Canvass White, Esquire (1790-1834): Civil Engineer.

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Canvass White, Esquire (1790-1834): Civil Engineer

by

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Preface and Acknowledgement

Canvass White's career paralleled the development of the civil engineering profession in the United States. He was active in its inception on the Erie Canal, and went on to become a leading figure among the first generation of American engineers. Through natural aptitude, increasing knowledge and practical experience, he advanced the frontiers of technical knowledge and helped to establish a new type of professional occupation.

White held a number of important posts and appointments during his short, but illustrious career. He was a seminal figure at a time when there was a tremendous demand for engineering skills, but few textbooks and no schools. His rise to the summit of a new profession was rapid and dramatic. His reputation became such that the mere association of his name with any project increased public confidence, and seemed to guarantee that the goals of entrepreneurs would be met. After learning the engineer's art, he remained at the leading edge of technological progress, never flinching when faced with the most complex and perplexing challenges.

As a group, the first generation of American engineers wrote very little. There simply was too much to
do. Their work was tremendously important, but they left a scant record. The substantial collection of White's personal papers that have survived are therefore extremely valuable, because they provide so many insights into the attitudes and abilities of the first American canal engineers. White was the unquestioned leader of his generation, and his papers reflect the wide scope of his activities and the depth of his influence.

I would like to thank Kathleen Jacklin, Archivist at the John Olin Library, Cornell University, and her staff for allowing me access to the university's Regional History Collection, and for their generous assistance. I would also like to thank the staff at the Division of Archives and Manuscripts of the Pennsylvania Historical and Museum Commission for their helpfulness during my research on early canal engineering in Pennsylvania.

Lance Metz, Historian of the Canal Museum in Easton, Pennsylvania deserves credit for suggesting the topic, and has been a continuing source of support and advice. Professor Roger D. Simon of the History Department at Lehigh University has acted as advisor during the research and preparation of this paper. I would like to thank him for his help in focusing on important issues. Also, I am indebted to him for his critical reading of the text, his encouragement and his patience.
## Table of Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>One: Early Years and Education</td>
<td>3</td>
</tr>
<tr>
<td>Two: The Erie Canal Experience</td>
<td>11</td>
</tr>
<tr>
<td>Three: The Discovery of Natural Hydraulic Cement</td>
<td>35</td>
</tr>
<tr>
<td>Four: New York City's Water Supply Problem</td>
<td>55</td>
</tr>
<tr>
<td>Five: The Union Canal in Pennsylvania</td>
<td>75</td>
</tr>
<tr>
<td>Six: Career Developments and Conclusions</td>
<td>91</td>
</tr>
<tr>
<td>Bibliography</td>
<td>100</td>
</tr>
<tr>
<td>Vita</td>
<td>105</td>
</tr>
</tbody>
</table>
Abstract

Canvass White, born on September 8, 1790 at Whitestown, New York, was among the first American civil engineers. In 1811, he graduated from Fairfield Academy in Herkimer County, New York, having studied surveying, mathematics and the natural sciences. In 1816, he joined Benjamin Wright's surveying crew on the Erie Canal and immediately demonstrated an aptitude for engineering. At Wright's request, he inspected public works projects in England during the winter of 1817-1818, interviewed British engineers, and returned with much useful technical knowledge, including information on hydraulic cements. His subsequent discovery of an American variety of natural hydraulic cement was crucial to the engineering success of the Erie. White's attempt to patent the cement failed because of the opposition of the New York canal commissioners, and an inability to protect the formula.

The scarcity of civil engineers and the great fervor for public improvements enabled White to pursue an independent career. In 1822, while still active on the Erie Canal, he served as consultant to a committee of the New York Common Council investigating the city's water supply problem. This was the first in a series of appointments that put White in touch with many of the
major civil engineering projects of his time.

In 1823, White became chief engineer of the Union Canal Company of Pennsylvania. He resolved difficulties between the engineering department and the company's managers left by his predecessor, Laommi Baldwin, and successfully completed the canal across difficult ground. The Union Canal included two technological first: the longest tunnel and largest dam yet constructed in the United States. During construction of the canal from 1823 to 1828, White trained several assistants who went on to have distinguished engineering careers.

From 1825 until his premature death on December 18, 1834, White took advantage of the great demand for his engineering skills. He was active in public works projects in New York, Pennsylvania, Connecticut, New Jersey, Kentucky, Maryland and Delaware. Perhaps the greatest of America's canal engineers, he helped to establish the science of engineering as a practitioner, innovator and teacher.
Chapter One
Early Years and Education

Canvass White was born into a family that could trace its history back to the earliest Puritan times.1 His grandfather, Hugh White, was a lineal descendent of Deacon John White, one of the first settlers of Hartford, Connecticut in 1632. The White family prospered and lived in comfortable surroundings in Middletown, Connecticut until the Revolutionary War. Hugh White was a quartermaster during the war, and he expended what small fortune the family had in return for continental paper money. When the war ended and the paper money proved worthless, the White family looked for a fresh start and new opportunities in the frontier wilderness of central New York State. In the spring of 1784, Hugh White moved with his wife, five sons and four daughters to an area known today as Oneida County, and established a community that they called Whitestown.

