’t have some control on usage, they might just as well been giving the millpowers away.

The entire story of the Lowell Canal System is told in the second book in this series, The Canals That Powered a Textile Empire. To rewrite the entire book here would serve no purpose but it should be read in conjunction with this book. The tale of what the corporations had a right to expect in the way of a water supply from the PL&C deserves retelling before we continue.

The head of the water in the upper Pawtucket Canal, and later the Northern Canal too, was supposed to be maintained at 30 feet. If the Merrimack River was higher, the height in the canals was supposed to be controlled by the various gates at the dams at the Swamp Locks, Lower Locks and the Hickey Hall Dam on the Western Canal. The entire canal system was designed with these levels serving as the gospel and the water wheels in each mill were constructed to run the most efficient at these levels of water. Too little head and the looms ran at slower speeds limiting production. Too much head and the wheelpits would flood through the tailraces because the water used in the wheelpits couldn’t discharge back into a lower level achieving the same disastrous results. When turbines were introduced in the late 1840, the machines proved much more tolerant to fluctuations in the water levels and especially the backwater in the wheelpits.

Remember that the Pawtucket and Western Canals that were the feeder canals for the Western and Eastern Groups of mill complexes were constructed on two different levels to achieve the drop in the water level, and thus the difference in the head that developed the waterpower. The drop in the upper level was 13 feet and the drop in the lower was 17 feet accounting for the full 30 foot drop. If the
reader is confused because this book alone was read or read first it is understandable. But read on and give the big picture a chance to expand.

Consulting the map on page eight and following the description of the individual mill complexes and their location on the canals in the system will greatly help to define the difference between Upper and Lower Canals and the purpose of the drop in the head (water level) as it passes over the falls.

The Eastern Group is comprised of the Appleton and Hamilton Mills on the Upper level of the Pawtucket Canal, and the Middlesex, Prescott, Massachusetts and Boott Mills being fed from the Eastern Canal on the lower level. The water fell 13 feet over the Swamp Locks Dam (also called upper or middle) and so created a difference of 13 feet in the head or water level between the Hamilton Canal which fed the Appleton and Hamilton mills and the Lower Pawtucket that received the discharge from the two mill’s wheelpits. This difference in the falling water levels is what turned the water wheels or turbines.

The lower level mill complexes utilized the 17 foot difference in the levels between the Eastern Canal and the Merrimack and Concord Rivers to create the power to turn those wheels, the canal waters falling from the canal and through the wheelpits into either of the two rivers. This example holds just as true for the Western Group fed from the Western Canal, the Suffolk and Tremont Mills comprising the upper level and the Lawrence Mills the lower. The Lawrence Mills are actually fed from the Lawrence Canal which is no more that a raceway into which the waters from the lower Western Canal flowed.

The Merrimack Mills were left to constitute their own group fed from the Merrimack Canal. The canal waters were supplied directly from the Upper Pawtucket. It was the only mill complex that used the entire canal head of 30 feet in its operation. It was fed from the Upper Pawtucket Canal and its wheelpits emptied directly into the Merrimack River. But along the route of the Merrimack Canal, the Lowell Canal branched off to feed the Lowell Manufacturing Company. This secondary canal traveled 500 feet and dropped 13 feet into the Lower Pawtucket to turn that company’s water wheel in its cotton mill.

A fair question to arise right about here is the apparent inequity in the amount of power being dealt out to the various mills. Certainly the 30 foot drop in head is going to provide more power that the 17 or 13 foot drop. All the mills purchased the same mill powers so how was this discrepancy corrected. The best explanation is probably to quote the formula for mill powers from the Form of Lease of Water Power at Lowell. This was the contract between the PL&C and the Corporations and this was what the mills expected.

Article 1 –“Each mill-power or privilege at the respective Falls (ed. note – Swamp Locks or Lower) is declared to be the right to draw from the nearest canal or water course of the said Proprietors so much water as, during fifteen hours in every day of twenty-four hours, shall give a power equal to twenty-five cubic feet per second at the Great Fall (Pawtucket Falls), when the head and fall there is thirty feet”- (This is establishing the designed water height of 30 feet) It goes on, “-to forty-five and a half cubic feet per second at the Lower Fall, (Lower Locks) when the head and fall there is seventeen feet – and to sixty and one half cubic feet per second at the Middle Fall (Swamp Locks) when the head and fall there is thirteen feet.” So what the PL&C is doing is making for the difference in the fall of the water in the upper and lower canal is to increase the volume passing through the respected falls. There is more to the quoted article but let’s leave well enough alone if this much can be understood.

If this is the reader’s first foray into the canal system, a canal full of water is just that, a lot of water. What’s the big deal? And even if there is an interest in the purpose of the building of the canal
system it would be hard to perceive any real features of the workings. Much easier to understand if viewed when the canals are drained of water. Seems self-defeating but the water blocks the view of the working parts. It does no good to describe in a text the underground raceways if no indication of their existence can be offered. For sure, they are all covered and some even buried during more recent developments but there are enough signs of their presence, and accompanied with photos, sketches and illustrations from past records, the ultimate goal of the building of the system can be appreciated.

Here is a prime example of the Hamilton Canal full of water. Not much can be seen except water. The scene belays tremendous Force of its power the water is Pouring through the headrace and into the wheelpits to turn the water wheels and turbines.

Lowell National Historical Park Collection

This is the same view from a later date that accounts for the slight variations. In the top photo you see water. In the scene on the left you see the racks covering the headraces to the waterwheels and turbines, what it’s all about.

Photo by Author
The Hidden Waterways

Describing the locations of the surface canals in Lowell is fairly easy. The photographs used to show them may have lost something over the years as many of the mill buildings that framed the photos of the canals were torn down. This took away much of the identification of the location of the canals to the present day viewer, and even some of the streets in the area had changed names but for the most part the streets were still there that showed in the old maps.

The underground waterways have been exposed to a different fate. In many cases there are no landmarks to associate with clearly to establish their one time location. There may be no remnants of their one time existence left at all. The entire past may be locked up in just a few lines drawn on an old illustration, or maybe only a sketch of their one time route indicated that explained all that had to be known back when. An interested party may be able to follow some of the few archways and openings in granite stone walls and reap a great reward in a history lesson.

So the goal here will be to compile what records are available in text, photos, maps and sketches to hi-light the footprints of the underground waterways. They were the tie between canals and canals; or canals and the mills and steered the lifeblood of the waterpower from where it was to where it had to be. Many of the sketches used to illustrate the paths that the raceways wove in their underground course will be pre-Northern and some after the construction of the Northern Canal (in the case of the Western Canal).

That leaves the question of where to start. And that presents more questions. The primary object is to inform the reader and perk his interest in the history of the canal system, what and how it achieved its goal serving transportation and then industry. The reading of this book probably should have followed the reading of the *Canals that Powered a Textile Empire*” as it is almost a supplement to it, but then again, any place the reader starts is the right place.

Here, we will start with a description of the largest and longest of the underground waterways, outline two that were planned and never built and then get into the raceways that serviced the individual mills. If the reader finds himself getting bored from lack of interest, a walk taken to view any of the openings that defined the raceways first hand, at least their existence might become a reality and not just described by text.

Another problem confronting the reader is not, really knowing what purpose the water power serves when it reaches its destination at the mill sight. So it turns water wheels and turbines. Can a mental picture actually be developed of this procedure if neither has ever been experienced by the reader? Most likely not. The only way to fully explain this motive action is to compile a separate book that will outline the series of developing steps from the gates at which point the penstock leaves the canal or at least from the forebay supplying the water to the wheelpit beginning at the water wheel and follow each step through the mill machinery.
Chapter Two
The Moody Street Feeder

The grand daddy of all the covered waterways, bar none, is the Moody Street Feeder shown as a dotted line in the center of the map on page eight. Approximately 1,400 feet in length and averaging 30 feet in width the depth of the feeder was given as approximately ten feet in the middle. It probably deserved to be cataloged as a canal but that’s not the title it was given at conception and who are we to second guess the builders.

The Moody Street Feeder originates from the eastern bank of Western Canal between Morrisette and Moody Streets. This location places it only a few hundred feet from where the Northern Canal enters the Western at the opposite bank. The goal of the feeder was to intercept the waters from the Northern Canal and funnel it into the raceways of the ever water hungry Merrimack Mills via the Merrimack Canal.

This is the entrance to the Moody Street Feeder leaving the Western Canal. It was constructed as three single parallel channels covered over by Moody Street for its entire length. The canal is somewhat drained down so the archways are clearly visible and the stonework can be readily appreciated.

Photo by Author

This photo show the Moody Street Feeder as it exits from under the street and enters the Merrimack Canal. The gatehouse on top served just that purpose. It housed the machinery that enabled the operator to control the water flow between the two canals.

Photo by Janet Pohl
The map on page eight does indicate the position of the Moody Street Feeder in relation to the other canals and mill complexes which was the object but why that name, simple, Moody Street was dug up and the feeder built in the excavation. On completion of the underground channel, it was backfilled and the street rebuilt. The map below will outline the location of the Moody Street Feeder in relation to the streets in the vicinity along with two other feeders proposed in 1855 and deemed necessary at the time but never built and all identified by the numbered arrows.

Reproduced from ‘Sundry Papers’ by James B. Francis, 1855

Arrow #1 identifies the Moody Street Feeder with the angled entrance from the Western Canal and the angled exit into the Merrimack Canal.

Arrow #2 indicates the proposed location of the never built Mechanic Street Feeder. It was designed to flood the Swamp Locks Basin with water from the new Northern Canal via the Western Canal.

Arrow #3 indicates the Merrimack Feeder that was to connect to the Inner Canal and distributed the water from the newly completed Northern canal to the Merrimack Manufacturing complex. This feeder was also never built.
The photograph on the bottom of page 15 depicts the exit of the Moody Street feeder into the Merrimack Canal. The gatehouse on top has been photographed and written about many times but for some reason the feeder is treated only to a mention if at all. Being buried it’s out of sight and certainly out of mind. The building of the feeder is often described as completed in 1848 along with the Northern Canal but an article from the newspaper, Lowell Courier seem to rebut that statement. The January 1, 1848 edition states “Materials are now in readiness for bringing the water in a subterranean aqueduct underneath Moody Street into the Merrimack Canal. This aqueduct will be completed next summer.”

No mention of any digging. Only the fact that preparations for the construction of the feeder were in place. Even though it’s only a single observation its hard to dispute an eye witness as to the exclusion of all others, especially if the ‘others’ are based on modern day interpretations of past records. But the Cultural Resources Inventory, a work commissioned to catalog the historic structures in the City of Lowell in 1979 states that “the feeder was build during the second year of the Northern Canal project.” It goes on to add “completed by 1848 and opened in 1849.”

Too many discrepancies have been found in some recent texts of the past history of the canal system and one seems to beget the next and soon it becomes documented as fact. It’s only a small singular mistake at first but add up enough inconsistencies and they tend to get to be big mistakes and its enough to distort the overall historical picture.

To continue on, at the PL&C Directors meeting of September 15, 1846, it was decided to enlarge the Western Canal and run a flume or watercourse from the New Canal (Northern) to the Merrimack Canal. This was to be the Moody Street Feeder. But for some reason it took until December, 1847\(^4\) to obtain the necessary permits from the City of Lowell and April, 1848\(^5\) to settle on a width of thirty feet with regulating gates at the eastern end of the feeder (Merrimack Canal end). These entries in the Directors Minutes seem to support the dates in the preceding paragraphs as to the construction and completion of the feeder regardless of the conclusions of any other sources.

In one way the Moody Street feeder was unique, different from any other in the fact that it was constructed entirely from brick excepting the granite archways that herald the beginning and end. The bottom was covered with wooden planking to reduce the friction of the water as some of the canals were.

The feeder was comprised of three separate aqueducts over the entire length. Each of the three channels had brick laid for the walls rising to an arched overhead and together supported the road. Quite possibly a single 30 foot span would have resulted in to much strain from the weight of the load above and so it was divided into three separate ten foot chambers. The aqueducts were constructed in a straight line from the Western to the Merrimack Canal under Moody Street. At the beginning as the channels left the Western they were angled at 45 degrees allow the rapidly flowing water to enter at a fairly smooth rate without backing it up into the canal because of friction. Again it was angled at 45 Degrees as it intersected with the Merrimack to avoid the turbulence that would have been created by a head on collision with the two fast flowing currents. The Merrimack Canal was widened from where the feeder connected to the canal down to the Inner Canal, the wasteway and the Boott Penstock.

A drawing or photograph is worth a thousand words so let’s take a minute to examine the construction of the Moody Street feeder illustrated by what is believed to be two undated photos of the subterranean raceway. In any case the brick domed chambers and walls are unbelievable as are the fact that three of them over 1400 feet long each were excavated, built, backfilled and the street above them rebuilt in less than two years.
This view depicts the ten foot wide tunnel with five workers staring back. The bottom appears to be covered with debris and some sort of square bucket to remove it.

Both Photos from PL&G Collection Center for Lowell History

Canal workers with their numbers stretching into the background. The brickwork in both photos stands out. The arched overhead is visible in all its grandeur.

Both pictures are quite evidently posed and these unnamed faces will always remain anonymous. The results of their work outlasted them by decades and will probably outlast us by at least the same amount of time if not much more.

What remains a mystery is the source of illumination. It actually appears to be reflecting off the walls in both photos. Being undated there’s no way of telling if electricity was available but in the lower picture there could be a gas fixture with a petcock to control it projecting from the lighted patch on the left wall.

With a little perception the wood planking can be made out on the canal bottom in the lower photograph.

The whole purpose of the feeder was to add to the water level of the Merrimack Canal. This would greatly alleviate the seasonal water shortage to the Merrimack Mill Complex but the secondary function of the waterway was to raise the level in the water starved Eastern Canal. A wasteway controlled by a dam ran from the end of the Merrimack Canal to the river and from this wasteway the Boott penstock was constructed to funnel water into the Eastern.
The Northern Canal ran directly from the Merrimack River to the Western Canal as is obvious from the drawing on page eight. This meant that the water had the same head as the river that was two feet higher than that from the Pawtucket Canal. The lower level of the water in the Pawtucket resulted because of the longer semi-circular course and the resulting loss in head because of the narrowness of the Pawtucket and the friction caused by the water flowing through the irregular shape of the banks and the bottom. Consequently the torrent of fresh water reaching the Western Canal from the Merrimack River through the Northern reversed the current in the Western (fed from the Pawtucket through the Swamp Locks basin) and poured water back into the Swamp Locks.

This additional volume assured that the Suffolk, Tremont and Lawrence Mills also would be well supplied and supposedly the Merrimack as well through the Moody Street feeder. We are primarily discussing the feeder but as the saying goes, all ships rise and fall on the same tide. In other words, everyone ultimately benefited from the building of the feeder.

The map on eight should be consulted from time to time as all of these canals and mills are mentioned to establish at least a familiarity with the relevance of the location with each other. The preceding explanation of the new waters from the Northern Canal and its distribution through the canal system was fragmentary at best as each step was outlined individually as they occurred in the bigger picture. Let’s repeat the actions of the Northern Canal waters as it flowed through the system and the ensuing results as one large picture for a better understanding and consulting the maps as we go.

The Pawtucket and Northern Canals left the Merrimack River within a few hundred feet of each other. Whatever the level in the river was, that was the head of the water at the beginning of both canals. Because of the topography of the land and the fact that the Pawtucket Canal followed the course of the existing Speen’s Brook, the Upper Pawtucket followed a somewhat meandering course until it emptied into the Swamp Locks Basin from where all of the power canals except for the Eastern originated. This also meant that the Pawtucket had already traveled almost 2400 feet longer than the entire length of the Northern over a very irregular course. Here is where the friction and resulting loss of head begins to enter the picture.

The complexes being fed from the upper canal were still in comparatively good shape water wise. This included the Appleton and Hamilton Mills fed from the Hamilton Canal, the Machine Shop and the Merrimack Mills fed from the Merrimack Canal, and the Lowell Manufacturing Company that alone was supplied from the Lowell Canal. The Western Canal was its own entity serving the Tremont, Suffolk and indirectly the Lawrence Canal and mills. The map on page eight illustrates the locations of these mills and the canals that served them very clearly.

The mill complexes fed from the Eastern Canal and supplied from the Lower Pawtucket Canal were a different story. This whole Eastern Group comprising the Prescott, Massachusetts and Boott Mills were isolated from the rest of the system (shaded on map). While the Moody Street Feeder performed as was expected by increasing the level in the Merrimack Canal, the effect on the Eastern Group was minimal until the Boot Penstock was constructed tying the wasteway of the Merrimack Canal into the lower end of the Eastern Canal. That didn’t solve all of the problems by a long shot. It did succeed in siphoning some water for the Eastern from the Merrimack causing the Merrimack Mills once again to complain of low water.

It seemed that there was no happy medium and stealing from Peter to pay Paul was a losing proposition. The fact remains that the Moody Street Feeder was a success but because of the separation of the canal system feeders, the Pawtucket and the Western, only so much could be accomplished. The
water was there in the river. The problem remained how to move it from where it was to where it was needed. The solutions offered ranged from digging another canal paralleling the Pawtucket from the river to below the Guard Gates to widening and/or dredging several of the feeder canals.

These schemes were abandoned partly because the further along the canal one traveled the closer to the canal banks the buildings were built, some right to the edge. This also eliminated another option, dredging the canals. Such extensive shoring would be required that it made that plan cost prohibitive. It was agreed any plans to further increase the volume of flow in the Pawtucket was beating a dead horse and hence the building of the Northern Canal. But even this endeavor was not the cure all as far as the distribution of the new water. The Northern deadheaded into the Western. For sure the water flowed to the right and left and all of the upper canals received more water aided greatly through the Moody Street Feeder. But the water starved portion of the Eastern Group fed from the Eastern Canal was still water starved even given the added volume from the Boott penstock.

But all still wasn’t well with the Merrimack Mill complex at the foot of the Merrimack Canal. The canal actually terminated into a smaller power raceway known as the Inner Canal and is represented as a jug-handle within the circle outlining the Merrimack Mills in the map on page eight. This Inner Canal dispersed the water to the individual waterwheels in the mill complex and it took a lot of water to turn the huge 30 foot breast wheels that ran the mills. When the Moody Street Feeder was completed and the canal widened from the feeder to the mill, there appeared to be an abundance of the liquid gold. But when the Boot Penstock was constructed to serve as a second source for water to the Eastern Canal and the Eastern Group of mills, the water from the Northern Canal was shared between them and consequently there still wasn’t enough for both.

The PL&C hadn’t given up on solving the problem, at least not yet. James Francis and his engineering crew still had a few tricks up their sleeves to solve the seemingly perpetual water problems.
Chapter Three

Two Other Underground Schemes that were abandon constituted two of several of James B. Francis’ ideas for increasing the water flow evenly between the Mills, but it was part of the Eastern Group made up of the Booth and Massachusetts Companies that were in the most trouble because of low water. Each of the Mill Companies contributed an amount equal to the shares they held in the Locks and Canal Corporation to build the Northern Canal and it was only fair they received their equal share of the Water Power now available upon the completion of the construction of the New Canal.

The Chapter offered here is only presented to show how far the Locks and Canal Corporation was willing to go to supply the mills with the waterpower necessary for maximum production. Still, only so much investment could be justified. In many cases the mill complexes had reached the limits of possible expansion on their acreage and had added floors to cram in more looms. But there was a limit.

The construction of the Northern Canal and other works involved had cost $650,000.00. Every means possible to fully utilize the advantages of the New Canal certainly had to be investigated. The canal system was awash in new water, a great over abundance for the first time.

The necessary improvements were first contemplated in 1854 at the Directors meeting of July 18. It was voted “that the agent (Francis) be requested to examine the present canals and suggest any improvements wherein which he may think necessary or desirable for a more convenient use and just distribution of the water to the several parties entitled thereto.” Francis, also the head engineer, was prepared having already foresaw the necessity of canal expansion and his conclusions were presented to the Directors Committee on the improvements of the Canals in September, 1855 outlining the necessary work and the costs involved.

The Proprietors of the Locks and Canals on Merrimack River were businessmen with large investments and figures in red were to be avoided. When any new construction on the canals was contemplated, Francis produced alternatives, the cost of each, the return on each, the gain to the mills, etc. Everybody knew exactly where they were headed every step of the way. Not one of the proposed improvements was implemented so certainly the figures didn’t jive with the anticipated results.

The map on page 16 comes into full play in this chapter, indicating the location of the two raceways being discussed in this chapter but never built. The Merrimack and Mechanic Street Feeders were very much a part of the master plan drafted by Francis for the Proprietors of the PL&C. The following description of the proposed works have been condensed from Francis’ original text from the Committee report outlining the construction and a sketch of the layout of the routes open to the paths of the proposed feeder reproduced on the next page.
SKETCH OF THE PROPOSED FEEDER FROM THE NORTHERN CANAL IN THE YARD OF THE MERRIMACK MANUFACTURING COMPANY.

Sections of the several modes of construction for which estimates have been made.

Sept. 1855.

Reproduced from a sketch of a plan that accompanied James B. Francis' 1855 report on the "IMPROVEMENTS THAT MAY BE MADE IN THE MEANS OF DISTRIBUTING THE WATER to the SEVERAL COMPANIES AT LOWELL (sic)"
The Merrimack Feeder

The first question to answer, why the added construction of the feeders; what added purpose would they serve? What ultimate benefit to the PL&C and the mills?

The perennial water shortage in the system had been hashed and rehashed over and over between the PL&C and the Corporations almost to the point of resignation. There was now more than enough water available since the completion of the Northern Canal. The challenge was to get it into the wheelpits of the Mills where it was needed. The reader should at this point be well aware of the problem that existed. Francis’ plans were to overcome this problem.

First of all, take a good look at the map on page eight to familiarize yourself with the general layout of the canals and mills. Now turn to the map on page 16 showing the locations of each of the proposed Feeders in relation to the Canals and keep flipping between them until they are familiar enough to remember.

The Merrimack Feeder is designated by the arrow marked number three. Take a minute and compare the route of the Feeder on the map with the sketch of the proposed construction that accompanies this chapter on page 22. Now you are as familiar as Francis was when he submitted the plan, Improvements that may be made in the Means of Distributing the Water to the Several Companies in Lowell to the Directors Committee. You are ready to tackle somewhat of an understanding of the text that will be more enjoyable if you picture yourself involved in the work.

This feeder would be no more that an extension of the Northern Canal. The fact that eventually the proposed route was change to accommodate construction going on at the Merrimack Mills has nothing to do with the original plan to build it. The map on page 16 shows the original proposed path of the construction through the buildings of the Merrimack Mills to tie into the Inner Canal that fed water to the Mills in the complex. The sketch shows both routes along with the various schemes offered for the actual building of the underground raceway.

Francis’ plan on the opposite page describing the route as presented to the Committee was “Starting from the Northern Canal, the first 200 feet in length to be an open canal, 40 feet wide, 12 feet deep, with walled sides; then a gatehouse occupying about 20 feet.” Alternate building methods were offered according to price and several plans submitted but this section of the proposed feeder never varied and if the sketch of the work is consulted it will be come apparent why. The room available for the construction was limited with the existing Tremont Gatehouse and Picker Building that housed the Waterwheels to be skirted. Then the Merrimack Manufacturing Company’s Print Works was standing in the way and those building would have had to be tunneled under as on the original sketch. This is the dotted path as shown on the sketch and meeting the Inner Canal at the lower right hand corner of the drawing.

The revised route in order to avoid the buildings and excavating under them was to go around, following the indicated street as was done in the building of the Moody Street Feeder. The three solid lines indicate the alternative route and would directly enter the Merrimack Canal instead of the previous designated point that was the Inner Canal that tied in directly to the Merrimack Mills. This path was only offered as an alternative and will be discussed a little further on.

It was difficult to leave the description of the maps and sketch while the readers attention was so focused, but after all, it’s Francis that has the stage.
Francis’ text goes on to state, “By this scheme it is propose to supply the Merrimack Manufacturing Company’s Mills by a Feeder 1150 feet in length, directly from the Northern Canal.”

He now delves into different materials to be used in the actual building of the Feeder and the varying costs of each of three schemes as he outlines the path of the feeder and the methods to be followed in each of the three phases of construction which are easily discernible on the drawing.

In all three schemes the first 200 feet of the feeder would be an open canal leaving the Western Canal where joined by the Northern and terminating at a Gatehouse. Leaving the Gatehouse the feeder was originally suppose to follow the path of the dotted lines and connect to the Inner Canal that distributed the water inside the Merrimack Mills yards, shown connecting at the lower right hand corner of the plan. After the Feeder left the Gatehouse, the plan varied in the construction of the remaining 950 feet, the design and materials to be chosen from one of the three schemes appearing as inserts superimposed on the plan.

The deciding feature would probably have been the cost against the projected life of the type of materials used. The density of the buildings or lack of same on the land to be traversed certainly would enter the picture. Was the channel passing under streets? Were there mill buildings to be tunneled under? The plan indicates both.

Scheme ‘A’ was comprised of mostly wood about 800 feet of it with only 150 feet to be constructed of masonry and that was in the vicinity if large buildings and hence the cheapest way to go at $139,000.

The diagram of the proposed path of the Merrimack Feeder is reproduced on page 16. As most of the canal work in the 19th century, it was simple, straightforward and efficiently engineered.

Scheme ‘B’ was planned with 950 feet of the feeder constructed from masonry, the entire length from the gatehouse to the Merrimack Mills. The building would follow the plan in the upper section shown in the Scheme A drawing and came in at $192,000.

Scheme ‘C’ detailed in the lower left hand corner of the plan was the most elaborate, would last the longest under the constant use of the waterway and thus was the most expensive. It would consist of 950 feet of cast-iron pipe in three lines each ten and one half feet in diameter. $207,000.

Then almost as an after thought to define the reason behind the building of the feeder, he adds the advantages of the waterway.

“Another important advantage that may be derived from this Feeder is, that the Merrimack Company may, in the ordinary state of the river, have one and a half to two feet more fall (head) than they now use, provided they should see fit to put their yards and buildings in a condition to receive the water at a greater height,” as the original plan went, now that the Merrimack Mills would be receiving their own water supply separate from any other source of the other complexes, the entire flow from the Moody Street Feeder would be utilized to raise the head in the Eastern Canal via the Boott Penstock. The Boott Penstock was just that, a penstock or waterway that tied the Merrimack to the Eastern Canal and described a little further on in Chapter four. Therefore the lower Eastern Group of Mills, the Boott, Massachusetts and Prescott would benefit tremendously.
What would the alternate route of the Feeder achieve?

The last paragraph describes the object of building the Northern Canal, and really the prime reason. The goal was to assure that all Companies would benefit from the flow of water from the new canal but not necessarily from that Canal’s waters as such. As long as the low water problem was solved it was to the advantage of all and that’s all that mattered in the end. Keep the Wheels turning was the byword.

Let’s get back to the change in the route of the Feeder. No reason ever showed up in the minutes of the Directors Meetings as to why the project wasn’t followed through with but the fault could be in the following scenario.

The main purpose of the Feeder was to supplement the water of the Merrimack Canal feeding the Merrimack Mills. That’s why the original route of the Feeder tied directly into the Inner Canal that supplied the individual Mills in the complex. In no way the Feeder could replace the entire volume from the Canal but it would greatly limit the draw from the Canal that was necessary for the mill operation.

This would also allow large amounts of water to be directed into the Wasteway from the Canal, and thus into the Penstock that was angled off the Wasteway and then funneled the water into the Eastern Canal, Huzza...mission accomplished.

But now the alternate route raises its ugly head. As the revised plan would dictate the proposed Feeder would now empty into the Merrimack Canal just as the Moody Street Feeder does, instead of the Inner Canal as the original route was designed to do. The Merrimack Feeder would no longer supply the Merrimack Mills and only the Merrimack Mills but would now be sharing its waters with the Boott, Massachusetts and Prescott Mills by way of the Penstock and the Eastern Canal.

Under the alternate plan it seems quite doubtful either Canal would achieve the desired results that were planned for and fueled the original concept for the project. There’s no way of knowing if this assumption on the researcher’s part is what killed the project, or if it just wasn’t deemed financially viable, or a million other reasons. The one positive was that the Mills wanted to be able to purchase all of the Water Power that they could, and the PL&C wanted to sell all of the Water Power that they could. Why the project was consigned into limbo will probably never be known for sure, just almost educated guesses.
Mechanic Street Feeder

One more plan that flunked the finals but it’s worth examining what information we have about its proposal and why it was considered necessary at the time. The next page has a reproduction of the proposed route of this Feeder plus the suggested widening of a section of the Western Canal to make the scheme workable. The Canal had only been rebuilt and widened from the Northern Canal to the Moody Street Feeder to increase the water flow from the Northern to the Merrimack Canal. The rest of the Western was no more than a glorified ditch and it still is if you want to take the time to view it without water. The construction of this Feeder was part of the master plan right along with the Merrimack Feeder that was just presented. Again, before the reader continues with the text, get familiar with the map on page sixteen that outlines the general location in the Canal system and is indicated by the arrow marked two.

Arrow number three on the map is showing the original proposed route of the previously discussed Merrimack Feeder. The alternate route for this Feeder would have entered the Merrimack Canal about half way between the Moody Street Feeder (arrow No. 1) and the end of the canal. And as explained in the previous chapter outlining the construction of that proposed Canal, this change in the proposed route could be very well what doomed both proposals.

Even in the text of the Report offered to the Committee that was appointed by the Directors of the PL&C to oversee the planning of the Canal Improvements, not much ink was given to the proposal for this Feeder. Francis himself favored this proposal only marginally over several others, apparently scuttling those other plans too. One was paralleling the Upper Pawtucket Canal with a new Canal from the Merrimack River to just below the Guard Locks but that plan was abandoned because of irregularities in the contours of the remaining part of the Canal would have greatly impeded the expanded flow of water. The dredging of the Lower Pawtucket created another problem because of the Mills built right on top of the Canal banks and the added cost of pilings to add support and keep the banks (and Mills) from crumbling into the Canal during the dredging was deemed prohibitive. Likewise the widening of a part of the Eastern Canal would have been a waste if the proposed Feeders were built making it possible for the Boott Penstock to supply the Boott and Massachusetts Mills with all of the Water Power they could use.

In Francis’ presentation to the Committee he only allotted one short paragraph in favor of building the Mechanic Street Feeder and even he didn’t sound too convincing. “Another scheme, also represented on Plan No. 4 and intended as a substitute for the preceding, over which it has some advantages, is to widen the Western Canal from Moody Street to Mechanic Street (now Broadway) and to make an arched Feeder through Mechanic Street, from the Western Canal to the Merrimack Canal.” That’s it. That’s all he had to say in behalf of the Feeder’s selling point and he never mentioned it again. It could very well be, again just an educated guess, that Francis was well aware that if the route of the proposed Merrimack Feeder was realigned to enter the Canal instead of the Mill yard, it was probably a dead issue. And so would follow the rest of the proposed improvements.

All this talk of canals and feeders going this way and that way can get confusing enough to simply flip to the next page with a “to heck with it.” The map on page sixteen coupled with the sketches is the easiest way to go to understand the text, because that’s what it’s all about anyway.
SKETCH OF THE WESTERN CANAL
WIDENED TO 60 FEET AS SUGGESTED
TOGETHER WITH THE
FEEDER SUGGESTED
IN
MECHANICS STREET
Sept. 1855

Sketch of the widening suggested for the Western Canal.

SCALE OF FEET:

Lowell Machine Shop.
Francis continued to expound his remaining recommendations for the improvements but his convictions appear to be wavering. “According to my view, the improvement next in order of importance is: “Deepening part of the Lower Pawtucket Canal, and widening part of the Eastern Canal (sic).”

Wrapping a mantle of unimpeachable credentials around the rest of his opinions, Francis announces that from an engineering point of view, the Canals are too small to carry the amount of water that would have to pass through them. “That is to say, if they were to be constructed anew to carry the water now passing, they would under ordinary circumstances, be made of much larger dimensions.” And he adds that if the cost is not too great that they should be made much larger right now than even he is proposing.

True to Francis’ exacting ways he goes on to offer calculations of the end cost of those proposed improvements. Keep in mind that now all of the Corporations share in whatever costs are incurred by the PL&C for whatever reasons. All Water Power that operates the Mills is based on the formula for Mill Powers. Each Corporation contracted with the PL&C for so many Mill Powers according to their individual needs. How many shares the Corporation owns is what determines the percentage of the cost each is responsible for. The total amount of Mill Powers a corporation contracted for was based on the number of spindles in its Mills. The more spindles, the more Mill Power was necessary to operate the Mills. The average cost of the Mill Power worked out to be about three dollars in the 1830s. If these proposed improvements were implemented, the cost would work out to be very nearly $14. per spindle. We’ll pause a moment to allow the echo of the past gagging to cease.

Francis closes his presentation of Improvements That May be Made in the Means of Distributing Water to the Several Companies at Lowell after this little revelation of the cost with some parting words.

“Judged by this standard alone, the proposed improvement would appear to cost more than it was worth.” There’s more but the rest is just as negative.

So died the Mechanic Street Feeder, and all the digging and all the dredging and all the widening of the rest of the Canal improvement along with it. The Mills would have to suffer through the low water of the hot, dry summer months just as they always had and the backwater of the freshets in the wet seasons and the icing problems that would appear in the winter months because of the lack of surplus water to push the ice over the Dams and away from the trash racks protecting the turbine headraces.
Chapter Four

The Boott Penstock

The Boott Penstock – such a small waterway and yet it played such a big part amongst such large Corporations. But without it, the Boott and Massachusetts Mills (and the Prescott that was a part of the Massachusetts Corporation) that depended on the Eastern Canal for Water Power would have been in big trouble. By the time the water from the Merrimack River reached the Eastern via the Upper and Lower Pawtucket Canal, there really wasn’t too much Water Power left. Between the friction of the flowing water created between the walls of the Pawtucket Canal and the irregularities in the shape of the waterways left after the reconstruction of the Canal in 1823, both greatly impeded the flow. Add to that the debris from the granite work scattered along the bottom of the Canals where it was just left to lay where it fell, and the passage through the obstruction of the Upper Falls, the head could be reduced by a couple of feet. A portion of the water had already flowed into the Hamilton Canal powering the Appleton and Hamilton Mills from the Upper Level of the Pawtucket before being returned to the Lower Canal through the tailraces of the Mills which took away a little more of the head. As this water was ejected back into the Lower Canal in a perpendicular stream from each tailrace, it formed a water barrier to the natural flow of the Canal reducing the head even more and compounding an already bad situation.

The Boott and Massachusetts Mills certainly ended up with on short end of the stick in the Water Power lottery due to their location as the last Mills in the pecking order so to speak. The formula that would equalize the amount of water flow to each Mill irregardless of their site in the system, the cubic feet per minute they were allowed to draw to create the contracted for Mill Powers, was fair enough but if the water wasn’t there in the Eastern Canal, all of the Mill Power calculations in the world weren’t going to help matters.

This was the problem. And the Eastern Canal, and so the Boott and Massachusetts Mills, suffered greatly from low water. The problem was magnified in the drier summer months and really it really compounded matters by allowing ice buildup in the winter because there wasn’t enough water to push the ice over the Boott Dam at the end of the Canal. We’ll return to the icing problem a little further along in the text.

The Merrimack Canal was the first canal to draw from the Upper Pawtucket and it drew the full 30 foot head to feed the huge 30 foot Breast Wheels of the Merrimack Mills. It was from the Wasteway at the end of this Canal that the Penstock was tapped as shown in the map and the sketch, and fed into the Eastern Canal. It seems simple enough; just dig a trench from one Canal to the other and they were in business. Next to the thousands of feet of Canals the PL&C had blasted and dug this should have been a cakewalk, right? Well, not quite, but we’ll take it one step at a time and the Penstock will eventually evolve to be a viable waterway in its own right and do the job as Francis had envisioned it doing originally, and that was to alleviate the low water condition in the Eastern Canal.

First of all the two Canals were not on the same levels. The Merrimack was fed from the Upper Level of the Pawtucket Canal and the Eastern from the Lower. That little difference was 13 feet, the lower being the latter Canal. Judging by the current configuration, a gated spillway of some sort would have had to be built at the higher end of the Penstock to control the water flow between the two levels. No problem; it was all downhill from there so to speak.
First the old ‘one picture worth a thousand words’ act. Where is it situated in relation to the Merrimack and Eastern Canals? It’s easy to say the Penstock does this job and describe how it does that job but if you can’t visualize where it physically is in relation to the Canals it’s all a waste of breath.

The dotted lines outlining the Penstock are a little hard to make out on the map so a circle has been drawn around it to pinpoint its location.

From the map of the Canal System the reader should have a pretty good overall idea of at least what the design of the penstock was trying to achieve. To funnel water from the Merrimack Canal into the Eastern Canal and elevate the level of the water in the Eastern was the goal.
Here we can reproduce a sketch of a 1896 site plan of the Boott Mills showing the Eastern Canal and the Boott Penstock. The arrows and the description of what they are indicating should add greatly to the text. At least this raceway and the Canals can be viewed without much trouble. Even with the Canal full of water the outline of the Penstock wall traversing it can be seen. With the Canal empty, every detail of its construction stands out in all its detail.


Arrow #1  Location of Spillway where Boott Penstock begins at the Merrimack Wasteway drawing water from the Merrimack Canal.

Arrow #2  Underground portion of Penstock, originally a wooden raceway, now a steel pipe, from the Spillway to the open section of the Penstock.

Arrow #3  Open section of the Penstock paralleling the Eastern Canal and separated by a granite block wall. There are 15 rectangular openings underwater between the Penstock and Canal that allow the waters of the Penstock to mix with those of the Eastern Canal.
All of these photos show the Penstock as it looks today. There are none of its past and to date not even a sketch has been found even though sketches are mentioned in the records. But if the route of the waterway is viewed, a little imagination can complete the picture of yesteryear.

To begin with, these are photos of the beginning and end of the underground section of the Boott Penstock. There is rusting machinery perched on the top at one time raised and lowered a gate that regulated the water flow from the Merrimack to the Eastern Canal.

The steel pipe that constitutes the beginning of the Penstock is concealed behind a barrier of wooden planks that now cover the opening. Notice the angle to the entrance of the Penstock in order to facilitate the flow of water from the Merrimack Wasteway into it and to avoid creating a large turbulence at the opening.

Both photographs by Author

At the end of the underground section of the Penstock that began in the photo above, it empties into the main water-way of the Eastern Canal. To the right is the granite block wall that separates the Penstock from the Canal. The overall Length of the underground section was about 128 feet.

All of the photos presented here and on the next page were taken when the Canals were empty of water. However if you chose to view the Canal and Penstock when it is full, the capstones on the granite block wall of the Penstock will be visible.
Two more photographs will complete the visual tour of the Boott Penstock. The only way more can be seen, and its really worth it, is to walk the Canal when its empty as every Canal should be to be appreciated.

But to continue, the next two photos are of the Penstock and the granite block wall that separated it from the Canal to the left. This section of the wall was the last piece in the Penstock puzzle to be completed in 1888 and ends opposite the middle of the two trash racks that protect the headraces to the Mill turbines under building number Six. The Canal wall is to the right.

This is a good view of the wall taken from the end of the pipe comprising the underground portion of the Penstock. The capstone is always visible even when the Canal is full of water. The openings in the wall between the Penstock and Canal are out of view here.

This photo is from the vehicle bridge that spans the Eastern Canal. It shows the rectangular openings in the granite wall separating the penstock raceway from the canal itself that allows the two waters to merge with the least amount of turbulence.

One advantage in the telling of this tale is that the Penstock exists. Maybe not in its original form but at least we have a visual imprint of the beginning and end and with a peek at the records through the text, photographs and a site plan as we are doing can bring it somewhat to life.

From here on the records can spin the tale of the construction of the Penstock.
Chronology of the Penstock

Two sources have the initial construction of the Boott Penstock in 1846. A report titled *Changes in the Boott Mills* by Donna Richardson in which she describes it as “a tunnel which sent additional water from the Merrimack Canal to the end of the Eastern Canal” and a second in a HAER Inventory. The first mention of the Penstock in the Records of the meetings of the Directors of the PL&C shows up on April 14, 1848. “Voted; That the Agent be authorized to construct a wooden penstock leading from the Merrimack Canal Wasteway to the Eastern Canal, for the purpose of supplying the mills on the lower level with an additional supply of water, when they are impeded by backwater.”

One way or another, something had to be done and its construction evidently was a stop-gap effort to do something to try to improve the water flow to the Eastern Canal and the Mills located there but it couldn’t have been large enough to do much good. Understandable though, because it was drawing from the same source as the Merrimack Canal that fed the Merrimack Mills. How many ways can you split the same hair?

At any rate upon completion of the Northern Canal project with the accompanying Moody Street Feeder and the widening of the Merrimack Canal, the Boott Penstock was completed in 1849 to aid in the distributing of the additional volumes of water to the Eastern Canal.

It was turning out that the ‘let’s just dig a ditch and be done with it’ rule wasn’t the final solution though; far from it. There was still not enough capacity in the waterway but PL&C would keep at it until they had it right.

They worked at it for over forty years rebuilding and enlarging it again in 1873, 1889 and 1906 and by the time it was really done to the satisfaction of all, so was the life of Water Power. Steam Power had over run the Lowell Canal System and made obsolete the 5 1/2 half mile network that had fostered the Industrial Revolution. Just as the railroad had signaled the demise of the Middlesex Canal, the steam engine was about to play grim reaper to the Canal System.

But in no way can you knock the perseverance of the PL&C in trying to handle the problem of the low water being experienced by the Boott and Massachusetts Mills. The low water reduced the Mill Powers that the Corporations had contracted for. If the Wheels didn’t run at full speed, the machinery didn’t run at full speed and the end result was lost production. And in the eyes of the investors, this was to be avoided at all costs.

Everybody can appreciate how the loss of head could effect the Mills operations; easy to understand with just a simple explanation. But there was a second effect of the low water that was even more disastrous and that was in the winter months. This was the forming of ice in the Eastern Canal. It would form starting at the end of the Canal in front of the Booth Dam and the water would progressively freeze up, backing further and further in the Canal until it would block the trash racks and consequently the headraces leading to the Boott Mills Wheelpits. There was not enough force in the water flowing in the Canal to overcome the heavy current of the water pouring in through the higher Penstock to push the ice over the Dam and being at the end of the Canal the Boott Mills suffered the heaviest. The Eastern was the Canal to feel the results of the ice affect the most of all the Canals, and they all had the problem to one degree or another. The ice from the other Canals had a tendency to accumulate in the Eastern because it was the last in the system. But the Boott Penstock is our only interest at present so we’ll overlook the rest and continue on centered on the Penstock.
The first Penstock as constructed did offer some relief as far as increasing the water level in the eastern Canal. This was what the Penstock was designed to do. But the waterway stopped abruptly where it intersected with the Canal. Remember that the source of the water fed into the Eastern from the Penstock was coming from the Merrimack Canal which was 13 feet higher in elevation. This meant that the new water had to be pouring into the Eastern at a tremendous flow rate as it dropped through the Penstock and clashed head on with the current in the Canal. At this early date, the granite block wall that now separates the Penstock from the Canal didn’t exist. But that was no problem in itself as long it was just water to water; the Canal would even out the levels over its length and the average head at the Boott headrances would be raised enough to justify the building of the waterway.

But the new high water scenario in the Eastern and thus at the headrances of the Boott Mills was not the final hoped for total solution. The amount of new water it added in fact worsened the ice problem in the winter by counteracting the current in the Eastern and holding back any ice that had formed in place, not allowing it to be pushed through the Boott Dam and into the Merrimack wasteway and the River. Also by pumping more water onto the top of the already frozen ice in the Canal it was probably adding to the thickness and certainly making worse the resulting backup of the anchor ice that could thicken until it actually clogged the Canal from top to bottom.

The PL&C must have felt it was living with one long headache. It would no sooner solve one problem, and because of the solution, another would arise. But true to form they pressed on. From time to time, several times during the day if necessary, they would close the Gate at the head of the Penstock to stop the flow of water from that direction. Then the gates in the Boott Dam at the end of the Canal would be hoisted to give the ice a path to return to the River through the Wasteway without combating the adverse current pushing against it from the Penstock.

These two actions together would accomplish exactly nothing without a heavy flow of water introduced into the Eastern Canal from its beginning at the Lower Pawtucket Canal. To achieve this volume of water the Gates at the Middle Dam (Swamp Locks) would have to be opened in order to flood the Lower Pawtucket and add to the water flow into the Eastern to provide the force to push the ice over the Boott Dam and into the River. That wasted water represented wasted money to the investors and another way had to be found to handle the low water.

Keep in mind almost all of the problems with the low head at the Boott were caused simply by the unique location of the Mills at the far end of the system of canals. The reader is probably sick of reading about canals and penstocks and gates and ice and probably gave up trying to sort out one from the other. Maybe the page has already been turned.

It is to be supposed that this ice problem was an ongoing occurrence year after year on a regular basis involving the Boott Mills. Yet the records are strangely silent much of the time. Why it took 25 years to approach the PL&C is anybody’s guess but a communication from the Boott was finally read at the Meeting of the Directors on January 2, 1873 on the subject of “ice in their Canal.” It was voted “that this communication be referred to a committee to confer with the Agent (Francis) as to what shall be done, how it shall be done and what will be the probable cost, to report at a future meeting.”

Pretty good results for a committee as we find an answer from them on May 1. The report states that they examined the premises that is the entire situation of the ice problem, and agreed that it was partly because of the peculiar location of the Mills at the end of the system. They also concluded that the problem was increased by the construction of wasteways by the PL&C “for the discharge of ice from the Upper to the Lower Canal at the Mills of the Hamilton and Lowell Companies.” In other words because
of this action the ice formed there was also floating downstream and into the Eastern Canal and adding to an already bad situation. They also added “we are doubtful as to the liability of the Locks and Canals.” That appeared to have ended that. There was no mention as to the effects of the water flow from the Penstock compounding the problem

But something was accomplished at that same meeting after more or less seeming to abandoning the ice problem. The Agent (Francis) informed the committee that the existing Boott Penstock was in bad shape and must either be repaired or replaced. It was recommended to the Agent that the Penstock be rebuilt as soon as possible out of wood again, “in an improved form.”

For 15 more years the Boott Mills must have continued to fight the ice battle alone. The records and the Minutes of the PL&C Directors Meetings are silent on the issue, until an entry in the Minutes of March 14, 1888. The date alone would suspect that the matter referred to was once again the ice problem from the previous winter. At any rate. It was voted to “refer the matter of extending the penstocks through which water is discharged into the lower end of the Eastern canal.” The referral was given to another committee.

What probably sparked the sudden interest in the Boott Mills situation with the ice most likely had nothing to do with a sudden change of heart in the part of the PL&C as much as the continual complaints from the Hamilton and Appleton Mills about their wheel pits flooding every time the Lower Canals were flooded with water to push the ice over the Dam at the end of the Eastern canal.12

As mentioned before, the success of the Penstock also compounded the ice problem and it still remained for a solution to be found. It would make sense that the issue is what resulted in the vote on March 14 to extend the Penstock again.

At any rate, it was dumped in Francis lap. He had already prepared a report after the meeting of March 14 and as usual had all the facts at hand. He presented his proposal in a report titled, The Proposed Extension of the Penstock for Discharging Water into the Lower End of the Eastern Canal. He suggested that extending the Penstock further into the Eastern Canal instead of deadheading it abruptly when it entered the Canal would facilitate the discharging of the ice over the Boott Dam.

Francis outline two schemes for the proposed extension complete with the costs and he states that sketches are included with the proposals; alas, they seem to be lost to time. A brief summary of both proposals will be offered, and only brief. When Amory Street is mentioned in the descriptions, that is the roadway that paralleled the Canal when the proposals were written in 1888 and still does today.

Scheme 1 would have a covered conduit in Amory Street 326 feet in length with two outlet conduits, each 20 feet long (Leading into the Canal.)

Scheme 2 would have a covered conduit in Amory Street for a distance of about 128 feet,13 thence by an open conduit along the southerly side of the Eastern Canal, about 198 feet14 with openings into the Canal.

In both cases the overall length is given as 326 feet15 and this is the figure we will go with for our own reference. In any case, just viewing the end result, Scheme 2 was the selected preference.

Francis’ presentation must have been persuasive to the Directors of the PL&C.
At their meeting of August 30, 1888, they voted that “the Agent be authorized to extend the Penstock by which water is discharged into the lower part of the Eastern Canal in accordance with the plan submitted by him.” What wasn’t mentioned in the vote, but was included in the report was Francis’ recommendation that the PL&C construct the proposed waterway and “the expense of carrying out this plan should be borne by the Locks and Canals.” This more or less overrode the official consensus that the Company had no liability in the situation as they had alluded to at the meeting on May 1.

The final OK for the building of the Penstock was given by the Directors on April 20, 1889 after referring to a report given to the Board by the Consulting Engineer dated March 18. James B. Francis retired in 1885 and the position was filled by his son. The mention of the Consulting Engineer is referring to Francis Senior.

But even after all of the building and rebuilding of the Penstock over the previous years to correct the water and ice problems in the Eastern canal, and the seemingly “dammed if you do and dammed if you don’t” consequences of the decisions the PL&C made thrown their way by the Mills on the upper level of the Canals, they still hadn’t heard the last of that waterway yet.

The underground section of the Penstock was evidently reconstructed of wood during every improvement made to the waterway, and all of the negative features of that type of construction followed it. Finally it was voted by the Directors on July 27, 1909, to eliminate at least one final headache, and probably with great hopes the last, by reconstructing that portion of the Penstock of steel.

All has been quiet ever since. One section of the granite block wall that makes up the Penstock paralleling the Canal wall at about the halfway point has been removed for some reason but there doesn’t seem to be an answer as to why. If it had collapsed the remnants would be evident on the Canal bottom when it was empty which they aren’t. This damage defeats the original intent of the openings in the wall to eliminate the turbulence where the waters meet but it really doesn’t matter anymore. The silence of the Mill operations is deafening.
Chapter Five

The Subterranean Powerhouses

If the reader can appreciate the endeavors of the Canal builders in the four preceding chapters, he should be mesmerized by the tale of the underground raceways that is about to unfold in the following pages. The mighty Merrimack River that raged over the Pawtucket Falls, and the elaborate canal system that tapped into it to harness the power of the water that coursed between the banks, would all be for naught if were not for the little known and sight unseen labyrinth of underground raceways that funneled the flowing horsepower to the machinery in the Mills. Liquid gold it was, in the raw.

Long after the digging and stone laying was completed, the Morning Mail newspaper paid the only tribute it could by the way of a quote from one on the men most involved in the edition of Thursday, August 8, 1889.

“We think it was Kirk Boott who once said that he had spent more money below the surface of the earth than above it in this city, and this remark could be appreciated if one could see the mighty labor and subterranean water courses to utilize the waters of the Merrimack in turning our wheels of industries.”

Enough said as way of introduction.

A walk along the banks of any canal can certainly instill a sense of awe for the backbreaking energy that went into their building with the most primitive of tools. The pick and shovel and later blasting powder, and none of the spoils were moved without the wheelbarrow. Gaze up at the Mill buildings running one after the other in seemingly endless rows, and if one were around back then, to hear the deafening clatter of the looms weaving the miles of cotton goods.

The canal waters rush past all this in its journey from beginning to end without nary a pause and yet the mills machinery turns. But turns from what force? What motive power is working its magic, and how.

This time a walk along the empty canals will provide if not all the answers, at least afford a clue as to what process is taking place beneath the surface of the rushing canal waters. Those wood or steel grates placed seemingly at random along the canal walls in close proximity to mill buildings do more than decorate the waterways. They filter the trash laden water before it enters the headrace openings leading to the wheelpits and turbines behind them, and herein begins the story of turning rushing water to Millpowers.

The Proprietors of the Locks and Canals (PL&C) may have owned the Canals and claimed title to the water that coursed through them but that was the extent of their responsibility to the Corporations. As far as getting the waterpower from the Canals to the wheelpits and power the wheels to turn the machinery, that was up to the individual Mills. But it was the PL&C that had the expertise and organization to do the actual work of engineering and building in order to maintain the integrity of the system. The Mills were probably more than willing to turn over the responsibility to the PL&C for the building of the raceways. No matter how many Mill Powers they contracted for, it was only of use flowing trough the wheelpits.
It follows that seeing the scant information we have about this vital aspect of the power system that was developed to provide the access to the water power between the Canals and the wheels in the mills, we will have to make due. We will start with the first mill complex built, the Merrimack and progress from there in more or less the order that the succeeding mills were built.

Some of the lines that were drawn on the original sketches indicating the underground raceways have faded over time and some lines may have had to be traced over to better define them. But none were created where none showed on the original.

With so little to go on, the reader’s grasp of the overall picture may be vague to begin with but as an understanding of the system develops with familiarity and what the engineering was trying to accomplish, the larger picture should begin to emerge. An overall picture of each canal’s location in the system is reproduced on page eight but a more local sketch will accompany each presentation.

All of the basic construction of the underground raceways was primarily of the same design. Whether termed penstocks, or headraces that moved the waterpower from the canals into the wheelpits, or tail races that allowed the spent water to return from the wheelpits into the lower canal or rivers, the shapes were more or less the same. All we have had contact with were built with a curved granite archway covering a stone lined ditch of varying dimensions, at least at their beginnings and ends. That’s the extent of what can be observed.

The exception to the materials used in the construction of the underground courses is in the few later instances where steel pipe was used. This seemed to have come into vogue after the 1890s. One example is the final configuration of the Boott Penstock shown on page 32. Another is in three very large cylindrical shapes about nine feet in diameter shown below and utilized to move the water into turbines at the Tremont Mills and installed about 1896.17

There are three pipes in all and you are viewing the ends before they would have entered what was known as the forebay. They are prettied up with woodwork and a stone patio in front greets the visitor. Their overall length has been covered over and landscaped but the evidence of their existence can be followed back to behind the Tsongas Arena.

Photo by Corey Sciuto  2006
But the more typical underground waterway still remained the arch covered ditch, usually framed in granite block. The following photographs will serve to illustrate the configuration of them, some smaller, some larger and some much larger. Most headraces leaving the canals will be hidden by the height of the water and even if viewed when the canal is empty, will be covered with trash racks. As the waterways at each mill complex are examined, any visible openings leading to or from headraces or tailraces will be included. That way their existence will become more pertinent to the subject at hand and not become simply another picture with no meaning.

Here is one of the few remaining examples of a raceway that entered underground into a long gone building at the past location of the Tremont Manufacturing Company with its classic configuration.

Photo by the Author

Most evidence of tailraces from the any one of the mills wheelpits that emptied into the Merrimack River has been obliterated by work along the bank of the River. Again if one has the patience to walk along the dry canals, some of the remaining covered headraces leading to the underground chambers can be observed.

These two arched over opening are seen leaving the Hamilton Canal under the Appleton Mills. It is odd that they are not covered by trash racks but they appear to have fallen into disrepair over the years and simply been swept away by the Canal current.

Photo by Janet Pohl
Again a mystery surrounds the lack of any protection from the canal debris entering the head races. This is the wall of the Eastern Canal. The two openings are under the Middlesex Community College and led to the wheelpits of the long ago demolished Prescott Mills.

Photo by the Author

These are two very large tailraces on the Concord River and came from the now demolished Middlesex Woolen Mills and can be viewed from the Davison Street Parking lot. This Mill complex was unique in the fact that it drew waterpower from both the Pawtucket Canal and the Concord River.

Photo by the Author

Now that we have made an abbreviated tour and surveyed as an example some of the entrances and exits that outlined the routes of the water into and out of the wheelpits beneath the mills, it is time to examine the actual courses that the waterways followed underground. Each Mill complex will be treated as an individual entity to make things as simple as possible, hopefully, and this will entail going back to their earliest days.

But on the next page will be presented a master plan of all of the underground waterways as they existed in 1933. Each Mill complex is identified for easy following when reading the text.
Merrimack Manufacturing Company

The primary use of the sketch below is to magnify not only the location of the mills in reference to the Merrimack Canal but also to bring attention to the all important Inner Canal, the distributor of all the canal waters in the mill complex.

This was the first of all the mill complexes, began in 1822 and saw water flowing over its huge Breast Wheels by 1823. These mills used the entire 30 foot head available in the Upper Pawtucket Canal via the newly dug Merrimack Canal that was built just for their own use. Instead of drawing water separately from the main Canal for each mill, a smaller canal was extended from the end of the Merrimack into the property in the shape of a ‘U’ as shown in the sketch above and all of the mills were tapped from it.

Known as the Inner Canal it defied the traditional arched shape in its building. It was square and protected with a trash rack in the Canal to prevent the floating debris from entering the waterway.
Here is a view of the end of the Merrimack Canal as it turns to the right and flows over the small Dam housed under the wooden structure. To the left in the photo is the trash rack covering the entrance to the Inner Canal.

Lowell National Historical Park   LOWE 8479

This is the solitary photo of the interior of the Inner Canal. Trash racks are strewn about and some are mounted over headraces on the right hand wall. The top is open and one mill building can be seen. This waterway probably remained open throughout its use.

Lowell National Historical Park   LOWE 9359

All remnants of the Inner Canal have been obliterated. The Canal itself has been filled in and no trace remains today. The entrance from the end of the Merrimack Canal has been blocked with a concrete wall and that is the only evidence of the waterway that exists. While this Canal in itself probably doesn’t qualify to wear a label as being an underground waterway because it was in all likelihood never covered, it fed many thousands of feet of raceways that did. There is not a trace left of the complex except for the Merrimack Canal and the Wasteway that course from the Dam to the River.

The only footprint left of the underground maze of water power raceways that provided the power for the machinery, and to signify the passing of this once large manufacturing giant, and the underground raceways that powered the machinery in its bowels is the 1866 sketch reproduced on the following page. At least we have this much to help etch the past in our history books.
Copy of a plan made from actual survey by G. W. Stevens, 1866

Arrow #1 – Merrimack Canal that Inner Canal is connected to just under the position of the arrow.  
(There is a gap between two canals in this sketch that didn’t exist.)

Arrow #2 – Inner Canal looping in a big “U.”

Arrow #3 – The dotted lines represent either headraces leaving the Inner Canal and entering the wheelpits under the Mills, or tailraces leaving the Wheelpits and emptying into the River. This particular raceway has three channels.
These Mills used the entire 30 foot drop in the head that fell from the Dam above the Pawtucket Falls to the Merrimack River. This meant that the difference in the height of the water between the Inner Canal and the River was 30 feet. This 30 foot drop over the wheels or turbines in the wheelpits created the power to turn the machinery in the Mills.

If upon comparison of the two sketches on pages 42 and 45 it appears that the raceway layout isn’t quite the same, neither is the time frame. More than 60 years separate them and during that period the Corporations would simply relocated the raceways to where they relocated whatever Mill building which happened regularly.

But what you read here is the only testimony left as to the Mills one time existence. When the wrecking ball had finished its job, not one brick stood on another.
Lowell Machine Shop

First a glimpse of the background to familiarize the reader with a little history of the company.

It has had several names over the years but the Lowell Machine Shop was the name it was known as in the heyday of the canal and mill expansion so we’ll go with that throughout this brief endeavor.

This machine shop began as a branch of the Merrimack Manufacturing Company about 1824. Most of the early cotton mill’s had a machine shop attached as a necessity and not a convenience. There simply was no other available source to acquire the machinery except to build it themselves in house.

The machinery for the first Merrimack Mill building was fabricated in the machine shop of the Boston Manufacturing Company of Waltham. A cotton mill was a cotton mill and the machinery was the same to be used in both mills. As the Merrimack Manufacturing Company began to expand though, the machine shop in Lowell became a foregone conclusion. More so when Paul Moody relocated from Waltham under his new contract with the Merrimack. It didn’t take long before he and his crew of trained machinists began to improve on the earlier models, and the Merrimack Manufacturing Company began to expand with more mill buildings that had to be equipped,

What was different was the shop being located at such a distance and not as a part of the first mill building itself. The norm was to install the machine shop in the completed ground floor of the first mill building while still under construction and the fabrication of the machines could commence undeterred by the turmoil of the work going on around the site. An added feature was a shorter time delay in furnishing the mill, much being ready when the building was completed.

But just in case there was a change in plans, the building housing the machine shop was constructed along the lines of a standard mill building so it could be changed over to manufacturing at a given moment.

Anyway, that was the beginning of a storied career for the machine shop, being sold to the Locks and Canals in 1824 and then reorganized as the Lowell Machine Shop in 1845 and eventually ending up as part of the Saco-Lowell in a merger in 1912. Of the machine shop itself, our interests do not entail the physical building or its product; just the waterpower that operated it.

It seems odd to tell someone that our only concern is what’s under the ground it sits on. Our interest is in the waterpower that drove the machinery.

The master layout of the entire system in relation to the location of the various mills and indication of their separate underground raceways on page 42 pays scant attention to the machine shop, far belaying its importance in the development of the textile industry in Lowell by eventually furnishing the machinery for most of the mills. Even though it indicates that the shop has the fewest waterways in all the mill yards, it was because the machine shop needed nowhere the amount of mill powers that the mills did but the operation was still a giant presence in the industry. The maps on page 8, or page 42 indicates the location of the shop at the head of the line of mills and it truly was.

There really is nothing left to see of the once thriving site that was in the past crowded with foundries and machine shops. As for remnants of the bygone days, nothing remains except for parking
lots. And this is one of the few times a walk along the Pawtucket or Merrimack Canals that border the property and once furnished all of the waterpower will produce absolutely nothing for one’s efforts.

The sketch of the outline of all of the underground waterways that existed in the mill development in 1933 [none is known from earlier] is on page 42. The headraces and tailraces are shown entering and leaving the canals respectively with the wheelpits indicated within the single line outline of the mill buildings. As described before, the wheelpits contained the wheels or turbines that the water powered, in effect revolving the shafts and belts that they were attached to and producing the motive power for the mill machinery.

However in some close ups of the individual penstock layouts that are shown in following sketches, the wheels might be accompanied with a kilowatt rating as if identifying with an electric generator, which is exactly the reasoning. The water power still was the driving force turning the wheels of the turbines but now at this date instead of being engaged to the machinery by cumbersome shafts and belt and pulleys, the motive action was transmitted from generators to motors.

The generator and raceways indicated by the designation of No. 6 in the position where all three canals, the Pawtucket, Hamilton and Merrimack diverge from the Swamp Locks on page 51, is an oddity in the Eastern Group of Mills. This was once the site of the foundries at the machine shop. If the reader isn’t familiar with the topography of the site, he would assume from this sketch that the head and tailrace is starting and finishing from the same canal, the Pawtucket, which would get you nothing but wet feet. But it is, and it identified as generating 60 kw of electricity. The sketch is very vague in not better identifying the Dam at the Swamp Locks which is separating the Upper and Lower Canal causing the water in the canal to drop 13 feet between the Upper and Lower Pawtucket Canals. Thus between the headrace and tailrace the water is pouring over the dam creating the necessary drop in the level of the water of 13 feet to generate the waterpower as it fell. First over the water wheel and now through the turbine, turning the generator that it appears in the 1933 sketch and now long gone.

The three headraces leaving the Merrimack Canal and entering the Machine Shop property and marked No. 1 through 5 have had their one time existence pretty well obliterated. There are slight indents in the canal bank, filled with granite blocks or concrete that with a little imagination, can attest to the fact that there once could have been some sort of a waterway that left the canal. When the Merrimack Canal is drained of water, these so called indents become much more pronounced and actually project into the property. They look like they probably could have been entrances to a waterway, and that’s exactly what they were in the past.

Even the tailraces from generators No. 3, 4, and 5 that show emptying into the Lower Pawtucket Canal are hidden in that canal under an overhang that juts out over the canal from the property, outlined by a dotted line, paralleling the Lower Pawtucket. But if you follow the outline from that point on the canal to the left you will run into two solid parallel lines leaving No. 1 & 2 wheels and entering the canal, the one and only waterway that still at least partially exists and can be viewed. This is the tailrace of the waterway that once powered a sawmill first owned by the Merrimack Company, and the remnants can be seen from where it turns on an angle after leaving the wheelpits of the sawmill itself as shown on the sketch offered on page 42 and ends at the Lower Pawtucket Canal. It runs along side an old mill building now converted to condos at the end of the empty lot that used to house the buildings of the Pellon Corporation, [later Freudenburg] and now completely demolished.
The photo below on this page is all that remains of the waterways at the Lowell Machine Shop not buried under acres of asphalt in the parking lots.

The water is backup from the canal. No water runs in the Saw Mill waterway.

The mill building converted to condos is on the left. The site of the demolished Pellon Corp. buildings is in the right. In the distance is the junction of the Saw Mill tailrace with the Lower Pawtucket Canal.

The question would not be out of hand as to why are we chasing the tale of a ratty old long turned to dust sawmill. Because it’s all we have is a good answer. And it is documented. On the Map of the City of Lowell published in 1841 by Beard and Hoar, it was identified as a bobbin and shuttle factory. Another source put its origin as around 1824-25.

Maybe the purists will complain that this raceway doesn’t meet the definition for an underground feeder, not covered with an arched overhead and leading from the canals to the mills. Maybe that statement is true but the sketch on the next page places the sawmill as being for real on the very edge of the machine shop property where it abutted to the Lowell Manufacturing Company and supplied waterpower to the sawmill.

There are many who classify the Lowell Canal as a penstock for the simple reason that it only furnished waterpower to one building. It’s just a matter of personal interpretation in the long run.
Merrimack Canal designated at top left. Lower Pawtucket Canal is on bottom marked Main Canal. Saw Mill is laid out by rectangle in center of raceway running between canals. Large square at top of raceway and abutting Merrimack Canal is probably an enlarged section of the raceway where the logs were held until needed. Machine Shop land is area to left of raceway.

Plan of Land Near Saw Mill
Deeded to Lowell Man'g Comp'y Mar15, 1828 (sic)

All of the other generator sites numbered No. 3 to 6 inclusive at one time most likely were the location of wheelpits and turbine sites that supplied the motive power for the buildings they were situated in or close to. Apparently no generators were ever contained at site of Wheels No. 1 & 2 although the wheelpits and raceways still had to exist in 1933 to be present in this sketch. This was the approximate site of the Saw Mill described above and at least the original purpose of this raceway was exactly that, to power the Saw Mill as it produced bobbins for the cotton mills, and probably many more wooden products.

The sketch on page 42 really doesn’t do justice to the Machine Shop Mill Yard. The presentation below brings out the wheelpits and waterways much clearer. The Machine Shop, as vast and crowded with the foundry and various machine shops as it was, required nowhere the amount of Mill Powers to run their operation that a cotton mill complex did. If the reader just compares the amount of raceways at each site in the sketches, this will become evident.
A lot of words have been covered for such a small presentation of material to interest the reader in the past grandeur of the Lowell Machine Shop. Continually harping on the Saw Mill site gets a little old but the evidence of the existence of the Saw Mill centers around only the few sketches, a small bit of documented text and one partial view of the tailrace. What little evidence we have has to be expounded on.

Many pictures of the Machine Shop exist. Outside, inside and being torn down. Our only interest at this time is the raceways providing a channel for the waterpower from the canals to the mills. However least the reader labor under the impression that the Lowell Machine Shop was some penny-ante operation surviving in the shadows and on the fringes of the cotton mills, the picture on the next page should dispel that line of thinking.
This drawing was made of the Lowell Machine Shop when it had just about reached its zenith and before the merger into the Saco-Lowell.

The water indicated by the ink wash in the lower right hand corner is the Swamp Locks basin. Running from the basin diagonally across the drawing to the upper left center is the Lower Pawtucket Canal bisecting the Machine Shop; the foundry buildings are to the right and the machine shops to the left.

At the point where the Canal leaves the Swamp Locks is a low building that straddles the canal with a dam under it; a set of locks is on the right alongside. The head of the canal water drops 13 feet over this dam and the building houses the gates that control the flow. This drop in the water level is what supplies the force for the waterpower.
Hamilton Manufacturing Company

This was the first mill built after the Merrimack Manufacturing Company had shuffled itself around and re-organized the Proprietors of the Locks and Canals (PL&C). The Merrimack had had visions of developing the entire power canal system themselves which also entailed building all of the mills. It didn’t take long to realize this was almost an impossible task they were taking on. The Merrimack owned all of the stock in the now dormant PL&C and the charter was still valid. The best thing to do was to transfer the water and land rights to the PL&C and let that Corporation manage the sale and lease of the water and land.23

And so sprang the Hamilton Manufacturing Company in 1826 on a spit of land on a new canal called the Hamilton that was dug paralleling the old transportation canal, the Pawtucket. What made the location not only feasible, but prime really, was that it copied perfectly the ideal situation for a mill utilizing water power. Two canals on different levels separated by just enough distance to construct a mill between.

The best scenario was to have a source canal say flowing from a river. We’ll call it “A” just to identify it. It gets to a point when you want to build a mill. Now a dam is thrown across the canal and the water backs up into a basin. A new waterway, “B” is dug from the basin paralleling the original course of the canal that has been deepened, says by 13 feet but separated by a given distance of land. Now the water, “A” is allowed to flow over the dam and drop into the newly dredged lower level and go on its merry way, except that it is now 13 feet lower.

The spit of land between the two canals is where you build your mill. The water in the new canal “B” is channeled through a headrace, into the wheelpit and through the wheel or turbine. The channel continues on through the tailrace and empties into the lower canal “A.” This drop in the water level is what is termed the head. The difference in elevation is the force that causes the wheel to rotate and turn the shaft that turns the pulley that spins the belts and away goes the looms weaving and the cotton cloth spits out on the mill floor. So came the Hamilton Mills into existence.

This illustration tells it all. Hamilton Canal on one side feeding into the wheelpits and the turbines, and exiting into the Lower Pawtucket on the other with the water dropping 13 feet from the former to the latter.
This is the first ever plan proposing the development of land belonging to the Merrimack Manufacturing Company laid out in 1824. The canal angled in the top left hand corner is the Merrimack and feeding those Mills. The canal running horizontally straight across the upper center of the sketch is the Pawtucket and it is marked so in small letters. The wavy outline superimposed on the Pawtucket Canal was the course of the canal before it was straightened and filled in.

The lowest of the three canals is what is referred to as the Proposed Canal on many drawings. This will become the Hamilton. The “T” shaped structures are in reality the site of projected future mill buildings atop their headraces. Although the arrangement will be different, this is the location where the Hamilton and Appleton Mills will rise.

The classic canals built parallel on two different levels is really brought out in this drawing of the projected scheme of the mill development. All of the rectangular shapes indicated under the canal layout are occupying the area where the boarding houses for the mill workers would be constructed.

“A plan of the land on the south side of the Pawtucket Canal belonging to the Merrimack Manufacturing Company Chelmsford Jan’y 1824”
Center for History of Lowell, Shelf 106, No. 599
The first two buildings at the Hamilton Mills were not only constructed by the Merrimack Mills, their machine shop produced all of the machinery (under the guise of the PL&C after 1825). But the ownership of the two original Mills was under outside interests, although some of the interests of the stockholders overlapped both Companies, after fully realizing that developing the entire tract of land of 400 acres\(^2\) (700 to 800 according to some records\(^5\)) was unrealistic.

The land was no problem. There it sat. If it was thought to be a good choice, the Corporation would bargain with the PL&C for a price to buy, or to lease\(^6\). But the water was a whole different ball game and the Mill Power was introduced with the building of the Hamilton Mills as a measurement to control its sale and use. Sooner or later the mill power has to be defined and this is an appropriate place. It is the same for each mill. The only variation in the formula is the height of the head of the water and that depends on the location of the mills in the canal system and that never changes.

The mill power established was long termed the “Lowell Standard” at 62.5 horsepower. It was defined as when powering a wheel and the PL&C engineer James B. Francis figured it increased to 68 horsepower when the water powered a turbine\(^7\).

The amount of Mill Power was contracted for with the purchase or lease of the land but the determining factor that governed the amount of Mill Power needed was the number of spindles that the mill would run. One mill power was sufficient to drive 3,584 spindles\(^8\).

Definition of Mill Power\(^9\).

Article I. “Each mill-power or privilege at the respective Falls is declared to be the right to draw from the nearest canal or water course of the said Proprietors so much water as, during 15 hours of every day of 24 hours, shall give a power equal to 25 cubic feet per second at the Great falls, when the head and fall there is 30 feet\(^{10}\) to 45 and 1/2 half cubic feet per second at the Lower Falls, when the head and fall there is 17 feet\(^{11}\) and to 60 ½ cubic feet per second at the Middle Fall, when the head and fall there is 13 feet.”

The Article continues on giving examples if the water is lower at each falls but best to stop here rather than complicate an already confusing explanation if the reader has no prior knowledge of the nature of a mill power. Even the terms to describe the falls used in the above definition should be clarified. The Great Falls refers to the Pawtucket Falls. The Middle Fall is the Swamp Locks and the Lower Falls is the last falls before the Pawtucket Canal pours into the Concord River.

Louis Hunter in his *Water Power* defines the mill power nicely describing it as “twenty five cubic feet of water per second falling 30 feet, but with the amount of water varying according to the actual distance of the fall, whether more or less than 30 feet.”

Simple enough and we’ll leave it at that. It’s common sense that water falling thirty feet generates more power than water falling thirteen feet. The only way to compensate and equalize the power of the lesser with the greater of the water fall is to increase the volume of the lesser, and that’s all that the formula does.

Maybe another help to understanding the complexities of the explanation of the mill power calculation is the inclusion of the chart below. While the raw figures were recorded at the Hamilton, the results could be, and are, typical for any mill. The interesting aspect of the figures is the heading they fall under. The first column records the quantity of water used in cubic feet per second and the fourth the
correlating fall of the water from the Upper to the Lower Canal which is another way of expressing the fall of the water through the raceway and turbines.

<table>
<thead>
<tr>
<th>Date of the measurement</th>
<th>Time</th>
<th>Quantity of water used, in cubic feet, per second</th>
<th>Height in the Upper Canal near the Mills, in feet</th>
<th>Height in the Lower Canal near the Mills, in feet</th>
<th>Fall from the Upper to the Lower Canal, in feet</th>
<th>Machinery in the Mills, reported as not in operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 2</td>
<td>2h 28' to 4h 32' P. M.</td>
<td>839.21</td>
<td>31.65</td>
<td>17.69</td>
<td>13.96</td>
<td>[13 Warp Throstles, 6 Mules, 206 Looms, 6 Dressers, 3 Winders, 1 Spooler]</td>
</tr>
<tr>
<td>Aug. 3</td>
<td>9h 0' to 10h 55' A. M.</td>
<td>873.55</td>
<td>31.83</td>
<td>17.74</td>
<td>14.09</td>
<td>[9 Warp Throstles, 8 Mules, 239 Looms, 4 Dressers, 4 Warpers, 1 Spooler]</td>
</tr>
<tr>
<td>Oct. 14</td>
<td>9h 33' to 11h 47' A. M.</td>
<td>984.54</td>
<td>31.82</td>
<td>17.67</td>
<td>14.15</td>
<td>[6 Warp Throstles, 4 McCulley ring filling Frames, 1 Loom, 1 Dresser, 3 Winders, 1 Warper, 5 Reels]</td>
</tr>
<tr>
<td>Oct. 14</td>
<td>2h 4' to 3h 52' P. M.</td>
<td>901.57</td>
<td>31.78</td>
<td>17.65</td>
<td>14.13</td>
<td>[6 Warp Throstles, 4 McCulley filling Frames, 5 Looms, 3 Dressers, 3 Winders, 1 Warper, 5 Reels]</td>
</tr>
<tr>
<td>Oct. 28</td>
<td>10h 15' to 11h 52' A. M.</td>
<td>919.79</td>
<td>31.78</td>
<td>17.63</td>
<td>14.15</td>
<td>No return.</td>
</tr>
<tr>
<td>Oct. 28</td>
<td>2h 42' to 4h 46' P. M.</td>
<td>917.97</td>
<td>31.28</td>
<td>17.63</td>
<td>13.65</td>
<td>No return.</td>
</tr>
<tr>
<td>Nov. 16</td>
<td>10h 5' to 11h 28' A. M.</td>
<td>942.74</td>
<td>31.85</td>
<td>17.67</td>
<td>14.18</td>
<td>[14 ring filling Frames, 3 Dressers, 2 Winders, 6 Warpers, 2 Reels, 1 Picker, 1 Willow, 3 Stretchers, 1 Speeder]</td>
</tr>
<tr>
<td>Nov. 16</td>
<td>2h 9' to 3h 25' P. M.</td>
<td>918.35</td>
<td>31.90</td>
<td>17.65</td>
<td>14.25</td>
<td>[4 warp, 14 filling Frames, 2 Winders, 6 Warpers, 2 Reels, 3 Dressers, 1 Picker, 1 Willow, 1 Stretcher]</td>
</tr>
</tbody>
</table>

The relevant part of offering the chart is so the reader can compare the figures with what he has read in the mill power formula on the previous page, to understand how the fall of the water enters the overall picture.
Seeing at this point the mill power has appeared, the next logical question to follow should be how did they measure the water flow through the wheels or turbines to establish the mill power? There were two methods that were popular for measuring water flow. The first was simply a hollow pipe weighted on one end and its travel over a measured distance was timed. From that test, the amount of flow could be calculated.

In the case of the water wheel, or turbine, the flume (or weir) was the measuring device of choice. In the beginning it was simply a wooden chute of known dimensions installed in the tailrace so the amount of water passing through the wheel could be measured with some degree of accuracy. It was cumbersome and wasn’t a piece of equipment to be left in the tailrace permanently. It was only utilized when there was a doubt as to how much water the mill was actually using verses what they were being charged for. The mill contracted and paid for X mill power and that’s all they were entitled to.

After the advent of the turbine, the measuring end got a little easier with the adoption of the speed gate. Even though the gate that controlled the flow of water through the turbine traveled in feet, the indicating arm only traveled in inches. It was graduated and once the amount of water passing through the turbine for any given indication on the scale was known, by measuring the flow through a flume, or weir, there was no reason for the reading to ever vary. The exact flow could be calculated simply by comparing the scale to as prepared chart.
About all of the scant material that research has produced has been gone over in the previous text. And all of the material is adaptable to every single mill complex in the system, and every wheel and turbine. No matter what part of this book contains a reference to mill power, it will refer to this section and chapter.

This closing will be accompanied by a representation of the Hamilton Mill complex. One thing all of the cotton mills had in common was the use of every square inch of land that they sat on, and the Hamilton was no exception.
Incorporated in 1828 to be built to the west of and abutting the Hamilton Mills, the water to power the wheels was drawn from the Hamilton Canal and discharged 13 feet below into the Lower Pawtucket Canal. And like the Hamilton Mills, the buildings were contracted for by the PL&C and the machinery built by the Lowell Machine Shop now fully incorporated into the PL&C. The Hamilton and Appleton Corporations had much in common, including many of the same directors and shareholders active in the Merrimack and Locks and Canals Companies.

The constructions of the Mill buildings have no bearing at all on the water power that flowed through their underground raceways. Still, it doesn’t hurt to acknowledge the existence of the end user of the mill power. To expand on the statement that the PL&C constructed the buildings for the Appleton Corporation, we have to back off a little. When they were scheduled to build and equip the first two buildings, the Merrimack Mills suffered a disastrous fire in 1829.33 All was put on hold while the Merrimack was reconstructed and refurbished by the PL&C.

Into the picture enters one Capt. John Bassett, a well known builder of the time. It appears, or at least he is given credit for erecting the first two buildings for the Appleton Company. The record of the Directors meeting of July 11, 1829 states “The agent having exhibited a statement of the cost of the Machinery Mills Houses etc. (sic) built for the Appleton Manufacturing Company by the Proprietors of the Locks and Canals on contract-“The fact that the work was done by contract lends some credence to the notion that in fact the buildings were erected by an outside contractor and not by the PL&C themselves. An entry from the Lowell Historical Records found in a volume of Contributions also supports Bassett as being the builder.34

But like any well told tale of history, this one also seems a little distorted by a teller somewhere down the line. The fact is on February 4, 1828, a charter incorporating the Appleton Company was awarded to T.H. Perkins, E. Francis and S. Appleton. The fiction seems to be in the statement made by Joshua Merrill that “During the summer of 1828, the Appleton Mills were put into operation” and the statement attributed to Samuel Batchelder that ”By the end of 1828, the Appleton Company had commenced operations.”

It’s difficult to disbelieve these statements considering the stature of both the speakers. Joshua Merrill was a leading educator and Batchelder was an original investor in the Hamilton Mills. And yet in the Director’s Record of the Meeting of September 7, 1830, it appears the Directors are still debating over building and equipping two mills for the Appleton Company. It’s doubtful that they are a third and fourth mill building because according to Frank Hill in his book Lowell Illustrated, 1884; those additions were built in 1846 and 1861 respectively.

Also it is stated elsewhere that a mill building could not be put up and machinery installed in one season.35 If the charter for the Appleton Company was granted in 1828, no way could two mill buildings be up and running by the end of the year no matter who built them or how esteemed the person who described the happenings.

The Appleton was conceived by two long time associates, P.T. Jackson who was one of the founders of the PL&C and Paul Moody who was the top machinist in the system and came from the Boston Manufacturing Company in Waltham when the Lowell Mills were proposed. Along the way Moody had perfected the mill machinery used in the industry that gave it a higher rate of speed and promised great savings and his anticipations were justified. Jackson was an interested investor and it was
he that established the company known as the Appleton Company to utilize Moody’s improved machinery.

Like all other Lowell mills, the Appleton started out with breast wheels providing the motive power. The diameters of the wheels were usually the same as the fall of the head of water which in the case of the Appleton would have been 13 feet. Wood was the standard construction material of both the wheel and shafting back then, and when the change over to iron began it was slow and caused many problems because of the poor quality of the metal.

One thing the Locks and Canals had no shortage of was talent. When reading the history of this company and the feats that were achieved by the workmen using the most rudimentary tools and basic education, it is just short of amazing. How did we evolve into the cluck headed excuses for engineers today still working on $400 toilet seats and having trouble digging a ditch?

Uriah A. Boyden had been a surveyor with the Locks and Canals until moving on in 1834. Where he moved on to was learning all he could about waterpower which was the liquid gold of the day. Boyden’s main interests lie in turbines.

In 1844 Boyden convinced the agent of the Appleton to allow him to construct and test a turbine for a new mill building that he had been experimenting with. The chief engineer for PL&C, James B. Francis aided in the testing and verified the increase in power of the machine while at the same time occupying less space. The bells were sounding the death knoll for the breast wheels, muted at first but getting steadily louder.

It didn’t take the PL&C long to buy up the Boyden patents on the turbine, especially with Francis verifying the results of the tests. And it didn’t take much longer for the PL&C to convince the manufactories to switch over from the breast wheel to the turbine for the savings offered in the use of the water with the same results in horsepower. Still a fairly large expense was involved on the part of the Companies and there is evidence that breast wheels were still supplying 20% of the power to the mills in 1876.36

Finally we are returning to the subject of the waterpower and again to a very light agenda of information available. One thing all of the waterwheels or turbines had in common was the need for water, a lot of water for as said, that was their fuel. The Hamilton Canal had a great excess and seemingly no end but it was useless as a power source for the Appleton Mills without the underground raceways that would funnel the water from the canal to the wheelpits and then provide a return path to another but lower water course in the Pawtucket.

And in the case of the of the Appleton Mills, it is in the most perfect location that a mill could be built, on a spit of land flanked by two flowing canals, the Hamilton 13 feet higher than the Pawtucket as they rush by on either side.
This photo by Janet Pohl is of the Hamilton Canal taken from the street crossing the bridge from the Appleton Mill on the left to Jackson Street on the right.

This photo is by the author of the Lower Pawtucket Canal taken from an extension of the same street with the Appleton Mill site on the right.
This photograph appears to be the entrance of a headrace leaving the Hamilton Canal and entering a wheelpit under the Appleton Mills. Strangely enough it is not covered by a trash rack. This may indicate that the raceway is not a headrace feeding water to a turbine but instead serving some other purpose. Its location matches perfectly the feeder supplying turbine #3 on the schematic.

Photo by Janet Pohl

This is a photo opposite the raceway entrance above. The water in the Lower Pawtucket Canal is extremely high obscuring most of the opening. The square shape would give more credence to the object of the channel as being a wasteway rather than a penstock to feed water to a wheelpit and thus a turbine. But no such waterway shows in the schematic of the underground on the next page.

Photo by the Author

Simply dig a ditch, a headrace from the Hamilton Canal to the wheelpits containing the waterwheels under the mill and eject the wasted water from the wheelpits into the Lower Pawtucket Canal through another ditch, the tailrace. In the middle of it all, the waterwheel is turning and the machinery is turning and the cloth is turning the profit for the investors.
In the underground sketch of the raceways and turbines under the Appleton Mills below, three different groupings of penstocks are noted.

All three turbine locations are shown as outlined inside of a schematic of what would indicate a building. Some presentations of the underground show the raceways as simply a solid line. This sketch indicates two turbines to the far left, three in the center location and one to the right.

So far any diagrams of the actual underground raceways and turbine locations within the mills have been sparse at best. These were the earliest mill sites and the builders evidently didn’t think it was of any importance. They knew where the channels went from and to. Who else would even want to know, or care, was probably their thinking at the time.

The advent of the turbine began with its installation in the Appleton Mills and the era of the waterwheel was destined to become history. But it was more than just that cumbersome power device that was disappearing. Any good millwright could fashion a waterwheel. The casting methods and fine machining used in making the turbines removed a skill from his hands forever.
Every mill in Lowell looked just like every other mill, height, width and length and the brick count must have came close also. When one thinks of the untold hours of labor that were expanded inside those walls, the whole scene becomes mind boggling. Entire lives marching to the incessant beat and vibration of the demanding pulse of the machines, only the reaching smoke stacks appeared to have a shot at liberty from the shackles of the daily grind.

The Appleton Company from Lowell Illustrated
Middlesex Company

Probably every corporation that arose in Lowell had a story to tell about its history. All had a tale for the telling but none could match the epoch of the Middlesex Manufacturing Company from its inception to its demise. The topic of this book is underground waterpower but a glimpse of its use in the system, and how it evolved, hopefully will serve to expand the interest of the reader.

This is probably the most overlooked of all the mill complexes and by far the most interesting. Maybe one of the reasons so little attention is paid to it is that it wasn’t a cotton mill at all but a woolen mill, the only one in the system. If you study the history of any of the mills closely, mentions will be made here and there as to forays into manufacturing products with wool. Both the Hamilton and the Appleton Companies were incorporated “for the purpose of manufacturing cotton and woolen goods” as were the Suffolk, Tremont and Lawrence. The Lowell Manufacturing Company used wool in its carpet industry.

The Middlesex was the only textile Company that stayed with wool as its primary raw material. That in itself probably made the operation different enough to warrant exclusion from the ol’ boy fraternity. Another oddity was that it was the only mill to draw water from two different sources, drawing from the Merrimack River and during its early years utilized a source drawing from the Concord. And last but not least maybe the quirkiness of Thomas Hurd, the gentleman that started businesses at several other locations in the area before ending up eventually on these 37 acres through various transactions.

Lets start at the beginning. There is another book in this series titled The Canals That Powered a Textile Industry that tells the story of Hurd’s Canal on page 23. Hurd’s first two woolen mills on seven acres and the two canals he dug to power them was the forerunner of the Middlesex Company. The three sources that powered this mill site at various times were the Concord River and the Hamilton and Lower Pawtucket Canals fed from the Merrimack River and they came into use in that order.

The Middlesex got its ambiguous start with an implied act of skull drudgery. Thomas Hurd was accused of an underhanded act while he only duplicated the acts of the Boston investors who conned the locals when acquiring their land on the cheap to begin their textile empire. Hurd simply got to one prime parcel (Bowers sawmill) on the Merrimack River in 1822 before they did and held them up for what he could. Its location on the Dracut side of the river above the falls was where their proposed dam would be anchored on the northern end. With out it, no dam. No dam, no reservoir to pool the water of the Merrimack River needed to run the mills. No mills and this tale would be a work of fiction.

This is one chapter where the telling of the story of the waterpower lays the foundation of the tale, not as an afterthought but the inception.

Hurd already had two mills on the banks of the Concord River, the first bought in 1818 and the second he built in 1821. He also built a small dam above the falls in the River and ran a canal from above it and paralleling the Concord River for a source of power for his second mill. The sketch below illustrates the location of the dam on the Concord River and the two waterways that Hurd built. This area and the waterways within it were to form the basis for the Middlesex Company.
This little sketch contains more information and detail than many pages of text would provide. The circled area is the approximate location of the future Middlesex Company. The partial legend below the sketch accompanied the original drawing but the remainder was of no interest so wasn’t included.

Presented by A. B. Wright. Drawn by Ignatius Tyler.

1. Although the Locks don’t show, this is the Pawtucket Canal entering the Concord River.

16. This is Hurd’s original canal and Nos. 13 and 15 indicate his first mills.

18. The Hamilton Canal from where this second of Hurd’s canals began would be off the sketch at the top center. The canal is shown tying into Hurd’s original canal to provide additional water.

23. The description given of this waterway is “This was a subterranean canal constructed in 1832.” We will return to this waterway later in the text.
Hurd would need more water power than could be supplied by his canal from the Concord River and he held up the Boston investors for more than money with his little scheme. They agreed to allow Hurd to tap off the end of the Hamilton Canal (waterway designated 18 in the sketch). He had purchased one mill power in 1826 as part of the buyout of his mill site at the Pawtucket Falls. He went underground for a good distance from the Hamilton to avoid existing roadways before just digging along the surface and tying into his original canal.

Anyway he went on his merry way, doing whatever you do in a mill. Hurd must have become sick of combing wool and figured there was an easier way to turn a buck. There was and he hocked the whole works to William and Samuel Lawrence along with W. W. Stone in 1827 for $55,000, defaulted on the payments, went bankrupt in 1828 and faded away. At any rate whether or not Hurd’s Canals were canals in the strict sense or penstocks is a play on words. Hurd’s canals were already defined as such by all previous descriptions and we’ll continue to refer them it as canals.

History being history, and with many people reporting on its contents over the years, one can see why it could get distorted with frequent telling. But when two written records by unimpeachable sources cast doubt on gospel, the fact becomes a flip of the coin. Quoting from the Northern Middlesex Registry of Deeds, by August 9, 1830, the Middlesex Company had possession of Hurd’s property, buildings and machinery. That record is pretty cut and dry. Yet an entry from a Directors of the PL&C meeting dated April 6, 1831 dictates that “The Treasurer be authorized to exchange the mill power sold to Mr. Hurd on the Upper Level for one on the Lower & that he be authorized to receive $4000 on the sum to be paid for the same.” (Authors note: Upper is the Hamilton and Lower is the Lower Pawtucket). The dates of these entries, the bankruptcy, the Registry record and the Directors entry are three years apart. Maybe Hurd didn’t go away.

At any rate, by 1830 the epoch of the Middlesex Manufacturing Company had begun. Its expansion through the mid 1800s necessitated the purchase of more mill power from the PL&C until it totaled over five. It occupied seven acres in the beginning but was to expand to cover 37 acres. It seemed to have waterpower coming from every direction and source available. In a written Report signed by James B. Francis in 1857, an estimate was made of The value of the Land and Water Power belonging to the Middlesex Company in Lowell. Under the heading of WATER POWER, 5 23/30 mill powers were held under lease from the PL&C., Concord River Power with no amount and a third source listed as simply Wamesit Mill lot and water power.

As usual though, the Middlesex Company marched to its own drummer. Long after most mills had changed over to turbines, the Middlesex was still using breast wheels into the 1890s. Their use was most likely confined to the older buildings which were still in service all though there is no mention of this.

Our main interest of underground waterways has been overlooked somewhat. To get back in focus the next page has a series of two photographs that represent the headrace leaving the Lower Pawtucket Canal just above the Lower Locks on the top left and its course through the turbines in new mill number one and to eject the spent water into the Concord River from the Granite arches in the photograph on the top right.
And last but not least are the remnants of the only visible vestiges of the final power source that fed the Middlesex Mills.

Blocked headrace leaving the Pawtucket Canal from under the hotel wall.  
Photo by Author

Tailraces emptying into the Concord River through two granite arches.  
Photo by Author

Middlesex Company Mills  1850  Sidney and Neff
Massachusetts/Prescott Manufacturing Companies.

Both of these mill complexes are usually treated as a single entity. The Massachusetts Mills were chartered in 1839 and are regularly carried as being the last of the main mill complexes constructed. In a way this is true even though work on construction of the Prescott buildings was started in 1844. The company was bought by the Massachusetts Corporation in 1847 before it was in full operation and was simply absorbed by the Massachusetts. Geographically all that separates the buildings is East Merrimack Street that runs between the sites. Taken together their combined yards cover about 11 ½ acres and are bordered by the Merrimack and Concord Rivers, the Lower Locks Wasteway, Bridge, Prescott and Central Streets.

But their backgrounds and beginnings were diverse enough to treat the history of the two corporations separately until they merged and for no other reason than to give them their own identity, and their early development certainly allows for that distinction.

The Prescott Mills

The site completely demolished now and occupied by the Middlesex Community College, was the smaller of the two, sitting on about 4 acres. Compared to the larger complexes, even its power need was small, contracting with the PL&C for only 4.6 Mill Power. The five raceways that supplied the water ran from the Eastern Canal and emptied into the Concord River. There is no mention of a waterwheel by any of the early sources. The first reference to a wheel was a turbine installed in 1847 followed by the statement that there were two turbines powering the mills by 1848.

![Photo by Author](image)

Showing one set of pair of headraces leaving the Eastern Canal with Community College in background. Strangely none of the six headraces that once provided water power to the Prescott Mills shows signs of having been protected by trash racks.

It is quite possible the Prescott Mills never went through the waterwheel cycle given the date of its inception that bordered on the introduction of the turbine. At the first appearance of the turbine on the power scene many were doubtful if the new machine could out perform the large and well seasoned breast wheels. The trial installation was reported to be made at the Appleton Mills in 1844 and it was successful with no less than the head engineer for the PL&C, James B. Francis attesting to the excellent test results.
If the first mention of a new mill along the banks of the Concord that appeared in the Minutes of the Directors Meeting held on October 7, 1843 is any indication of the eventual size of the first building in the Prescott Yard, it took a lot of courage to go with an untried power system and install turbines and at this date it is possible the Prescott, and not the Appleton was the first. But even the looms installed in the Prescott were innovative. They were the first ever built by the machine shop with iron instead of wooded frames.

But let’s return to the channels that were to carry the water from the Eastern Canal and drop 17 feet into the Concord River. The sketch below shows the first proposed raceways.
These are the five tail-races Leaving the Wheelpits under the Prescott Mills. The water left the Eastern Canal through headraces as shown on page 69 and fell 17 feet to turn the turbines before being returned to the Concord River.

Lowell National Historical Park
LOWE 7937

All of these photographic reproductions were obtained from the collection, www.museum.nps.gov/ These views were take during 1918/1919 either just before or during reconstruction of the raceways. The photos below show the work in progress of installing a draft tube in the Concord River wall during the installation of 3-33” Hercules turbine wheels that will be attached to electric generators.

Lowell National Historical Park
LOWE 7970

Lowell National Historical Park
LOWE 7971
The Massachusetts Mills

This was the last major corporation chartered in 1839 and its construction on 7 ½ acres brought further expansion of the canal system to a halt. The simple fact was there was no more land with access to the canal waters available and it took the last mill power that could be produced in the canals to turn the machinery and eventually over 24,000 spindles. By 1841 the four mills were in full operation.

Only the Merrimack Manufacturing Company came up to par with the manufacturing capabilities of the Massachusetts. In the use of mill powers they were almost identical. However it took 1116.267 cubic feet per second of water flowing in the raceways of the Massachusetts to accomplish what the Merrimack could do with 616.667 cfps. The difference was in the amount of head the water generated at their respective falls and carried when leaving the respective canal and entering the buckets of the mill wheel. Definition and description of mill powers on page 55 gives a full explanation. The head supplied by the Merrimack Canal feeding the Merrimack Mills was 30 feet while that of the Eastern Canal feeding the Massachusetts was only 17 feet.

Four headraces left the Eastern Canal to supply waterpower to the Massachusetts Mills complex and remains of the two trash racks covering them are quite visible if the water level is down any at all. Here the canal is empty. At one time these raceways were open in the mill courtyard delivering the precious cargo of liquid power to each of the four breast wheels, one under each of the original mill buildings. They were covered over many years ago probably to allow other buildings to be built over them during periods of expansion.

Both Photos by Janet Pohl

The two photos above show the deteriorating racks covering the headraces that fed the mill wheels. Mills nos. 1 and 2 paralleled the Concord River and their tailraces emptied into it, now covered over with concrete. Nos. 3 and 4 mills paralleled the Merrimack and evidence of their tailraces can be seen from the Bridge Street bridge mostly covered over by a recently constructed sewerage conduit that hugs the river bank for most of its way.
This sketch is dated November, 1839. The plan shows the original layout of the Massachusetts mill yard including raceways supplying each of the four mills outlined by the dotted lines.

There never seemed to be a problem with engineering for the mill construction centuries ago. The best use of the land and water was determined and laid out in a sketch as presented at the left. The construction methods were kept simple and then the work began following the straightforward layout and designs of the artisan. Their works are still standing and while not serving the original use maybe, a good many are still functional and occupied.

PL&C Archives, Massachusetts Mills

These raceways were dug to supply the wheel pits for 17 foot wooden water wheels but the headraces, pits and tailraces would serve just as well to service the turbines that were beginning to appear on the horizon. After 1850 turbines were installed in all new additions to the complex and by 1869 the last breast wheel was removed. In 1856 a central wheel house was built containing four wheel pits containing two 10 foot 375 hp turbines with two pits left empty for future use.

In 1856 a central wheel house was built containing four wheel pits containing two 10 foot 375 hp turbines with two pits left empty for future use.
The two wheel pits designated for future use have long since been pressed into service with the installations of turbines. Eight tailraces can be counted leaving the powerhouse and this is the only instance uncovered in the research so far that indicates two tailraces leaving each turbine wheelpit.

To the right is a small portion of the sketch on page 76 showing the four turbines in the Massachusetts powerhouse and the double tailraces leaving each wheelpit and emptying into the Concord River.
Water, water, water. This was the power that fueled the mill machinery. As long as it flowed through the canals and was distributed through the raceways to the individual wheel pits, everything was working up to par. But what was the result when a mill within a complex lost one or more turbines for whatever causes.

Most mill sites had several power sources, whether they were breast wheels or turbines. Common sense would dictate that somehow the output of the individual wheels would be available for all. The answer would be through shafting. Any one mill that had multiple turbines coupled them together and through this method achieved a more balanced output. Also if one unit was down for any given reason, power was still supplied to all of the machinery, granted with less horsepower.

So why not tie several mills together using the shafting method between them and achieve the same results. And go a step further and supply power to a mill that was added to the complex. Digging a new canal amongst the existing buildings every time a new mill building was added could be daunting at best. It was possible to weaken the supporting foundations of the existing structures or loosen the fill of the banks containing the raceways that were supplying the current water power.

This was probably the concept behind the process of building separate and free standing wheelhouses with all of the wheels centrally located as mentioned previously, detached from the mill buildings and not installing the individual turbines in the basement as was the previous norm. Once this technique was adopted, provisions could easily be provided for future expansion without digging under and around a hodge-podge of scattered buildings with new raceways every time expansion occurred in the complex.

Centralization of the power producing turbines would also free up a large amount of space for production previously occupied by the great breast wheels and inherited by the turbines. One shaft running throughout the mill yard and tapped off at intervals using gearing was the answer. There are other mentions in the records of mechanical methods to feed individual mill sites but this is the first to show up in the order chosen to present the material.

To be sure the waterpower was still the prime motivator. The shafting was simply one more innovation amongst the many that were adapted to the industry to improve on the power transmission and thus add to the production. But this also allowed the output of the steam engines to be tied into the power train as that source was developed.

The composite sketch on the next page show the whole power layout of each site in its entirety. The parallel dotted lines indicated the underground raceways leaving the Eastern Canal and emptying into either the Merrimack or Concord Rivers. The circles are the location of the turbines and the notes tell the manufacturer and horsepower of the units. It’s quite obvious the solid lines are the shafting and they are noted as such. In the lines of shafting in both the Massachusetts and Prescott Mills will be a solid rectangular line heavier than the others. Look close and they are marked Steam Engine.

So through the use of the shafting all of the power motives at each site have been combined to operate as one.
A small section of the composite sketch has inevitably been eliminated effecting the layout of the Massachusetts Mills powerhouse. This has reduced the size and number of turbines shown. The correct layout of the powerhouse shows in the sketch on page 68 but the mistake does nothing to take away from the purpose of the distorted composite sketch.

Power Layout in 1889 at the Massachusetts Cotton Mills
Lowell National Historical Park

The prime study of water power, the delivery of it through a maze of underground raceways from the canals to the wheelpits and thus the wheels at the mill sites, is still the main objective of this book. But still one can’t be faulted for deviating for a moment to include mention of other power sources and methods of delivery such as steam and shafting if it serves to expand the overall picture.
Pause for a minute while looking at this drawing of the building layout of the Massachusetts Manufacturing Company in 1911. Waterpower was still being employed at this date although possibly as hydro-electric units only but still functional and providing power the complex. While steam power had been introduced in the 1870s, it was done so as a supplemental energy source to the water power.51

While there have been changes to the configuration of buildings in the mill yard, and probably some demolished and some added as the industry demanded, just to envision the force of the water from the Merrimack River as the prime motivator of the power supply is almost unbelievable. And multiply the demands of the other ten complexes and it becomes mind boggling.
Boott Cotton Mills

Chartered on March 27, 1835 by the Massachusetts General Court, the incorporators of the Boott Cotton Mills were Abbott Lawrence, Nathan Appleton and John Lowell. These same names appear as the controlling interest in many of the corporations. Even the name chosen for the mill complex honored the first agent of the Merrimack Mills who was to pass away in 1837.

But their projected operation would prove to represent more profit for the Proprietors of the Locks and Canals [PL&C]. The outstanding shares of the PL&C had been purchased in 1822 by the Merrimack Manufacturing Company and the company was now effectively controlled by the investors so they were welcome by any name. In 1825 the Merrimack Company realized the scope of building new canals, leasing water power and constructing new mill buildings was proving to be too complex on top of running their own cotton mills so the PL&C was re-organized and all of the excess land in their control, which was effectively all of it, was sold the new PL&C. The object of the game was to sell water and for that the PL&C was more than willing and certainly able, even to the point of digging a new canal to get the water to the chosen site of the Boott Mills, and they wasted no time. In fact the PL&C was one step ahead. At the Directors meeting of September 20, 1834, “the agent informed the board of an application for the purchase of four mill sites & machinery, and at the same time submitted a plan locating nine mills on the lower level & the canal to supply them with water.” In two subsequent votes, a committee was appointed to sell the mill sites applied for and to contract for the machinery and the agent authorized to proceed with construction of the canal.

Winter months were sure to put a cramp in any plans concerning the PL&C and their building operations but on March 16, 1835 the committee reported to the Directors at their meeting that they had contracted with Abbott Lawrence for a total of nine mill powers “for a price not less than Five Dollars pr. Spindle.” Another source quotes the price of the land and mill privileges as over $84,000. The site would prove to consist of 5.7 acres bounded by the Merrimack River, Bridge, French and Kirk Streets. An indenture dated November 16, 1835 also records the annual rent for each mill power as “sixteen ounces, seventeen penny weights, twelve grains troy weight of gold or two hundred and sixty ounces troy weight of silver.” We’ll stick to the dollar figures where possible.

This is the only mention found of the request for locating nine mills to supply them with water. No additional buildings except for the original four proposed for the site appear on the original plan of the Boott Mill yard. It is more possible that this line was meant in reference to nine millpower and was copied into the directors minutes wrong.

At any rate the Eastern Canal was dug from the Lower Pawtucket to the Merrimack Wasteway to provide waterpower in anticipation of the Boott construction. It was recorded as being of rectangular in shape at 2,000 feet in length, eight feet in depth and from 42 to 66 feet wide. An accounting ledger page presented at the Directors meeting dated July 30, 1836 gives a cost from the PL&C Records under the heading of Eastern Canal as $18,874.16.
This is a copy of the original plan of the Boott Mill yard in 1835 that accompanied the Deed. It can be found in the files of the Middlesex County Deeds—Southern Registry: Plan Book 36, Plan 17. The Eastern Canal is bisecting the property horizontally from Bridge Street at the left to the Merrimack Wasteway on the right. At the top of the canal is shown the proposed company boarding houses and to the bottom is depicting the four mill buildings each to be approximately 150 by 45 feet with the raceways to carry the water outlined between the dotted lines and emptying into the Merrimack River.

Proprietors of Locks and Canals, Draw 155, Drawing 7

Nine millpower were contracted for by the Boott Mills in 1835 which gave the mill complex the right to draw 45.5 cubic feet per second from the canal with a head of 17 feet as the water dropped from the canal to the Merrimack River. All four mills were completed by 1839. The Massachusetts Mills would also be built along side this canal and tap it for their source of waterpower.

Prior to 1852 when adjustments of the water powers were decided on, the Boott Mills had added one more millpower bringing the total to ten. After the adjustments were finalized on September 20, 1853 the total amount of mill powers contracted for was recorded at 17. The underground water distribution system for the canal system is the topic of interest and to plot these particular routes under the Boott Mills we started with the simple plot plan on this page dated 1835. Although the raceways
would expand considerably over the years with the expansion of the millyard, the source of the waterpower from the Eastern Canal would remain constant.

By 1896 the layout of the underground raceways at the Boott Mill site had been expanded considerably to accommodate the added mill buildings that had been constructed in the millyard and it remains substantially the same today.

In most cases, only the trash racks covering the entrances to the headraces are visible today. All of the remaining structure of the underground raceways are completely covered and out of sight. However the National Park Service has commissioned a report titled the *Historic Structure Report* that describes the construction of the raceways as “The four mill sites were provided waterpower by four brick barrel-vaulted underground raceways that ran perpendicular to the canal. It is likely that the water turned 17’ diameter wood and iron breast wheels that would have been set into the cellars of each mill.”59

Proprietors of the Locks and Canals   Draw 155   Drawing 7
The source of the research for this description is mute but we have to consider every bit of available information that we come across as being reliable unless proven otherwise and the National Park Service probably feels the same.

View from vehicle bridge that spans the Eastern Canal and runs from foot of John and Amory Streets and enters the Boott mill yard between buildings #6 & 8. Trash racks shown are under building #6.

Photo by Janet Pohl

View from pedestrian bridge over Eastern Canal. It runs from Amory Street and enters building #8 in the Boott Mills. The bridge spans the trash rack.

Photo by Janet Pohl

The trash racks covering the headraces under mills Nos. 6 & 8.
Most photographs of the canals illustrate well the majestic and slightly view of the serene waters flowing between the granite walls but the working parts only appear when they are viewed empty, warts and all. The debris on the empty canal bottom may be unsightly but it is there and it is part of the underwater scenery for better or worse. At one time these canals were drained every Saturday late afternoon and not refilled until late Sunday for that one purpose of cleaning and maintenance but with the demise of the mills that too is a thing of the past.

As mentioned before the trash racks cover most of the headraces leaving the Eastern Canal and entering under buildings Nos. 6 & 8 of the Booth Mills. In the sketch of the underground raceways on page 80, two turbines are shown located between mills Nos. 5 East and 5 West. The two headraces are located under the vehicle bridge that crosses the Eastern Canal at the foot of John Street and provides access to the millyard.
If the reader was to follow the path that leads to the Riverwalk that runs between the Boott Mills and the River from the vehicle bridge straight through the millyard toward the River, and it is accessible between the No. 5 buildings, the turbine pit can be seen to the left under the #5 West building. Also visible are the head and tailrace entering and leaving the turbine pit. It is only a small piece of the extensive underground raceways but it remains an impressive small piece.

Steel guard erected over the turbine pit. There is also a grate that bars even the light from the view and greatly restricts the photographs that can be taken.

The view down into the turbine pit showing the headrace entering the forebay with the turbine housing projecting from the bottom.

This partial view shows the opening allowing the tailrace to enter the River from the wheelpit. A short trip following the directions is recommended.

Photographs by the author
The series of pictures presented above show probably the only raceway that at least complete portions of can be followed, and then only the underground system providing water to power the wheel in building #5 West. The entrance to the headrace leaving the Eastern Canal is depicted in page 83, the turbine pit and its associated raceways on the previous page and just below on this page a pair of tailraces emptying into the Merrimack River. The bank of the Merrimack River under the Boott Mill site is encased in granite block but these tailraces may not be authentic to the described turbine raceway. Never the less the photograph does portray a typical archway framing a typical tailrace.

Proprietors of Locks and Canals - #1405
Center for Lowell History

If the mill sites were anything, they were constantly being changed; rebuilt because of the industry demands, floors added because of space restrictions imposed by other surrounding mill sites and simply geographic boundaries. So any source that enabled expansion that arose was quickly taken advantage of.

The straightening of the banks of the Merrimack River was seized upon as a gift from the gods. The southern bank on which the Boott Mills were constructed on was extended in 1882 by 25 feet and allowed for a four story addition to the #5 East Mill on the newly filled land. The informative Cultural Resources Inventory compiled by Shipley, Bullfinch, Richardson and Abbott quotes the General court of the Commonwealth of Massachusetts when it refers to Chapter 89 of Acts of 1882 which declares that “several manufacturing companies were granted the right to ‘define’ and improve the rivers channel.”
One more point can be illustrated to portray exactly the flow of the water through the underground raceways at the Boott Mill complex. The sketch below shows a cutaway schematic of the chambers that exist beneath one mill building that funnel the waterpower through the system. It is by far the simplest and likewise the most complete presentation imaginable. From the beginning at the headrace (penstock) into the forebay and into the turbine to empty into the tailrace and ultimately a lower canal or the river.

This sketch is shown in an abbreviated view as it is the only part of the complete original drawing that is of our interest. And many words have been written just to explain the motive process that is before us with a few stokes of a pen.

The romance of the rushing water pouring through the wheels and spinning the great looms of the Boott Mills was approaching obsolescence; first as turbines replaced the breast wheels by 1857 and then it became the turbines to slip into oblivion, heralded by the introduction of steam to supplement the waterpower in 1873 and 1878.\textsuperscript{61} Still, both modes of power continued to be used as late as 1932. At this time it was calculated that 5/8 of the power of the Boott Mills was produced by steam, and the remaining 3/8 by water.\textsuperscript{62}
Environmentally, waterpower couldn’t be beat in it’s day, or even today for that matter. Lowell’s biggest manufacturing rivals, the mills of Britain, were buried in the smog from burning coal to fire their steam boilers. But waterpower did have its natural disadvantages not seen in steam. Fluctuations in the height of the water in the Merrimack River, too high or too low, all contributed to the problems of the PL&C in providing the millpowers to the manufactories. Too low in the mid-summer hopefully could be controlled by flashboards at the Pawtucket dam and reduced hours of operation by the mills in order to pool the available water above the dam could all help somewhat. This solution was just common sense. But spring freshets generated by the melting snows of the North Country could cause havoc with the resulting flooding of the river. The excessively high water levels didn’t so much overpower the canals and their ability to handle the volumes that poured down the Merrimack River. That was suppose to be controlled for the most part by the upper (Swamp Locks) and lower (Lower Locks) dams and their gates regulating the water level in the canals, and the capacity of river itself.

The major problem was the flooding of the wheelpits at the mills. The major supposition amongst people when the threat of flooding is broached is just let the excess volumes of water pour down the canals. What’s the difference? So the mills gain a little extra power for a time: the PL&C will charge them accordingly and everybody will be satisfied. Yes, as the canals fill up, more water does flow through the headraces at an increased rate and into the wheelpits propelling the waterwheels or turbines with greater power. But the same increased volumes of water also pour down the lower canals or the river into which the tailraces eject the water spent from turning the wheels.

Backwater is the term given to this condition. Instead of the spent water being ejected from the wheelpit and allowing the wheel to turn freely from the weight of the inrushing water in the headrace, the same volume of water is rushing backward into the wheelpit through the tailrace because of the increased water level in the lower level canals or the river effectively chokes the motion of the wheel. The net result is a loss of power, not a gain from all of this excess water. The input and output of the volume of water through the wheels is a delicate balance that has to be maintained to effectively operate the system. This was the reason why the level of water in the canals was regulated so closely at the overall level of 30 feet with a calculated fall of 13 feet at the upper falls and 17 feet at the lower. These are the levels that the system will function at most efficiently.

The ice problem in the Eastern Canal

As already explained in chapter four, the Boott Cotton Mills had a unique problem not experienced by any other mill complex. All experienced a somewhat loss of production because of ice jams in the canals that fed waterpower to their wheels but none to the extreme extent that the Boott did. The Merrimack Mills as well, being at the end of the Merrimack Canal spent many hours and days clearing the ice from their trash racks that blocked the flow of water into the headraces. But at least the workers there could break up the ice and force it over their dam and into the Merrimack Wasteway to allow it to flow into the river.

Take a minute and consult the map on pages 8 and 30 to get a better picture of the locations of these mills and canals and their locations in the system. The reason the Boott Mills ended up with the largest problem with the ice isn’t easy to understand unless one can envision the ice problem as it is explained further into the text. It was simply that a lot of the cause of the excessive ice build-up experienced by that mill complex was primarily the poor selection of that particular location in the system. True, it placed the Boott at the extreme end of several miles of fast flowing waterways but the mill complex was bypassed by most of the volume of water, once again by the location in the system of
the Eastern Canal which supplied it. And the solution to the low water was the Boott Penstock which was to create an unforeseen problem down the road.

A given was simply that in the winter, the ice on the Upper Pawtucket Canal was no problem. The ice was forced over the Swamp Locks Dam and became the problem of the Lower Canal. The ice in the Hamilton Canal was also fed into the Lower Pawtucket Canal through its own wasteway and consequently all of the accumulated ice was pushed by the heavy currents down stream to jam against the dam of the Lower Locks and accumulate in the Lower Locks basin.

Open the gates at the dam and push the ice over the spillways and into the Concord River; so what’s the problem? There is no problem to that solution to the method of removing the ice from the Lower Canal, just in the cost. The cost was to the PL&C if the precious liquid gold had to be squandered to wash ice out of the canals, especially if it appeared that it wasn’t their responsibility in the first place but more on this further on.

As mentioned before, the Eastern Canal was about 2000 feet in length feeding waterpower first to the Massachusetts Mills and then to the Boott Mills before dropping through the underground raceways and into the Merrimack River. The Boott Dam straddled the end of the canal and then merged with the Merrimack Wasteway before any surplus waters entered the river. This waterway should have presented the ideal answer to the question of what to do with the ice, providing a somewhat direct route from the Lower Locks basin to the river. The swift flowing canal water was going that way anyway so also no added expense would be incurred with the wasting of water.

This seemingly simple solution was actually no solution at all. This ongoing examination of the ice problem that plagued the Boott Mill Complex has nothing to do with our interests in the underground raceways that fed water to the wheelpits in the various mill buildings. And yet it is everything. This problem could be so severe as to prevent the amount of water to which the Boott Mills were contracted for from flowing into the wheelpits and thus interfere with the manufacturing process. If the freezing persisted for a long enough duration, the anchor ice could build up all the way to the bottom of the canal allowing no water at all to flow in the raceways.

Seeing that we’re bound and determined that this ice problem has to be addressed again, let’s approach it from a different angle than that presented in chapter four. A quote from a booklet outlining the operation of the Lowell canals and the experience of the men who worked them titled Working the Water will be included here. A little literary license will be taken with the re-telling to make it more readable and brief.

The author, Steve Turner, starts with the statement that winter means headaches on the canals and heavy snows can clog the waterways. And then there is the anchor ice, the oddly named glue like slush that forms (under proper conditions) on the surface of the flowing canals as a kind of forerunner of solid ice.” He adds that the proper conditions are bitter cold and a little wind. “It sticks to almost anything it touches, mounding up quickly.” This description should more that paint the picture for our purposes.

Why wouldn’t the swift currents of the Eastern Canal simply push the accumulating ice over the Boott Dam and alleviate the problem from the beginning before the jam grew so massive that it couldn’t be handled? We have to go back to the penstock that was built between the Merrimack and Eastern Canals after the completion of the Northern Canal and the Moody Street Feeder in 1848 that connected those canals together. The purpose of the penstock was to allow the increased volume of water now
pouring into the system from the Northern to supply the Eastern Canal with an added flow from that source to alleviate the chronic shortage in that canal because of it’s location at the end of the water supply chain. It served the purpose to increase the level to a degree but was also the prime cause of the ice build-up problem that we are discussing.

How? How could the successful introduction of adding water to increase the volume in the Eastern Canal have caused as much, if not a greater problem than it was meant to solve? The fact that the water from the Merrimack Canal that was entering the Eastern Canal through the Boott Penstock was flowing in the opposite direction as the current in the Eastern Canal had much to do with the unanticipated results.

The two water flows collided head on but the turbulence created didn’t affect the quality of the added volume one iota. It added to the level in the canal and so the end result of the Boott penstock was achieved. Boott was happy because the looms were turning full speed and the PL&C was happy to be receiving the extra $6,000. the penstock generated in revenue. All was bliss, that is until winter raised it’s ugly head, or rather it’s ugly ice. The ice was always present in the winter and that was true on every canal, not just the Eastern. But the Eastern was the only canal that had a heavy flow of water pushing against its current with its own forceful current, that which was generated by the flow from the Boott Penstock. This opposite current was what held the ice jam in place and prevented all efforts to freely allow it to flow over the spillway at the Boott Dam and into the Merrimack River.

This very question was addressed by Thomas L. Livermore and a report made to the Boott Cotton Mills. The Directors received a copy and the Minutes of their meeting of March 8, 1889 stated so. The report was printed in the Sundry Papers and titled, Removal of Ice from Eastern Canal. We will quote in part from the observations that Mr. Livermore made in his writings concerning which party had the obligation for the removal of the ice. “The question now arises whether the Proprietors of the Locks and Canals are bound by anything in their lease to the Boott Mills of December 1, 1853, to remove the ice. The lease grants to the Boott Mills 17 26/30 ‘mill powers or privileges at the Lower Falls.’ It is to be remarked in the outset that no right is conferred by the lease on the Boott Mills to touch the canals or the weirs of the Lessor, and unless the Lessor is bound to remover the ice, the Boott Mills must submit to its presence (if the Lessor so wills) unless they construct a wasteway through their mill site, and with the ‘mill powers’ to which they are entitled, float the ice over this wasteway.”

He goes on to add that nothing indicated that the Lessee was to use its mill powers from clearing ice from the canals.

Everywhere the Boott Mills turn to alleviate the ice seems to leave them between a rock and a hard place. Mr. Livermore next quotes from the Form of Lease of Water Power at Lowell, 1853,65 that the PL&C and all of the manufactories signed and adopted as their contract form. Article III provides that the Proprietors of the Locks and Canals shall “from time to time, as occasion may require...remove from the said canals and water course all obstructions and accumulations that may sensibly interrupt the flow of water therein.”

It appears that the Boot may have won a point in their favor but the PL&C was prepared to argue further for their cause. They claimed that “Article III of the lease referred only to the accumulations and obstructions which sensibly interrupt the flow of water ‘in’ the canal and not the flow ‘out’ of the canal, and that the ice which accumulates in front of the Boott Mills does not sensibly interrupt this flow of water in the canal.”66
All of the PL&C’s arguments were based on a court case brought by the Essex Company at Lawrence because of the ice problems they had in their canals with ice but the two cases were apples and oranges. The reader can decide on his own by reading the article that the previous text is quoted from. We have beaten this issue to death but that the flow of water through the underground raceways and into the wheelpits was severely restricted by the ice jam cannot be disputed.

Before leaving Mr. Livermore, at least we know he reached the same conclusion in 1853 as we did with our research of today as to the cause of the huge ice jams at the Boott Mills. We will quote him one more time before we take leave for good and put the entire past ice history behind us.

“But the greater part of the ice which accumulates in the Eastern Canal opposite the Boott Mills is stopped and detained there, not by the inflow to the wheels or the racks, but by the southerly current from the Boott Feeder, which acts like a dam across the canal, and this is in no was the result of any act chargeable to the Boott Mills. Furthermore no amount of attention or care on the part of the Boott Mills could clear away the accumulation of ice because the currents in the canal make it impossible for the Boott Mills to move it one way or another.”

Chapter Four describes in detail the Boott Penstock, its final configuration, and the part it played in raising the water level of the Eastern Canal. The photograph on page 33 illustrates how the waters of the penstock were intermingled with those of the canal through ports in the stone wall separating the penstock and canal. By allowing the penstock waters to enter the canal at a right angle to the trash racks, much of the problems because of the immovable ice packs were solved.

With that last paragraph we’ll tuck the ice problem into its bed as a solved historical question and return to our quest for descriptions and explanations of the construction and operation of the underground raceways that furnished the mill complexes with their contracted for millpower from the PL&C.
Tremont and Suffolk Mills and the Lawrence Manufacturing Company

As on any unfamiliar trip, a map always eases the burden of navigating unfamiliar territory and this foray into these three mill complexes is no different. At least a quick glance by the reader of the site layout and becoming somewhat acquainted with the relationship of the three manufactories with each other can’t help but make the following text more comprehensible.

The layout of the buildings and canal in the Lawrence Mill yard is left blank in this drawing but will be presented in full detail in the following pages when its underground operation is described in detail.

Copied from an informational folder describing the mills and slightly abridged.
Tremont and Suffolk Mills and the Lawrence Manufacturing Company.

Why, the reader is probably asking himself, are these three manufactories lumped together? Are they all under one roof or the same ownership? Or have they all merged such as the Massachusetts and Prescott Mills did as outlined in the previous text. To answer the prior questions, no, somewhat and at least the Tremont and Suffolk were always treated as one entity because of the close ties of the management of the two down through the years.

The inception of the first step toward construction of these three mill complexes appears to be in an entry in the records of the PL&C Directors Meetings dated November 19, 1830. It reports that a committee had already been appointed to consider a contract with the Suffolk Manufacturing Company for two mill seats and power at Lowell.

This seems to indicate that the contracts between the PL&C and the Lawrence brothers for the land, buildings and power to operate the machinery were finalized in late 1830. The Tremont and Suffolk Mill sites were documented as having the construction commencing shortly thereafter even though the proceeding were not actually recorded until 1832, around the time of the completion of the Western Canal.

The three complexes did have several common denominators. The planning for the construction of the mills seems to have been contemplated by the PL&C as early as 1830. On a page from a ledger taken from 1830 is an entry, "Western Canal & Mill Sites," $32,800.40. [The first recorded mention of the Suffolk Manufacturing Company addressing the PL&C to obtain two mill seats with full power and contracting for the buildings, gearing and machinery appears in the record of the Directors Meeting of November 19, 1830]. They were all incorporated in 1831, the Suffolk on January 17, the Tremont on March 19 and the Lawrence June 7, and all three manufactories bore the name of William Appleton as one of the incorporators. Benjamin Nichols was involved in at least two of the manufactories, the Tremont and the Lawrence among the others.

All three corporations were actually organized by wealthy Boston merchants Amos and Abbott Lawrence. Both Lawrence names are listed as incorporators of the Tremont Manufacturing Company and the Lawrence Manufacturing Company was to bear the family name. They were both seasoned businessmen and eventually were to hold tight reigns on the entire textile industry of Lowell through the merchantile outlet they established of A. A. Lawrence that soon became the largest purveyor of the finished product of the mills in the industry.

By November 30, 1830, the PL&C had already let a contract with stonemasons Russell and Barr for the foundation walls of the underground work. All of these doings may seem to have taken on an extremely fast pace for a contract that was only agreed on in the previous weeks but the PL&C was very familiar with the plans for these mill sites. In fact they had been laid out in the early 1820s by the incorporators of the Merrimack Manufacturing Company when they were making plans to develop all of the land and power for their own use.

So it is not surprising that they were referred together as the Western Group when they were constructed alongside the Western Canal by the Proprietors of the Locks and Canals [PL&C].
This is a presentation of the three mill yards as they were conceived at the time of their planning. Nothing is identified in this sketch of the three mill yards. The author maybe overstepping literary allowances by taking the liberty to include descriptive passages indicated by arrows and explained on the next page but here it is almost unavoidable for clarity.

Tremont, Suffolk and Lawrence Yards  Benj. Mather  1832

Arrow #1  This indicates the layout of the Lawrence mill buildings as they were in 1832. The waterway running parallel and below the buildings shows the location of the Lawrence Canal in relationship to the mills.

Arrow #2  Indicating the secondary yard of the Lawrence Mills with the Lawrence Canal supplying the water source.

Arrow #3  the site of the Suffolk Mills yard. The parallel lines running vertically to the left of the indicated buildings is the Western raceway that collected the spent water from the mill tailraces.

Arrow #4  The site of the Tremont Mills yard with its raceway shown vertically to the right of the two mill buildings.
Arrow #5 Indicates the path of the Western Canal. The bulge in the canal in the center of the sketch shows the location of the Hall Street Dam. The canal water dropped 13 feet at this point to supply the head for the motive power for the Suffolk and Tremont mill wheels. A short distance above a single line crosses the canal before it reduces in width to indicate the wasteway before it enters the Merrimack River. Here the water drops another 17 feet to create the necessary head to drive the wheels of the Lawrence Mills.

With this grouping of the mill complexes it’s quite obvious that all received their waterpower directly or indirectly from the Western Canal or that the Tremont and Suffolk when described or written about seem to share the same background as the two did merge in 1871. But from the very inception of the two complexes, Frank Hill records in his Lowell Illustrated “The management of both these corporations was substantially in the same hands, even before they were merged in one company.” The biggest single difference was that they were almost mirror images of each other only because each was built on opposite sides of the same canal directly across from each other.

The Lawrence Mills were constructed at the end of the waterway, the so called Lower Western Canal, and utilized the same water source as the Tremont and Suffolk from their tailraces, admittedly second hand. So the trinity was grouped together and they are treated in this manner in much of the material that was researched.

Our interest is in the underground raceways that fed the waterpower to the mill complexes and regardless of how close the complexes resembled each other in the site layouts, they evolved their individual underground systems quite differently. The completion of the Northern Canal in 1848 also greatly affected the source of the water supply to the Suffolk and Tremont Mills. The direct result was the Tremont Gatehouse built at the same time as the Northern to cut off the flow to the existing waterway below the gatehouse from which the headraces for both these complexes originally drew their waterpower.

This entailed relocating both headraces. The Suffolk was tapped directly from the Northern Canal as it passed in front of the complex for its waterpower and the Tremont would now have its penstocks leaving the canal at the junction of the Northern and Western. This supposedly minor alteration of the raceways was to have major implications on how the underground waterways would evolve.

That difference dictates that for our purposes each manufactory has to be treated entirely separately whether their configurations are closely alike on the surface or completely alien as is the Lawrence. For that matter, so were the canals that fed them. We are getting too far ahead of ourselves now. One step at a time and the first will be an abbreviated description of the topography of the Western Canal itself.
The Western Canal was built on two levels as was the Pawtucket. This gave promise for the canal to be able to support more wheels using two smaller drops along its length of 13 and 17 feet respectively rather than the full 30 foot head at its end before dropping off into the river. Whether or not this was the most efficient use of the fall of the head of water in the system was debated pro and con and several outside sources were highly critical.74

The Suffolk and the Tremont Mills were built on the upper level of the Western Canal. The Lawrence Mills were built on the lower level and received their water power from the Lawrence Canal which was an extended raceway of the Western really, accumulating waters from the runoff of the Suffolk and Tremont Mills and utilizing the spent water being ejected from the tailraces of those mills a second time to power the wheels of the Lawrence Mills. If for any reason either or both, the Suffolk or/and the Tremont Mills were not operating and thus no water was flowing from the tailraces to enter the Lawrence Canal, then the normally closed gates at the Tremont Dam would be opened to flood the Tremont Wasteway and thus the basin above the Hall Street Dam. With that dam’s sluice gate open water would pool behind the Lawrence Dam and provide all of the water needed to fill the Lawrence Canal until the Suffolk and Tremont were back in operation. This in fact would bypass the tailraces of the mills on the upper level as a source of the waterpower for the Lawrence wheels temporarily.

At the risk of repeating myself, and I am, one picture can replace a thousand words and do a better job too. The sketch on the following page should need no more explanation than as it presents itself and the brief description of the waterway as presented above. It will help to refer to it often as the text unfolds to describe the genius involved in the design of the Western Group.

An excuse has to be made here in some ways for showing this sketch at all. It in no way presents the actual layout of the waterways at any time in history except in the most remote respect. What it does do is schematically indicate the sources of the various water supplies without making any claim for accuracy. For example the notation in parenthesis under the identifying heading of Tremont Wasteway makes the claim that the wasteway is normally dry. The Tremont Gates actually would have had to been opened regularly just to sustain normal daily operations. It is an impossible situation at any time seeing that the Lawrence Mills drew more waterpower than both the Suffolk and Tremont together could supply when running at their peak. This fact will be discussed more fully in the section on the Lawrence Mills.

The reader should just take the sketch with a grain of salt and understand its intent without letting it confuse the issue as the rest of the chapter unfolds. More will be said on the validity of the information in the sketch further along in the text.

Because this sketch is suppose to indicate an overall explanation of the water flow of the waters of the Western Canal and the way it was used to supply the various mills in the group, the author will take the liberty of superimposing the junction of the Northern Canal with the waterway after 1848. The dotted parallel lines entering from the left will indicate the approximate point of entry that the Northern Canal made into the Western upon its completion. Without this overlay to the sketch, the sketch would be useless for any reference to it after 1848.
Reproduced from “Water Power in Lowell” by Patrick M. Malone.
For all the misgivings the sketch produces, and for want of a better description and allowing for the distortions it presents, the genius of the men who build the system still shines through. They came, they saw and they conquered.

While all the canals were somewhat effected by the completion of the Northern Canal in 1848, primarily do to the increase in water flow and in some cases rebuilding to handle it, it was extreme in the case of the Western. The two following sketches should at least illustrate the topography of the position of the Western in relation to the Northern Canal.

Arrow #1 designates the Hickey-Hall Dam.

Arrow #2 designates the Swamp Locks with its dam.

This is a sketch of the entire canal system as it existed in 1836. The mills the canals fed are indicated by circles drawn at their locations.

Pre - Northern Canal

This is the identical map as the pre-Northern shown above. The addition of the Northern Canal in 1848 was to effect the water levels in all of the canals.

Post - Northern Canal

Both sketches drawn by Mark M. Howland for HAER 1975
Most of the main canals diverged from a common point on the Pawtucket Canal designated the Upper Locks or also known as the Swamp Locks. The water level in the basin at the Swamp Locks was the same height as that of the Merrimack River providing a 30 foot head. The dam that exists here creates a 13 foot drop, the water falling into the Lower Pawtucket Canal. This drop in the water level provided the head that powered the Appleton and Hamilton Mills on the Hamilton Canal. The full 30 foot head continued down the Merrimack and Western Canals.

For all practical purposes with the opening of the Northern Canal, the Western Canal became two different waterways with completely separate roles from each other. With the overpowering volume of water pouring into the Western from the Northern, the current in the Western was reversed so that the waters were now feeding back into the Swamp Locks basin and the canal was effectively cut in half at this point. The Upper section of the canal no longer fed any of the mills in the Western Group and it was now the upper nothing. Instead of being a feeder canal, it was now simply a 3500 foot canal funnelling the Northern’s water into the Swamp Locks basin.

In fact the Lower Canal had for all practical purposes ceased to exist. The lower water course was now termed the Tremont Wasteway and the Tremont gatehouse at the head of the Wasteway effectively blocked any water from entering unless by choice. The Northern Canal now fed waterpower directly to both the Suffolk and the Tremont penstocks. The tailraces from both these mill complexes fed the spent waters from their wheels into the Lawrence Canal to power the Lawrence Mills. What was left of that 1000 foot waterway only contained the waters backed up against the Hall Street Dam that overflowed from the Lawrence Canal. This description of the new role of the Western Canal really takes a lot understanding on the part of the reader. You can examine both maps on page 96 showing the pre and the post Northern Canal but in no case does the effect on the Western become evident. Only by reading and re-reading the text, and visualizing the reversal in the motion power does the change fall into place.

No other mills exist on the Upper Western Canal as shown in the two maps on the previous page until the Tremont and Suffolk are reached. This abbreviated description of the Canal just about completes our brief history of the waterway, more a refresher course than a history lesson, before delving into the text describing the underground waterways of the Tremont, Suffolk and Lawrence Mills.

For our purposes, our tale starts at the bottom of the sketch on page 95. It is at this point in the sketch that the waters of the Upper Western Canal are tapped by both, the Suffolk and Tremont Mills. The water has flowed 3500 feet between the canal walls uninterrupted from the Swamp Locks and it is about to be put to work. Keep in mind that this appears to be a composite sketch containing some of the characteristics of both the pre and post Northern Canal eras. As the reader sifts through the sketches of the underground raceways scanned from material uncovered in the research, the presentations may, no will not exactly match.

For example the sketch is described as “adapted from ‘plan of the Suffolk Mill Yard,’ Locks and Canals Drawing, 1941.” Was this drawing executed in 1941? If so, why isn’t the Northern Canal shown which would have entered this area just to the left of the Upper Canal. And the Tremont gatehouse didn’t exist until the Northern was built. And no drawings of the proposed underground raceways that we came across in the research ever showed the original penstocks leaving the upper canal at these points. After 1927, the dam referred to in this sketch as the Hall St. Dam was renamed the Hickey-Hall Dam and even that hasn’t caught up with the producer of this sketch.
So treat this sketch as a stylized drawing that was meant to portray the direction that the water took in order to feed the mill powers into the wheel pits in the two mills, a sort of schematic or blueprint if you will. And that’s the way we will use it. If the reader has no comprehension whatsoever of how the water entered the two mills there is no better presentation than this sketch. Letting your fingers do the walking so to speak and we will follow the course the water took before getting involved too deeply with the actual underground raceways.

At the indicated point of the water entering our picture at the bottom of the page, that is the Upper Western Canal, the head or the level of the water is the same as that of the Merrimack River. When the head of 30 feet is given what is meant is that the water stands at approximately 82+/- feet above sea level at the Pawtucket Dam, and this is the point that the canal system draws its water from. At some point all of the canals empty back into the river below the Pawtucket Falls or the Concord River, either through individual tailraces or over the spillway at the Lower Locks Dam. At this point the water level is approximately 52+/- feet above sea level and that difference in water height is what creates the 30 foot head in the waters in the canals.

Bypassing the stylized sketch that is being criticized so drastically, an individual head gate would have been located where the penstocks left the canals by agreement with the Proprietors of the Locks and Canals [PL&C] written into the lease last updated in 1853. This allowed either the mill or the PL&C to interrupt the water flow for repairs to the machinery or the raceways themselves if necessary. Under normal operating conditions the spent water that had flowed through the headrace, wheelpit, waterwheel or turbine of the Suffolk and Tremont Mills and then through their tailrace and into the Lawrence Canal would have dropped 13 feet leaving a 17 foot head to power the Lawrence Mills.

Keep in mind, the Upper Western Canal is carrying the full 30 foot head of the water level originated from behind the Pawtucket dam. The Suffolk and Tremont were located on the Upper Western Canal. At the point on our sketch on page 90 where the Hall Street Dam in indicated, the water fell 13 feet into the Lower Canal leaving 17 feet to power the Lawrence Mills. These mills ejected their spent water directly into the river below the Pawtucket Falls and just above the Concord River.

Now we have more or less followed the course of the water from above the Pawtucket Falls to the re-entry back into the River and have expended the entire 30 foot of head in doing so. But what part does the Northern Canal play in all of this? Why is it needed? The water flow and the operation of the mills seemed to be running smoothly so what was the need for the added 4100 foot waterway. It left only a few hundred feet further down river from the Pawtucket and its beginning was still behind the dam.
The role of the Northern Canal

The old existing canal system was really too small to do the job. The expansion of the mills as fast as the canals could be built to the extent that they were, beginning with the Merrimack in 1822 through the construction of the Boott in 1835 was unforeseen, never mind the development of each complex using every available inch of property they commanded. The canals simply couldn’t handle the demand of the volume of water now called for.

Besides, physically the mills had built right to the canal edges so widening or the dangers inherent with dredging to deepen the canals with the fear of weakening the walls left the PL&C with no alternative except to find an alternate solution to providing more water into the system. Several plans were proposed; digging another canal paralleling the Upper Pawtucket and emptying into the canal just below the Guard Locks was one of the favorites, but they all entailed adding more water to the existing canals and that was proving impossible. Thus the construction of the Northern became the only alternative. This entailed that the entire volume from that canal would flow into the Western Canal. This flood of water demanded the construction of the Moody Street Feeder between the Western and Merrimack Canals to assure the most effective distribution of this sudden wealth of the liquid gold into the Western. Add to this construction the building of the Boott penstock to funnel the water into the Eastern Canal which had always been water starved because of its location at the end of the waterway and it appears the Northern was needed years ago.

Following the paths of the canals in the map on the bottom of page 96 will greatly simplify the explanation for the need of the Northern Canal outlined in the text above. The one major effect on the canal system because of the construction of the Northern that can’t show on any map was the reversal of the current in the Western Canal. Where as the water always flowed from the Swamp Locks north in the canal toward the Western group of mills, the greater volume from the Northern now forced its waters back up the Western and into the Swamp Locks which was the intended effects from the inception of the canal to add its waters to the volume in the existing waterways.

This is what entailed the necessity for the building of the Tremont gatehouse, the re-routing of the penstocks from the so called Tremont Wasteway to directly feed water from the Western Canal to the Tremont wheels and now providing the waterpower supply to the Suffolk directly from the Northern Canal. At this point all indications of how the mills on the Upper Western on the sketch on page 95 received their water power can be disregarded. Future text will clarify all of the underground right from the canal and through the wheels in each individual mill.

One last gasp at a meaningless history lesson. All three manufactories were incorporated within six months of each other in 1831, the Suffolk in January, the Tremont in March, and the Lawrence in June. In 1871 the Suffolk and the Tremont were consolidated. The strange part of the incorporations in 1831 is that the Western Canal wasn’t even finished until 1832, even though started in 1828. Even stranger is the fact recorded in the minutes of the Directors Meeting of April 20, 1831 that the PL&C had contracted to build the mill buildings and supply the mill power for 20,000 spindles? Foresight? From here on each of the mills and their accompanying underground waterways will be treated as a separate entity. Some repeating will be demanded especially in the case of the Suffolk and Tremont Mill complexes. No matter how much text is provided, the answer to all of the questions pertaining to the waterways will be answered in the sketches that accompany the work.
In the sketch below, the Tremont Mill complex is portrayed in the upper center and it is marked as such. The Suffolk Mills are on the right. In the blank area in the lower portion of the sketch is where the Lawrence Mills would be located.

This photo is of the 1928 Lawrence Manufacturing Company at its zenith. The buildings on this site were jammed on every inch of available space. The Lawrence Dam is in the lower right with the waters of the Western Canal flowing over it.
Suffolk Manufacturing Company

From a ledger page offered by the PL&C and dated July 31, 1831, it appears that the PL&C was paid the sum of $135,000 under the heading of “by Suffolk Mang. Co.” But this up front fee didn’t represent all profit. On the same ledger page is the figure of $16,756.36 expended by the PL&C on the Western Canal.

The first Suffolk Mill buildings followed closely the dimensions and layout of all of the mills that preceded them in Lowell, approximately 150 by 45 feet and four or five stories high. Most were constructed parallel to the canal from which the mill drew its water. This allowed the power canal to be dug in a more or less straight line from the feeder canal to slightly off center in the mill basement to feed the wheel pit that would be located there. This brief paragraph explains the entire complexity of the basic plan for supplying the water to create the power to operate the mill machinery.

A more detailed description of the course of the underground waterways is given in an outline simply titled Suffolk Mills \(^76\) prepared by Cornelia Wyma and Paul Cloyd. “An 18’ wide feeder ran from the Western Canal to the center section of each mill. The feeders continued through the mills and emptied into a race, known as the Western Race that flowed north to the Lawrence Manufacturing Company.”

The plan of the proposed buildings and underground waterways that were to be built to supply the water is what was being described in the text above. The Lawrence Mills are off to the right. Company housing showed above Race Street on the original plan.

Copy of original plan to accompany Deed for the sale of land from PL&C to Suffolk Mfg. Co. Jan. 1, 1832 Courtesy of HAER

The authors added a little more detailed picture of the construction of the waterways with the observation from their source “that the sides of the feeders were stoned, with timbers laid across and planked over the top.”
Before we go any further, as long as the raceway from the Suffolk to the Lawrence is brought up, a little point of interest should be explained here. It’s difficult to separate the operations of the Suffolk, Tremont and Lawrence Mills from each other because all of their operations are so intertwined, and that includes their water usage.

As mentioned on page 101, the tailraces from the Suffolk wheel pits merged with the Western Race and that race then tied into the Lawrence Canal. The water has already dropped 13 feet through the wheels in the Suffolk Mills and was now used for a second time being utilized to power the wheels in the Lawrence Mills. Here it dropped 17 feet through the Lawrence wheels before being discharged into the Merrimack River.

Because of this unique arrangement of the tailraces of the Suffolk and Tremont emptying into their own races, the Western Race in the case of the Suffolk, and what has been referred to as the Eastern Race for the Tremont, and then into the Lawrence Canal, this total volume of water had to be used by the Lawrence mill wheels or risk backwater from the height of any unused portion of this water backing up the raceways and into the wheelpits of the feeder mills.

As a matter of fact the Lawrence mill complex was much larger than either the Suffolk or the Tremont. The Lawrence had contracted for more mill power than the Suffolk and the Tremont combined so using all of the waters emptied into the Lawrence canal by the two upstream mills was certainly no problem. As mentioned before, if not enough water was supplied by the two of them to the Lawrence, the gates at the Tremont Dam would have to be opened to make up the difference. It now appears that even in normal operating conditions the volume of water being ejected from the tailraces of the Suffolk and Tremont Mills combined could not even meet the demand of the Lawrence Mills wheels.

In the 1853 report by the PL&C and titled Statement of the New Adjustment of the Water Power at Lowell, the total “number of powers to which each company is entitled by the new adjustment” is listed in a column under that heading. The Suffolk and Tremont each drew \( \frac{15}{30} \) for a total between them of 13 mill powers. The Lawrence Manufacturing Company alone was contracted for \( \frac{9}{30} \) mill – power more than the two combined.

Under the title of the afore mentioned chart defining the distribution of the waterpower between the mill complexes an exception is included pertaining to the water usage of the Suffolk and Tremont Mills, “who, by the consent of all parties, are entitled to divide equally between them, the quantity of water to which the Lawrence Manufacturing Company is entitled.” So were the Suffolk and Tremont Mills shortchanging themselves out of water they were entitled to command by the exception outlined in the above statement?

Evidently not. There were 12 columns in the statement and only that one which pertained to the entitled millpowers of the mills was quoted above. Under another, “Maximum Quantity of Water Used by the Measurement of 1852” given in cubic feet per second, the Suffolk and Tremont made up for the discrepancy. Combined they made use of 726.95 cfps against 787.02 cfps for the Lawrence. The amount of water flowing over or through the wheels is what calculates the millpowers which translates into the work of the machinery being done and these figures indicate that the Suffolk and Tremont were playing catch-up, probably through the usage of surplus water.

Most of the previous page may appear to be a trip to the sidebar but when a dispute involving historical figures shows up in the research, better it be handled where it arises than try to pull the facts out of a dim remembrance.
To return to the underground raceways, various dates show up in several different sources declaring assorted specific dates for the incorporation and construction of all three mill complexes. All are probably right and depend on what time frame one wants to assign to what stage of any of the development of each complex but most agree that construction was started in the late 1830s or early 1831 by the PL&C on the Suffolk Manufacturing Company. One outside faction probably should put the cap on any disagreement and help place a date as to when the Suffolk actually existed in terms of the original deed and plans. The 1832 plan below shows the Suffolk, Tremont and Lawrence Yards.

Plan of Lowell by Benjamin Mather
Motive Power of the Suffolk Manufacturing Company

Page 101 in itself well describes the entire procedure that was followed by the Suffolk Mills to create the power necessary to allow them to operate their machinery. Simplicity at its finest. Basically it had worked perfectly to lay the groundwork for the entire textile industry in Lowell at the time. But after the digging of the Northern Canal in 1848 and connecting it into the Western in order to increase the available waterpower from the Merrimack River, all of the original plans became obsolete. The methods for generating the motive power remained the same but what became different was directing the waterpower that now flowed from the Northern Canal instead of the Western to the wheels.

The place to start is at the beginning and the headraces leaving the Northern Canal to feed the wheels of the Suffolk are the prime source. At the Directors meeting of April 19, 1847, it was determined by the appointed committee to go with the construction of the plan to build four wheelpits leaving the Northern Canal. Even though the go ahead was immediate for the ordering of the materials to construct the raceways, there must have been some mix up in plans between the Corporation and the PL&C for the Suffolk was assessed for half of the costs of extra work that it cost the PL&C.80

Photo of Suffolk headraces leaving the Northern Canal by Author
What the revamped direction of the water supply did entail was the digging of four new wheel pits and that entailed all of the connecting raceways as well. The power source from the added waterpower was to be expanded and it was no longer from the Western Canal but from the Northern. The Western was now for all purposes in a new role as a feeder canal, back feeding the Swamp Locks Basin and having nothing to do with the old role as the feeder to the Suffolk Mills.

The new headraces leaving the Northern Canal shown in the photograph only stretched for maybe 30 feet before they entered the forebay that directed the water into the wheel pits. This is what it was all about for the wheelpits, built to contain the waterwheels and/or later the seven turbines. The breast wheels had served the industry well but their end was foretold. The turbine was of a smaller size and still produced more horsepower, plus it wasn’t affected by backwater, the nemesis of high water situations in the canals and river.

The Suffolk Manufacturing Company had experienced some difficulties with the first turbine they installed. It was modeled after the original that had been tested at the Appleton Mills with excellent results but the experience caused the Suffolk to proceed slowly with the changeover. In fact from 1851 to 1855 the Suffolk continued to utilize both water sources, the Northern for their turbines and the Western for the breast wheels. In 1853, the Suffolk was still using two breast wheels with two turbines. In 1854 they were using only one wheel and three turbines but by 1856 all four machines were turbines. The wheels had reached the end of their life in the mid 1850s.

This is a later draw-showing the four wheelpits leaving the Northern Canal with the associated tailraces. The draw-has been altered slightly to show only the portions of our interest and disregard the several solid lines running vertically in the left center as they represent electrical wires installed with the future generators.
After the water left the tailraces of the Suffolk wheels, except for Mather’s 1832 map of Lowell reproduced on page 103, the visual tale of the courses of the underground raceways comes to an end, covered over to protect from the elements or under buildings that were built during the never ending expansion of the yard. The rest of the story describing the waterpower and its role in operating the mill machinery will continue to be told in the accompanying text.

The trouble with using more than one source in the research is the possibility of contradictions or simply exclusions of the material by the author of the record. The choice is to disregard both because of no way to tell which is more correct, or tell both stories. This is so in the case of the covering over of the original raceways from the Western Canal feeding the turbines of the Suffolk Mills. In this version which appears in a volume of the Cultural Resources Inventory, the construction of the feeders was described as; “The sides of these races were covered over with timbers upon which planks were laid.” The same offering goes on to state, “The foundation of the former Suffolk Manufacturing Company Counting House (the only structure in the yard remaining from the 1830s and 1840s) is still containing stone elements from the arches that spanned the original eighteen foot head race.” This statement appears to be declaring that the headrace was constructed and covered when the raceway was dug as stone archways indicate a permanent part of the structure and built prior to 1831 when the Counting House was erected.

The second source under the sub-heading of Original Feeders and Raceways [check superscript] in the document we examined states “The foundation of the counting house still contains elements of the stone arches which spanned one of the original 18’ feeders that led from the Western Canal and passed under the counting house to Mill #2. These early feeders were evidently left uncovered in the beginning, but within two years they were covered with boards and the Western Race was vaulted (covered) over to prevent freezing.” This statement indicated a two year delay between the construction and the covering over of the raceway.

To illustrate how records being used in research can unwillingly become distorted in the final results, or simply difficult to unravel the original intent to put the meaning in context, a third source is offered here that begins by describing the 18’ feeder from the Western Canal to the Suffolk Mill buildings that continued through the mills and emptied into the Western Race. Describing the possible addition of two more mill buildings and the expansion of the race to handle the expected added volume of water the race will have to carry from the two new additional buildings, Henry Hall, the treasurer of the Suffolk Mills wrote to Kirk Boott, the agent for the PL&C on August 22, 1833 to describe the work he was recommending be done on the Western Race. Hall is discussing in a part of the letter that “taking up the present side walls (on the Lawrence land) and widening the race 3 or 4’. He goes on to add, referring to the proposed two new mill buildings at the Suffolk although he alludes to four mill seats, “I have supported that if they were ever occupied this course would actually be necessary -- & that the expense would be very small compared with that it would be after the arching was complete.” He emphasizes that the sides of the feeders “were stoned, with timbers laid across and planked over the top.”

Here is a gentleman well versed in the construction and operation of the power system that the mills relied on. He is clearly discussing the Western Race which carry’s the runoff from the tailraces of the Suffolk Mills to feed waterpower to the Lawrence Mills. Yet he himself apparently uses the descriptive wording of feeder for either or both the headrace carrying the water from the canal to the wheelpit or likewise the tailrace that now carry’s the water after it has done its work flowing through the turbine and is being ejected into the Western Race.
This dual usage of the word feeder to describe two entirely different but complementary operations that are close enough in their definition so only the author or speaker can differentiate his meaning because of the singularity of his topic can easily confuse even the most well informed reader.

There most likely was only one great, great, great, great grandfather who uttered or wrote the phrases from which all of recorded history evolved concerning the construction of the canals and was handed down to modern times just as happened in any other topic. The problem is there were many stories told to many people, or different versions of the same event recorded by different interested parties. The covering or not covering of the raceways at the time is very minor, or is it? It leaves the question of what other supposed statements of fact are open to -------discussion?
Proprietors of the Tremont Mills

This company was actually incorporated as the Proprietors of the Tremont Mills on March 19, 1831. The two Lawrence brothers, Amos and Abbott, financiers of the Suffolk, Tremont and Lawrence Mill complexes were included as two of the several incorporators of the Tremont. They were born in Groton and went on to become wealthy Boston businessman with previous ties to the cotton industries.\footnote{86}

The Suffolk and Tremont have been joined at the hip so to speak since the inception of the two manufactories, and a little curious history has been dredged up during the research into the background of the two companies. Both of these mill sites had been first laid out in the early 1820s by the incorporators of the Merrimack Manufacturing Company as part of their early plan. They owned all of the surrounding land and the water rights. When the Merrimack was organized by the Boston Manufacturing Company, the extended vision was for that complex to expand and not only control but occupy all of the land and mill powers generated by the Pawtucket Falls for its own use.

If the sketch of the proposed layout of the Tremont Mills seems a slight bit familiar, it should. As brought out before, it is an exact mirror image of the Suffolk Mills, part of which was reproduced on page 93. In that case the anticipated housing that was projected to accompany the mill’s development has been edited out and all that is shown is the actual mill site.

Flip this sketch upside down and you are looking at the plan of the Suffolk Mills. Notice the dotted headraces leave the top of the Western Canal on the Suffolk Mill site plan on page 101. The Tremont plan is the exact opposite. The housing is shown on the bottom.

Copy of original plan to accompany Deed for the sale of land from PL&C to Tremont Mills. Jan 1, 1832 Courtesy of HAER
The housing for the mill workers was built in both cases just beyond the indicated race above and below the mill structures.

The fact that the Tremont and Suffolk Mills were more or less operated by the same people has already been hashed over in the previous text on the Suffolk Mills so we’ll dispense with any duplication of the past histories and get right into how the underground waterways of the Tremont differed considerably from its sister mill complex on the other side of the Western Canal, and the reason why.

Following the completion of the Northern Canal, the Tremont like the Suffolk were obligated because of the changed location of the new source of waterpower that not only the headraces be relocated but that new wheelpits be dug as well. Because four were determined to be the best plan which would allow for sufficient capacity for the present power needs and future expansion at the Suffolk, the same was adopted at the Tremont without question. It was to be very seldom that one complex would make a move that the other didn’t follow but it was to happen as expansion began to dictate separate routes. Even though they were mirror images at conception outside forces were about take over.

When the Northern Canal was completed, it passed directly in front of the Suffolk and presented a large frontage to the mill site giving the opportunity to the complex to more or less design its access to the waterpower to suit itself. The sketch on page 105 shows the entire Suffolk waterpower system as it was adapted and updated in the later years but from the descriptions of the wheelpits constructed in 1848 given in earlier writings, the locations probably remained the same from day one, right until today.

The Tremont wasn’t afforded the same luxury of picking and choosing the site of the headraces from the Northern. The only contact at which the waters from the Northern brushed the Tremont Mill site was at the point where the two canals came together and the Northern merged with the Western Canal. The movers and shakers of the Tremont Mills simply decided if that was to be the only location where they had access to the waterpower of the Northern Canal, so be it. A site for the wheelhouse was decided on 90 feet inside the Eastern bank of the Western Canal and plans were laid for a wheelhouse with four wheelpits also.

The new raceway layout at the Tremont would encompass nothing of the original and all of the underground would be dug anew. But to begin at the beginning, the following photos show where the headraces feeding the turbines in the new wheelhouse left the Western Canal. They are blocked off now and a wooden barrier has been build where the racks would have been located. The underground raceways left the canal on a slight angle to enter the wheelhouse building.

The remains of the single story wheelhouse still stand but in worse than poor condition. Sections of the floor as well as the roof have collapsed and the future of the site is now under consideration. A clandestine visit to the fenced-in yard by an intruder has produced a few photographs of the building and the ground that has cave in covering the underground raceway in places. If you look close enough in person, some of the stone remains of the raceway walls can be detected under the openings in the ground.
This photo taken of the Tremont Gatehouse in 1915 has the trash racks covering the headraces to the wheelhouse and turbines in the Tremont Mills showing to the right. The only surviving building is the wheelhouse.

Proprietors of Locks and Canals - # 1519
Center for Lowell History

The degeneration of the Tremont Wheelhouse is certainly apparent in this photo taken in 2006. This building is under consideration at this time to be rebuild and added to with an exhibition of the original turbines to be offered.

Photo by Author

This is the rear entrance into the wheelhouse. It led to an addition that was built to house the electrical equipment installed after generators were mounted on the turbines. Note hole in ground front of door. Tailrace below.

By unknown person
The original wheelhouse was built in 1847 and rebuilt in 1862 with three floors added above but no change to the Picker/Wheelhouse itself.\textsuperscript{88}

The underground feeders must have been satisfactory in its original form because it remained the same throughout the many developments made in the yard and the machinery.

The Tremont mills were one step ahead of the Suffolk as well in changing over from the breast wheel to the turbine. The Suffolk continued to operate with at least some breast wheels for several years after the turbines became available. The Tremont switched over immediately with the completion of the new wheelhouse.\textsuperscript{89} The Suffolk was skeptical as to the overall performance of the newly introduced turbine when they determined that the first one they installed didn’t operate up to expectations. It wasn’t until the mid 1850s that the change over from breast wheels to turbines would be completed at the Suffolk.

Even though the Tremont prepared for the installation of four turbines, and with wheelpits constructed for that amount of wheels, it appears from the records that only two were installed initially. In a Report to Directors of the Proprietors of the Lock and Canals under the title, Tremont Mills, dated 1853, the report states that “the water used at these Mills is all drawn through two turbine wheels”. Why only two turbines were installed at that time leaves something of a question after reading the rest of the report. “The Turbines are not sufficiently powerful, to drive all the machinery in the Tremont Mills at the desired speed.” Accompanying this written report was a list of the machinery that was down, “purposely stopped, in order to allow the remainder to run at speed.”\textsuperscript{90}

Now the above statement presents another conflict between the supposedly infallible records that the reader has no other choice except to rely on as gospel. As was said before, how many different sources can the historians rely on, and if those differ to extreme, then the researchers are not doing their job. The ultimate tellers are all writing about the one and same incident. In 1857 Henry Hall, in his 25 annual Reports as treasurer of the Tremont Mills, amongst other milestones, reported that “In 1852 the old wooden breast wheels were removed, and four turbines, which, with the Penstocks, are entirely of iron, were substituted.”\textsuperscript{91}

The Suffolk Mills delayed an immediate change over from breast wheels to turbines after a poor showing of the efficiency of the first turbine they installed. Yet the Tremont changed over completely. Why this sudden deviation from the past habits of the two mill complexes always following each others decisions as to time tables for buildings, procuring machinery, and even to identical product lines. If the installation of the first turbine didn’t perform at the Suffolk, why did the Tremont assume it would do a better job in their mills. The turbines supplied to both mills were identical machines. They were made from the same designs and patterns at the same time. So alike they were considered to be in their operation that the discharge of the water from one of the Tremont turbines was gauged by James Francis during testing for his future famous Lowell Hydraulic Experiments for the purpose of testing the efficiency of the wheel and the results were applied to all of the wheels in both complexes.

What do these conclusions expressed in the previous discussions tell us about the performance of the turbines supplied to the Suffolk and Tremont Mills? With all of the touting of the superior results at the Appleton Mills where the first turbine built by Boyden was tested, why weren’t the same results obtained at these other two mills. All were built from the design Boyden had developed. In Francis’ report to the Directors mentioned above, “The Suffolk and Tremont wheels were all made at the same time from the same designs and patterns and were considered identical, in all the parts affecting the discharge of water.”\textsuperscript{92} Something had to be different; there had to be some variation in the input to the
turbines to obtain results that were so erratic. These dates of the installations in the three mills are so close that it’s doubtful that even any improvements that Francis would make to Boyden’s design wouldn’t have had time to be implemented. Boyden’s first machine was accepted for testing at the Appleton Mills in 1844. The turbines at the Suffolk were installed over several years with all four planned turbines installed by 1856. The Tremont complex removed their breast wheels and replaced them with turbines and iron penstocks in 1852. The results at the Appleton were raved about. The Suffolk and the Tremont would prove to be less than acceptable. Why?

Very dry weather conditions resulting in low water in the river and the canals had been hinted at as an excuse for the poor performance of the Suffolk turbine but if that were so all of the wheels should have suffered the same fate.

No factual explanation that the researcher has come across has ever been offered in the historical records to explain the discrepancy in the performance of the turbines. The Appleton Mills were perfectly satisfied so they went their own way with the turbine installation. The Suffolk Mills held off before a complete change over until the mid 1850s. As mentioned before even for James B. Francis, the chief engineer for the PL&C, to conduct his famous Hydraulic Experiments on the Tremont Turbine, the machines wouldn’t carry the full load of the mill and much of the machinery was either stopped or running at reduced speed. 93

If the mill operators who were on top of the entire process, or Francis who was on top of them offered no explanation, how can we, 150 years later, contribute to solving the dilemma? Never at any time were RPMs mentioned as a constant for any wheel, just horsepower. And they were fairly simple machines. There was no fuel involved but water of which the amount that flowed through the runner on the turbine determined that. If it was agreed on that all of the wheels were identical that were installed in the Suffolk and Tremont Mills, then it makes sense that the only variable that could be deduced to vary the speed and power was the amount of fuel. And that translates into water.

The adjustment of the waterpower under the new rules of the available water initiated in 1852 [this after the added volume supplied by the completed Northern canal] was allotted and the figures published in the reported measurements of the Water Power Used by the Manufacturing Companies of Lowell There is a chart that accompanies the Report found inside the back cover titled Statement of the New Adjustment of the Water Power at Lowell, Based Upon the Measurement of 1852. It contains 12 columns that record every conceivable figure that could possibly be taken into account in the computations that would be presented to the PL&C by Francis and Baldwin. Every mill complex is represented and the figures vary with each complex as to amounts before and after the adjustments of 1853. For example the columns list Powers, before and after, number of shares held in the PL&C, balance paid to and received from the PL&C; this type of information was recorded for each Company in the columns.

The Tremont and Suffolk have their place on the list and when their figures are compared with each other, all are identical. All that is except under the column that recorded, “Maximum quantity of water used, by the measurements of 1853, in cubic feet per second.” The Suffolk is recorded as using 423.52 cfps while the Tremont used only 303.43 cfps, a difference of 120.09 cfps. Each Company was contracted for the same amount of Powers, 5 1/3. This allowed them to draw a certain quantity of water and to push it through their wheels. If the Tremont Mill didn’t make use of the amount of water allotted to them, how were the wheels going to provide the required power to the machinery.
Evidently the Suffolk and Tremont Mills were both underpowered from the beginning. Was this the reason the Suffolk was dissatisfied with the performance of the first turbine they installed and they stuck it out with the breast wheels until more waterpower became available after the new adjustment came into effect? Are they inferring that the breast wheel outperformed the turbine or were the two wheels just compatible with the waterpower they were drawing? Was this also the reason when Francis conducted his experiments using the Tremont turbine that some of the machinery had to be left off-line because the turbine couldn’t carry the full load? The Tremont utilized much less water than the Suffolk as recorded in the chart. Why? Their operations were identical in every way and manner.

And why was the Appleton Manufacturing Company so enthused by the results of the tests done on the turbine they installed? They were contracted for almost the identical millpowers that the Suffolk and Tremont were, 5 1/2 and they drew almost the same quantity of cfps as the Suffolk at 441.33. Something is amiss.

What are we trying to prove here? Do we know? With the re-distribution of the added volume of water made possible by the completion of the Northern Canal, the PL&C was now able to legally increase the amounts that could be sold to the individual mills, something they were prevented from doing under the old agreements because of a fear amongst the mill owners that there wouldn’t be enough water to go around during times of drought, even to the point of restricting what new businesses could be built along the canal banks.

The topic on the waterpower we just left sort of got carried away before its time but it would have to be brought up somewhere along the line. To return to the underground raceways, there is every reason to believe that the headraces leaving the Western Canal at its junction with the Northern [text and photo above] are the original raceways. The description given in a 1979 archeological study of the site appears to support this conclusion very well.94

The unscrupulous person that prowled the yard of the Tremont Wheelhouse and took the risk to snap a few photos was a little reluctant to venture inside the decaying remnants of that building for safety’s sake [his] so any proof of the underground headrace entering the building is conjecture at this point and relies on secondhand information. Some of the underground channels on the site have been filled in and the threatened development of the wheelhouse site is sure to expedite the destruction of any underground archeological remains that exist.

The forebay and the wheelpits under the Wheelhouse are deemed in the same archeological study to be the original although its commented on that maybe they have been dug a little deeper.

The accompanying sketch showing the original 1847 layout of the raceways and turbines is reproduced below. It is simple and straightforward. The Northern Canal is marked and shown bisecting with the Western Canal. The Tremont Gatehouse controls the water in the Western Wasteway leaving toward the top right the three headraces indicated with dotted lines, leave the Western Canal to the right and feed the forebay and ultimately the four turbines. The water drops 13 feet at this point as it flows through the turbines. This action is what creates the mechanical energy that is the output of the revolving turbine blades and is transferred through gearing and shafts, and at a later date, shafts, pulleys and belting. To transmit this motive power from mill building to mill building, it was common to construct the buildings in a line so the shafting could be continuous.95 There are many examples of this method of power transmission between mill buildings, one of the most elaborate we have come across to date being the layout of the Massachusetts Mills. The first mill building in order in this sketch is represented by the rectangular protrusion abutting the wheelhouse at the top.
Peabody Museum’s final report on Tremont Yard.

The four dotted lines forming a right angle as they leave the wheelhouse to the far right indicate the twin tailraces that travel north toward the river for 900 feet before each splits in two as they reach opposite the Hall Street Dam. At this point one section of raceway from each tailrace empties into the basin formed at the end of the Tremont Wasteway just below the Hall Street Dam.

Photo by Author
The remaining sections of the two tailraces emptied into the Lawrence Canal, of which this portion is now buried in a landfill along side the Tsongas Arena.

The saga of the Tremont Mills and the part it has played in water usage in the Lower Western Canal has ended. The waters that were ejected from the tailraces of the Tremont have reached the Lawrence Canal and will now be used a second time to fuel the wheels of the Lawrence Mills.
It is a continued oddity that the name of neither Amos nor Abbott Lawrence appears on the incorporation papers. They are credited with being the movers behind the development of all three complexes in the Western group, the Suffolk, the Tremont and the Lawrence sites and yet only the Tremont bears their names on the incorporation papers. Several investors appear as at least part owners of all three manufactories but this it not uncommon or unique among these businessmen.

The Lawrence is different from the Suffolk and the Tremont Mills in design and layout. In fact it is completely different from every other mill complex in the entire canal system. It is also probably the only one not directly effected, or at least to a lesser degree, by the water flow from the Northern Canal when it was completed. Prior to this major and much herald opening, the water supply for the Lawrence simply poured down the Western Canal, all the way down the Western when it was one continuous waterway for there was no Tremont Gatehouse to impede the flow and flooded the Lawrence Canal. After the completion of the Northern Canal and the gatehouse, the Lawrence Mills would rely on the secondary runoff from the tailraces of the Suffolk and the Tremont Mills for their water supply.

The Western Canal was to mimic the Pawtucket Canal in the fact it was constructed on two levels. In both cases a dam at the approximate mid-point in the canals established the fall in the water level that would differentiate the Upper from the Lower Canal by 13 feet. This drop in the water level is
also what developed the head that provided the motive power to the mills on the Upper Levels of the two canals.

The Western Canal achieved this drop in the water level at the Hickey-Hall Dam built along side Suffolk Street at the intersection with Hall Street. From that point the water flowed into the Lawrence Canal which bisected the Western Canal before reaching the Lawrence Dam that straddled the Lower Western Canal. It was at this dam location that the falling water developed the final 17 foot drop and generates the head that would power the machinery of the Lawrence Mills before emptying into the Merrimack River.

Pages of text can be written on the simple process of generating the motive power for the Lawrence Mills as described above but the two photos below of the Lawrence Dam as it was and as it is tell the whole story.

This is the Lawrence Dam as it appeared in 1914 when it was performing as a working dam. Following a common practice the gatehouse built on the top housed the mechanisms to lift or lower the gates and operate the spillway.

PL&C Collection
Center for Lowell History

Today the dam is a mere shell of itself with its glory days left long behind. The wasteway is empty with the only water backing up from the Merrimack River in the background.

Photo by Author
But something is amiss here with the dates offered in other records detailing the building of the Lawrence Mills. In the Directors Minute, March 14, 1833 is an entry that the PL&C will sell as much extra water that the Lawrence wants as long as it doesn’t exceed that is purchased by the Suffolk and Tremont. On September 20, 1834 a proposal is voted on and approved to build an additional nine mills on the Lower Canal and a canal to feed them. If this is the Lawrence Canal that is referred to, and the timing and the usage mentioned would deem it the only possibility, by what method did the Lawrence funnel waterpower to the mills prior to that date? According to the Research Report on the Lawrence Mills found in the Cultural Resources Inventory, production of the first two mills at the Lawrence had begun by May, 1833, 15 months before the canal to supply the water power was even reported to have been started.

Whether the Suffolk or Tremont had their gates open or not appear of no concern. Yet it is constantly stipulated that the very lifeblood of the machines in the Lawrence Mills depended on the ejection of water from the tailraces of the Tremont and Suffolk Mills. The only obstacle to the unimpeded flow of water in the Western Canal was the Hall Street Dam. Its primary object was to provide the 13 foot drop and develop the head of the flow in the Western Canal. After the construction of the Tremont Gatehouse, this dam had no gates, just a spillway. This dam was not designed like the dams at the Upper and Lower Locks on the Pawtucket Canal with a daily function of regulating water flow besides creating the drop in the head of 13 feet. It simply sat there, 13 feet above the continuing water flow in the canal and created a small basin behind itself, probably with a secondary purpose of storing the water for the operation of the two chambered locks that at one time was built along the left hand side of the dam looking downstream to give access to vessels locking through to service the Lawrence Mill yard.

After completion of the Northern Canal and the Tremont gatehouse, the dam was rendered obsolete and the locks removed. Only the remains of what once was the sluice gate still stands as a monument to the large part this small structure played in the Lowell textile empire that now also ceases to exist.

It was after the Tremont Gatehouse was built at the completion of the Northern Canal in 1848 that some interruption in the volume of water necessary for the Lawrence Mills could have hindered operations at the Lawrence. Now if the gates at the Tremont Dam were closed to the canal waters, and the Lawrence had to rely on the output from the tailraces of the Suffolk and Tremont Mills only, big problems could occur. Number one, both complexes running together wide open couldn’t supply the volume that the Lawrence required to operate their spindles at full efficiency; at least not without resorting to the use of Surplus water. The gates at the Tremont Dam would have to be opened, just like in the old days.

Keep in mind that after the completion and the building of the Northern Canal and of the Tremont Dam and Gatehouse, the Lawrence complex was suppose to operate entirely on secondary waters from the Suffolk and Tremont. The chart on the New Adjustment of the Water Power in Lowell that Francis compiled and reported on to the PL&C in 1852 describing water usage to the corporation’s exemptions concerning the amounts of water the Tremont and Suffolk were able to draw on over their allotted quantities. After stipulating contracted limits of all manufactories, the Report to the PL&C, Statement of the New Adjustment of the Water Power at Lowell went on with exclusion the case of the Western Group. “Excepting for the Suffolk Manufacturing Company and the Tremont Mills, who, by the consent of all parties, are entitled to divide equally between them, the quantity of water to which the Lawrence Manufacturing Company is entitled.” Its a cut and dry declaration stating that irregardless
of what the Suffolk and Tremont contracted for between them they were allowed to draw and extra $\frac{49}{30}$ mill power from the canal to satisfy the exclusion in the report to the PL&C.

The simplistic schematic shown on page 95 has a sub-note that notes that the waterway of the Tremont Wasteway is normally dry (between the Tremont and Hall Street Dams according to the indications on the sketch), presumably in normal, everyday operating conditions. This condition definitely indicates to the reader that the only source of water to the Lawrence Mills be provided through the tailraces of the Suffolk and Tremont Mills.

So here is one condition that existed for the Lawrence that no other manufactory in the system had to deal with. The fact that its mill buildings were located on both sides of the Western Canal didn’t make distributing the motive power exactly an easy task either. The Lawrence Canal had to be kept full at all time to even begin to furnish the mill powers they had contracted for and all references to the fact that the so called Tremont Wasteway was normally dry or that the Suffolk and Tremont raceways could handle the volume required by the Lawrence has to be treated as a historical distortion of plain fact.

Before we go any further lets bring this last statement to a head. Combined, after the new adjustments of 1852, the Suffolk and Tremont mills together had contracted for about 13 millpowers. The Lawrence mills contracted for 17 $\frac{9}{30}$. Only two other complexes needed more power than the Lawrence, the Merrimack and the Massachusetts with the Boott in a tie. The exclusion agreed on in the Directors Report quoted above was meant to correct this discrepancy of $4 \frac{9}{30}$ mill power. This added amount of water that the Suffolk and Tremont were being allotted in order to satisfy the demands of the Lawrence Mills could only be acquired by the use of surplus water that supposedly was available only during high water periods experienced by the level of the Merrimack River. What was to happen when water was low or all of the mills were drawing their maximum allowable limits?

Granted that after the completion of the Northern Canal there was no shortage of water in the Western Canal. But if both the Suffolk and Tremont were down for some reason, or even one of the complexes for any given reason, it seems the only alternative was to throw open the gates of the Tremont Dam and flood the wasteway.\textsuperscript{103} Now the question arises would, could a waterway with the dimensions of the Tremont Wasteway provide the necessary increased volume that the Lawrence Mills now drew under the adjusted allowances of 1852, to operate the machinery or would some have to be shut down or run at reduced speed. And how much of a barrier to the increased flow would the Hall Street Dam be?

In the official \textit{Reports on the Water-Power of the United States, 1880}, the dimensions of the canal were given as “8 feet deep and 30 to 80 feet wide.” The 80 feet was actually only possible at the site of the Hickey-Hall Dam. The canal now measures, and appears after extensive rebuilding itself, only about six to eight feet deep and 24 feet wide from below the gatehouse to the dam, reducing possible volume it can carry even more and is renamed the Tremont Wasteway. And the \textit{Lower Merrimack River Inventory} describing the dam states that in 1845 the dam was rebuilt in the present step configuration but not so to as accommodate the new upper level of the canal. Also “in 1868 the dam was cut down two feet in order to increase the supply of water directly into the Lawrence canal when the Tremont and Suffolk Mills were not in full operation.”

It is evident from these statements that our questions were not presumptuous.
Below is an the indentured copy of the drawing of the Lawrence Manufacturing Company, circa 1831

A brief explanation of the highlights of the drawing is in order to clarify mill layout and make the details easier to follow as it is referred to. This is the proposed site layout that accompanied the Deed.

The dotted lines feeding into the Lawrence Canal from above represent the tailraces from the Suffolk Mills to the right and the Tremont to the left. The dotted lines leaving the Lawrence Canal from the bottom represent the headraces feeding the individual mill buildings. Those leaving the mill buildings are the tailraces from the wheelpits and enter the Merrimack River.

The Lawrence Mill buildings to the left of the Western Canal are located in the secondary mill yard. Those buildings on the right are in the main yard.

Arrow #1 identifies the Western Canal.
Arrow #2 identifies the Hickey-Hall Dam. It is from this point that the water drops 13 feet to create the head at the Suffolk and Tremont Mills.
Arrow #3 is the Lawrence Canal which is fed from the Western in both directions and supplies water to the mills in both yards.
Arrow #4 identifies the Lawrence Dam. Here the water drops 17 feet to create the head for the Lawrence Mills before returning to the River.
After the reader has examined the raceways shown in the sketch on page 120, just keep in mind that this was the original indenture that accompanied the deed. The Lawrence Mill yard developed so rapidly that no matter what representation of the site one relied on as the ultimate of the site development, the layout of the buildings and thus the underground feeders were probably re-arranged by the next photo or sketch observed. And not so much that the development of the yard was constantly being improved as simply the constant adding of buildings as the manufactory expanded to five mills and the dye houses.

In the attempted to photograph the mill yard for his 1884 publication, Lowell Illustrated, Frank Hill resigned his efforts to failure. “We have not been able to present so good a view of this corporation as was hoped for owing to the crowded condition of the yard. Every available spot is so covered with buildings as to make it almost impossible to get a good general view from the inside.”

But the Lawrence Company maintained easy access to its water supply through the Lawrence Canal running parallel to the entire site. They didn’t have to dig under, around or between buildings to service a new building, and risk weakening or otherwise damaging the structures. The canal could be tapped anywhere along its length to feed waterpower to a new mill.

A little history provides the story of the Lawrence brothers, Amos and Abbott and their foray into the textile empire they were to launch. A twenty dollar loan and a rented store front filled with consigned goods in Boston provided the building bricks. Raw ambition, vision and courage the mortar. And Lowell would provide the catalyst. Hard financial times caused by a depression in 1829 effected the textile manufactories also and hit the Merrimack Manufacturing Company as well as the rest. Abbott Lawrence was able to deal to obtain excellent terms for the 20 acres and six mill powers. Not bad when one considers that the Western Canal wasn’t even built yet.

The canal had been begun in 1828 but when the financial picture soured, so did any potential investors and the digging was “slowed or halted.” This lapse in the construction may well be what resulted in the peculiar jug handle that ended up in middle of the canal’s course. It’s as if when the digging resumed it dawned on someone in command that the present tract of the canal would bisect with the middle of the Merrimack Mill Yard. Probably rather that start all over at the Swamp Locks and forfeit the money, time and energy all ready spent in the digging, a slight offset was decided on in the course of the canal. This is quite evident in any view of the canal on either maps or drawings such as on page 96 for example.

The Lawrence Manufacturing Company would expand rapidly once progress began to be made. The original plan called for four buildings to be built and equipped by the PL&C and they had contracted for 20 acres and six mill power as the base for the complex. Even the dates of record seem to follow the turmoil that appears to have preceded the first loom to begin spinning the golden thread. And of course the advancement of the progress of the Lawrence Mills had to proceed in lock step with that of the Suffolk and Tremont as well. All three were incorporated in 1831. From that date on at least the Lawrence progressed more or less on it’s own. They all had some of the same investors and Henry Hall was the treasurer for all three at one time or another starting in 1832.

The Lawrence Manufacturing Company was chartered by the Massachusetts General Court on June 7, 1831, for the purpose of manufacturing cotton and woolen goods in the town of Lowell. Thus its birth was assured even if the goals of the company were to vary and change over the period of time that it was in existence. This date can’t be disputed even if some of the later or even earlier do tend to leave a question mark.
The Western Canal was completed in 1832, jug handle and all. Apparently Abbott Lawrence was not one to sit around waiting for something to happen because other peoples actions. The minutes of the PL&C Directors meeting of April 30, 1831 records that he applied to the PL&C for land and water power for 20,000 spindles and for a print and bleach works. Along with the plans for the enterprise went a request that read in part – “That sufficient land for the above works being something more than 700,000 ft. may be furnished on the lower level of the Western canal & that it is expedient to offer him five millpowers.” Not a bad request of a man who was a tenant haberdasher only a few years before.

The story of the development of the Lawrence Mills is told in several writings, some of which agree and some of which vary in the slightest mode. There are only so many sources no matter how many times the story is told, and that comes down to one. There is correspondence available between the interested parties, the investors, the directors and others involved that chronicle all of the decisions made at the time that determined the direction of the company. It is interesting to follow but our primary interest is in the underground raceways and the power they delivered to the mills so we will simply skirt the heavy stuff and follow the early development in the records of the Directors minutes.

July 31, 1830  Here is an accounting entry over the name of Kirk Boott, Treasurer mentioning moneys expended for “Western Canal and Mill Sites of $32,800.40.” For whatever reason, the purpose isn’t given and it’s immaterial. It’s the mentioning that is. This date is long before the Western Canal was operating but the wheels of progress was already turning.

July 31, 1831.  Another expenditure appears on work at the Western canal for the sum of $16,756.36. July 31 must represent the end of the fiscal year or what ever term that was used back then to organize and report the yearly expenditures for whatever governing body.

July 31, 1832. The sum of $63,000 appears in this financial ledger sheet but apparently under the receiving column as in receiving a payment. This is followed by a report one year later on August 1, 1833 with another entry in the “BY” column for the sum of $218,213.98.

But at about this time something must have gone wrong with the finances of the Boston investors, or at least to the point that it made them hesitate in their grand plans for the Lawrence Company’s mill site. As recorded in the minutes of the Directors meeting of December 28, 1832, the PL&C was approached by the treasurer of the Lawrence Company with a request to suspend all operations pertaining to the construction and equipping of number three and four mills. There was some controversy between the PL&C and the company as both mills had been started and had various degrees of the construction work already finished.

At any rate, the work on the mills must have progressed without a great deal of interruption. On March 14, 1833 an inquiry was received by the PL&C from the treasurer of the Lawrence Manufacturing Company as to the feasibility of the PL&C to “contract to furnish the Lawrence Manufacturing Company as much water as they require for four mills and a bleachery.”

There is something disputable between the historical facts as presented between the so call recorded data by different authors and their sources. From the above entries recorded in the Minutes of the PL&C Directors we can be fairly certain of the source of the information as it is as first person as can be imagined.

Perhaps a step by step chronological sequence of events involved in the establishing, that is in the actual development of the Lawrence Manufacturing Company as recorded by the body governing the
construction of the buildings and providing the machinery, the PL&C, will help clear the haze from the jumble of supposed dates that appear in other writings.

Directors Minutes

1831, April. Prior to this date Lawrence approached the PL&C with his plans.

On the above date, the PL&C granted Lawrence his request for land and power on the Lower Western Canal.

June, 1831, the Lawrence Manufacturing Company received its Charter.

1832, December. The Lawrence Company requested that the PL&C cease all work on buildings number three and four at the mill yard.

At this same Meeting it was voted to complete mill buildings number one and two and fill both with machinery.

1833, March. Discussions by the Directors concerning water usage appear to establish that all four mills were up and running along with the Bleachery.

1834, November. It appears that the four mills mentioned above are running as these discussions are all about water power for those mills. The record does not mention in addition to the existing mills or any other phrasing that would lead us to believe that they are not the original mill buildings with the request for nine other mills sometime in the future.

1835, March 16. Abbott Lawrence requests the PL&C increase the allotted amount of millpowers available for the Lawrence Mills by one for a total of nine.

As the yard expands through development, more mill buildings are added and so is the volume of water needed to power the machinery. By the time the new adjustments are made in 1852 allowing all of the manufactories to increase the water usage, the Lawrence mills are drawing 14 1/2 millpowers. Under the new adjustments, the Lawrence will increase that total to 17 9/30.

Only the Merrimack and Massachusetts Mills drew more millpower from the overburdened canal system than the Lawrence. The Merrimack also had its own secondary canal known as the Inner Canal as the Lawrence did to feed the many mills in its yard. It also had its own feeder canal [tapped only by the Lowell Mills] known as the Merrimack Canal naturally and the advantage of a 30 foot head. The Massachusetts Mills took advantage of a complex internal shafting system to feed power to its many mills and maintain its position as the second largest complex in the system. In their heyday, they both utilized waterpower from the canals to operate the machinery. But little by little as improvements were made in the motive systems, steam began to make inroads but that was at a later date.
A more detailed layout of the underground as it existed after the Lawrence Mill yard was fully developed has not been located in the research. The profusion of buildings that existed at this later date is shown in the presentation below would probably place a strain any underground raceway system if each were supplied separately but what was the alternative. Mechanical shafting between the buildings as at the Massachusetts yard could have been the answer and that would justify why no up to date underground layout has surfaced.

The following is a condensed description culled from an article prepared by David Redding of the Lowell National Historic Park in 1983, titled the Lawrence Powerhouse and the Big Pulley Wheel. It is an excellent job of presenting the operation of the motive power of the Lawrence Mills as it was first proposed; clear, concise, and certainly grasping the very few particulars necessary to propel the mill machinery with the least amount of text and sketches. The accompanying sketch following the text tells the rest.

“When the four original mills of the Lawrence Manufacturing Company were built, they followed the typical pattern of design and set up of the other Lowell Mills. Each mill was supplied water by feeders ['underground'-authors note] running to the center of each mill basement. There the water fell 17 feet over the floats of breast wheels, 17 feet in diameter and about 20 feet in length, three breast wheels per mill. The name breast wheel refers to the iron breast or apron used to hold the water in place against the water wheel as the water wheel turns adding to the efficiency of the wheel.”
Below is basically an abridged copy of the sketch on page 120 that was included with the above text. It effectively eliminates ninety percent of the clutter and offers only the four original mills with their underground races.

![Herrimack River sketch]

Proprietors of the Locks and Canal - 1833

This sketch is a representation of the basic waterwheel that was contained in the basement of every cotton mill and supplied the motive power to the machinery that ran the looms.

Both of these Illustrations from David Redding’s “The Lawrence Powerhouse”

This sketch of a pitchback wheel was the type most commonly used in mills. Water enters high on the wheel at ‘A’, is held in the buckets of wheel by the apron [breast] ‘B’ and discharged at the bottom ‘C’.

The Lawrence Manufacturing Company was one manufactory that kept up with any new development adopted by any other mill to enhance production. The first Boydén turbine was tested at the Appleton Mills in 1844 and by the mid-1850s the Lawrence was digging new raceways and
wheel pits to take advantage of the reports of success of the trials. The turbine was to prove of less size, could produce more horsepower and was able to operate underwater so it was much less vulnerable to the old nemesis of the waterwheel, backwater.

Below is a sketch of the underground raceway system constructed, to service and to house the newly introduced turbines at the Lawrence Mills. Once again, the simplicity of the design and layout are evident as adverse to the complicated mess that would be produced by today’s engineering.

Lawrence Powerhouse by David Redding

This is a sketch of a Francis designed Boyden turbine that was probably chosen to operate the machinery from those newly constructed wheel pits. He was the chief engineer at the PL&C and supervised the testing to the turbine at the Appleton Mills.

Lowell Hydraulic Experiments
This photo taken in 1908 is typical of any wheelpit. The workers are in the process of removing a casing of an old turbine to be replaced. They are standing in one of the raceways.

All that remains now in the story of the hydraulic motive power that powered the textile empire of Lowell is to return the water to the Merrimack River from whence it originated. Regardless of what product the mills were producing, nothing was to interfere with the waterpower flowing through the underground raceways to provide the mill power for the insatiable thirst of the machinery.
Two massive stacks stand in testimony in the mostly demolished mill yard today, testifying to the eventual dependency of the motive power on steam engines. But long before the happening of this event, and for a good time after the introduction of steam power, waterpower was the prime mover. Waterpower had the advantage that it was simpler to operate and much cheaper fuel-wise. The drawback was the erratic functioning of the wheel or turbine, the power chain from the river through the feeder canal to the tailrace to operate the machinery, due to the low supply of water in the dry seasons that vastly effected the production of the manufactories. But this narrative is on waterpower not steam engines, and whether wheels or turbines, the end result was identical and the looms turned.
Bibliography

Hidden Waterways of the Lowell Canal System

Chapter One
Introduction to the Subterranean

1. Sundry Papers 1855 James B. Francis
   Form of Lease of Water Power at Lowell Article III pp. 8
2. ibid. Article I pp. 7
   also in “Water Power” vol. 1 by Louis C. Hunter pp. 257

Chapter Two
The Moody Street Feeder

4. Directors meeting of December 30, 1847
5. “ “ “ April 14, 1848
   Chart in “Water Power” vol. 1 pp. 214

Chapter Three
Two Other Underground Schemes that were Abandon

7. $600,000 Cultural Resources Inventory
   by Shepley, Bulfinch, Richardson and Abbott
   Vol. Industrial Canals Northern Canal
   $650,000 – letter from Francis to R. S. Fay pp. 11

Chapter Four
Boott Penstock

8. Cultural Resources Inventory Vol.- Industrial Canals pp. 3
   Minutes Directors Meetings Dec.24, 1821 Jan.17, 1822
9. HAER Inventory – Boott Penstock Historical American Engineers Record No. pp.
   Article “Change in Boott Mill” - Folder in Upright Files National Park Library “ “
   First mention found in Minutes of Directors Meeting Apr.14, 1848
10. Minutes of Directors Meetings – Jan.2 & May 1, 1873 and July 26, 1888.
    “Sundry Papers 1855” Removal of Ice from the Eastern Canal, Thomas Livermore
    ibid. pp. 2
11. ibid. pp. 3
12. Report Relating to the Proposed Extension of the Penstock for discharging water into the lower end of the eastern end of the Boston canal by James B. Francis
    ibid. pp. 2
13. ibid.
Chapter Five
The Subterranean Powerhouses

16. Form of Lease of Water Power at Lowell – Article ll pp. 7
17. Lawrence Mfg., Miscellany Folder at National Park Library note says from Cultural Resources Inventory – Lawrence Mfg. Co. pp 19
18. “Lowell Machine Shop History” 1979 Robert Weible Fig.14 - Merrimack Manufacturing Company - Lowell Machine Shop none
19. Saco-Lowell Shops G.W.Gibb pp. 57
20. ibid.
21. Cultural Resources Inventory indicates shop built along with counting house – 1831/1844 Saco Lowell Shop pp. 24
22. Cultural Resources Inventory Research Report Site of Lowell Machine Shop off Dutton Street at Swamp Locks pp. 1

-Hamilton Manufacturing Company
23. Cultural Resources Inventory Research Report Site of Hamilton Manufacturing Company off Jackson Street pp. 1
24. ibid.
26. ibid.
27. ibid. pp.211
28. Cultural Resources Inventory Research Report Site of Hamilton Manufacturing Company off Jackson Street pp. 2
29. Lowell Corporation Article I 1881 Book at Center for Lowell History Form of Lease of Water Power at Lowell 1853 pp. 6
30. Systematic Testing of Turbine Waterwheels by Thurston pp.441
32. Macheras Archives Compiled by Al Lorenzo Summary of Research into unpublished PL&C Record’s pp. 5

-Appleton Manufacturing Company
33. Lowell Illustrated 1884 Frank Hill pp. 69
34. Joshua Merrill, from “School District #5”, Contributions, Vol.1 pp. 27/28
35. Minutes of PL&C Directors meeting December 28, 1832
36. Census of Massachusetts 1875, 3 vols. 2:325 pp.325
-Middlesex Manufacturing Company/Hurd Mills
37. Cultural Resources Inventory Shows up on first page of each review of mill site reports
38. Cultural Resources Inventory Site review of Middlesex Manufacturing Company pp. 6
39. History of Lowell Vol. 1 Frederick Coburn Contributions Vol.3 Read by Dr. J. O. Green 1878 pp.234
40. (CRI) Northern Middlesex Registry Book 6 pp.256
41. (CRI) Northern Middlesex Registry Book 6 5/8/1827 pp.335
“ “ “ “ 3/18/1827 pp.290
“ “ “ “ 8/9/1830 pp.506
Chapter Six
Tremont and Suffolk Mills and Lawrence Mfg. Co.

67. Cultural Resources Inventory – Suffolk Mills  pp. 2
68. Minutes of the Directors Meeting   Vol.#2   July 31, 1830 pp.316
69. ibid.                                 November 19, 1830 pp.311
70. Lowell Illustrated   Frank Hill 1884 pp. 81, 83
71. Suffolk Mills  Cornilia Wyma and Paul Cloyd
   from a folder at National Park Library pp. XIII
72. Cultural Resources Inventory – Suffolk Mills pp.  2
73. ibid.
Lowell Illustrated

-Western Canal

74. Water Power  Joseph P. Frizell  1903  pp. 81

-The role of the Northern Canal

75. Sundry Papers, Lowell Corporation – inside rear cover
   Sketch#3  Improvements Upper Level Pawtucket Canal, 1855
   Suffolk Manufacturing Company

76. From a loose-leaf of the same title at the National Park Library
   Prepared by Cornelia Wyma and Paul Cloyd

77. Report Measurement of the Water-Power Used by the Manufacturing Companies of Lowell.
   Report to the Directors of the Locks and Canals, Merrimack River by James B. Francis and James F. Baldwin 1853

78. ibid.

79. Cultural Resources Inventory – Suffolk Mills  pp. 2

80. Suffolk Mills Upright Files-National Park Library  pp. 26

81. Suffolk Mills (Miscellany)  pp. 9

82. Cultural Resources Inventory – Suffolk Mills  pp. 12

83. ibid.  pp. 4

84. Suffolk Mills (Miscellany)

85. Suffolk Mills  pp. 13

86. History of Lawrence brothers The Merrimack 1958 by Raymond Holden  pp. 186

87. Handbook for the visitors to Lowell  1848  pp. 15


89. Cultural Resources Inventory – Suffolk Mills  pp. 13

90. Report to the Directors of the PL&C Francis and Baldwin  1853  pp. 13

91. Cultural Resources Inventory - Suffolk Mills  pp. 13


93. ibid.  pp. 13


95. Folder at NPL Tremont and Suffolk Mills: Miscellany Institute for Conservation Archeology, Peabody Museum - Ellen Rosebrock

96. Lowell Illustrated Frank Hill  1884  pp. 83

97. The Merrimack River Meader  1869  pp. 254

98. Lowell-An Early American Industrial Community MIT 1950  pp. 141

The basis for this statement is quoted from Lowell Directories referred to in the Research Report on the Lawrence Mills. Page 1, s/s#8, in the Cultural Resources Inventory

1834  pp. 8

1859  pp. 225

99. Cultural Resources Inventory SBRA Lawrence Manufacturing Company Transportation pp. 20

100. Report to the Directors of the PL&C Lawrence Manufacturing Co. 1853. pp. 14

103. Report to the Directors of the PL&C Lawrence Manufacturing Co. pp. 14
104. City of Lowell Directory 1886 pp. 443
105. Lowell Illustrated by Frank Hill 1884 Lawrence Mfg. Co. pp. 83
106. History of Lowell by Frederick Coburn 1920 (The Factory System) pp. 167
107. Cultural Resources Inventory Industrial Canal Volume Western Canal pp. 7
108. Cultural Resources Inventory Corporate History (Lawrence Mills) footnote#1 describes source pp. 1
109. See sketch of power layout at Massachusetts Mills 1889 this book. pp. 70
110. The Lawrence Powerhouse 1983 David Bedding Available in upright files at the National Park Library.

List of Photographs/Illustrations

Hidden Waterways of the Lowell Canal System

Page Source

11. Top Lowell National Historic Park Museum Collection Bottom Photo by Author
18. PL&C collection at the Center for Lowell History UML Top photo number 251 Bottom photo number 253
27. ibid.
30. from Working the Water – Life and Labor on Lowell Canals pp. 11 by Steve Turner and Charles Scullion
31. Slight modification of drawing 7, Drawer 153 of the PL&C.
32. By author.
33. Top – by author. Bottom – by Author
41. Both photos from Authors collection.
42. Proprietors Locks and Canals Shelf 165 Drawer 32.
43. From Water Power in Lowell Massachusetts by Pat Malone.
44. Both reproductions from www.museum.nps.gov/lowe.
45. From roll #4 PL&C microfilm at Center Lowell History.
46. Merrimack Mfg. Co.- Record of a City by Kenngott 1912
47. Remnants of Saw Mill Tailrace by Author
48. North Middlesex Registry: Book 2, Plan 7
49. Section, “Pawtucket & Northern Lock Structure Illustration #110 pp.263
50. Taken from Saco-Lowell Shops by G.W.Gibb pp.221
51. Pawtucket and Northern Lock Structure prepared by Anne Booth pp.263
52. Cultural Resources Inventory opposite pp. 58
53. Report - Measurement of the Water Power used by the Manufacturing Companies at Lowell pp. 9
54. PL&C collection Photo#204 Centers for Lowell History
55. “Lowell Illustrated” by Frank P. Hill pp. 74
56. Top from Collection of Canal Photos 2006-02-24
57. Bottom Photo by author
58. Top from Collection of Canal Photos 2006-02-24
59. Bottom Photo by author
60. Pawtucket and Northern Lock Structure sub-title Illustration #110 prepared by Anne Booth pp.263
61. Contributions-Journal of the Old Residents’ Historical Asso. Vol.3 accompanied an article copied from a talk by A.B.Wright pp.428
62. Top left: photo by author
63. Top right: “ “ “
64. Bottom: Cultural Resources Inventory from site review Fig.6
65. Prescott Mill Headraces from the Eastern canal by author
66. From PL&C microfilm collection, Roll #1, Blueprints and Sketches, at the Center for Lowell History.
67. Will be photos of Prescott mills tailraces emptying into Concord River
68. Trash racks covering Massachusetts Mills headraces leaving the Eastern Canal. Photos by Janet Pohl.
69. From National Park Library upright files. Massachusetts Mills:
   Plans and drawings: Miscellany dated 1839 (Middlesex County-North Registry of Deeds-Book 3-pp. 19)
70. Top - Tailraces of Massachusetts Mills entering the Concord River by author
71. Bottom- Power layout in 1889 at the Massachusetts Cotton Mills. From a collection at the National Park Library.
72. From a collection at the National Park Library bound in a loose leaf. “Lower Locks Complex-Negatives and Multiprints”. No.81-27-8
73. From National Park Library upright files. Massachusetts Mills:
   Plans and drawings: Miscellany. 1911 Insurance Survey.
74. From Cultural Resources Inventory – located in inventory form section. Vol. - Industrial: Lowell Canal System, No page number.
75. Boott Cotton Mills: Field work and measured drawings / HAER 1983 Folder at National Park Library.
81. Top - Taken from Vehicle Bridge over Eastern Canal. From collection. Bottom – Taken from Foot Bridge over Eastern Canal. From collection.
82. View from Amory Street. From collection.
83. All three photographs taken by author.
84. Center for Lowell History located at Mogan Center, 40 French Street.
85. Boott Cotton Mills: Field work and measured drawings / HAER. 1983 Folder at National Park Library.
86. Lowell Illustrated is in collection at Center for Lowell History.
88. From Peabody Museum of Archaeology Figure 6D No page number Archaeological Services conducted at Tremont Yard.
89. From Center for Lowell History
92. From Suffolk Mills prepared by Wyma and Cloyd pp. 9 Illustration 4 This print should have been dated 1832
93. Entrance to Suffolk Mill turbines in the National Park exhibition. History of Industrial Power 1831-1940 David Redding 1985 Figure 90
94. Indenture drawing for the Tremont Mills, July 1, 1832 PL&C Courtesy of HAER
95. Top -taken from where old Tremont St. intersects with Morrissett Blvd. Bottom –taken on clandestine journey inside protective fence.
96. Peabody Museum, final report, 1979 Archeological Services conducted at Tremont Yard, LHSP
97. By author from Suffolk street walkway.
98. Lawrence Mills from chapter in book titled Factory System pp. 167
99. top bottom
100. Indentured drawing for the Lawrence Manufacturing Company HAER
101. Cultural Resources Inventory Lowell National Park and Preservation District 1979 figure #1.
102. Taken from folder in the upright files at the National Park Library titled The Lawrence Power House and The Big Pulley Wheel by D. Redding.
103. Both of these Illustrations reproduced from the above folder.
105. Collection at the U. of Mass, Lowell, Mogan Center.
106. ibid.