1General biographical information was obtained from the following sources: Charles B. Stuart, Lives and Works of Civil and Military Engineers in America (New York, 1871); William P. White, "Canvass White's Services" in Buffalo Historical Society Publications, Vol. 13 (Buffalo, 1909), 353:66; and the American Society of Civil Engineers, A Biographical Dictionary of American Civil Engineers (New York, 1972), 126-27.
Canvass White was born at Whitestown on September 8, 1790 to White's oldest son, also named Hugh, and his wife, Tryphena Lawrence White, a native of Canaan, Connecticut who also was of Puritan descent. Young White was raised in a thoroughly Puritan community which placed a strong emphasis on enterprise, integrity and individual accomplishment. Those traits were to mark him during his years of public life.

The White family made major improvements in their community within a few years of its founding. In May of 1788, Canvass White's father entered into an agreement to build a grist mill on the land of a neighbor, Amos Wetmore, near the boundary line separating their two properties. Water to power the mill was taken from the nearby Sauquoit Creek by a canal. The creek was dammed to create a reservoir that fed water to the mill during dry seasons. Hugh White added a waterpowered saw mill soon after the grist mill and dam were completed. The canal and dam, and the fascinating technology of the mill, can hardly have escaped the attention of a young boy with an inquiring mind and mechanical sensibilities. The example of self-reliance, inventiveness, and faith in progress set

2Pomeroy Jones, Annals and Recollections of Oneida County (Rome, N.Y., 1851), 787.
by his family also contributed the positive attitude that characterized White during his adult life.

During his childhood, White suffered severely from a chronic illness that he inherited from his mother. In 1800, this illness claimed Tryphena White, leaving 10-year-old Canvass White in the care of his father. Often too weak to assist with farm chores, he contributed to the family effort by designing improvements in several domestic and agricultural implements\(^3\).

Young White regularly attended the town's common school and was an excellent student. His Puritan father, Hugh, placed great faith in education, and he provided his son with an opportunity to pursue further studies. From 1803 to 1807, Canvass White attended the newly formed Fairfield Academy in Herkimer County, only a short journey from his home. The early records of the school have been lost resulting in some confusion over the dates of his enrollment. He did graduate, however, and returned from 1809 to 1811 to attend special lectures and use the laboratory facilities.

Fairfield Academy was granted a charter by the Regents of the State of New York on March 15, 1803. The

\(^3\)Stuart, Lives and Works, 75; White, "Canvass White's Services," 354.
school held its first session in April of that same year and soon earned a reputation throughout the region for excellence in chemistry and natural science.

By 1809, the campus had three buildings, including a well-equipped laboratory. That year, the academy hired Dr. Josiah Noyes to lecture in the natural sciences and chemistry. Noyes received his degree from Dartmouth College in 1801. At the time that he came to the academy, he was thirty-four years old and extremely capable. His lectures and demonstrations reportedly held classes spellbound. From 1809 to 1811, White attended Noyes' engrossing lectures and became one of his best students. 4

By 1810, in addition to a well-educated faculty, Fairfield had excellent facilities for scientific research. Noyes claimed that the academy's laboratory and equipment were on a par with any in the country:

We have three buildings, one of stone called the laboratory containing fourteen elegant rooms. There are two lecturing rooms, one for anatomy, and the other for lectures on chemistry. These two rooms perhaps are better than any others built for the same purpose in the United States, except Philadelphia. Our chemical apparatus is more complete

than any in the city of New York, and the anatomical museum is equal to Dr. Smith's at Dartmouth. 5

The academy's remarkable facilities provided White with an opportunity to gain a thorough introduction to the sciences. He studied surveying, astronomy, mathematics and mineralogy, and left the academy fully prepared for some kind of professional career. Although he could not have known it at the time, he was uniquely qualified among local residents to make a significant contribution to one of the most important events in American history: the building of the Erie Canal.

After leaving Fairfield Academy in the spring of 1811, White found employment with a chemical manufacturing concern in Utica. For unknown reasons, this did not suit him and he soon returned to Whitestown where he took a job as clerk in the general store of a family friend, Colonel Carpenter. Within a few weeks of assuming his new position, his health began to decline seriously. Apparently, he suffered from some type of chronic pulmonary disorder that resulted in periods of severe debilitation. When in good health, he was a handsome young man of medium height, with brown hair and blue eyes. Only

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5 Josiah Noyes to Dr. Lyman Spalding, an associate from Dartmouth, as quoted in O'Donnell, Tip of the Hill, 51.
slightly built, his nagging illness often gave him a pale and haggered appearance. Local doctors recommended a long sea voyage, a standard remedy for pulmonary disease in the nineteenth century, and White hurriedly made arrangements to go abroad.

Being an enterprising young man, who was probably unable to afford the luxury of being merely a passenger, he obtained a position as supercargo on a merchant vessel. This was a great responsibility since the supercargo was the officer who had charge of the purchase and sale of the ship's cargo. Early in the summer of 1811, the ship left New York harbor bound for Russia, to return by way of Great Britain. While in Russia, the captain and crew remained ignorant of the declaration of war and commencement of hostilities between the United States and Great Britain. They did not become aware of the war until they sailed into the English port of Hull, were made prisoners, and saw their ship and its cargo seized. For some unknown reason, they were released, permitted to discharge their ship, take in another loading, and continue their voyage home. As the vessel left the harbor a violent storm, accompanied by a high tide and strong winds, drove the ship back to shore. When the tide receded, the ship lay on its side nearly three hundred yards from the sea. To make matters worse, when the crew
examined the ship's planking, they discovered that it was completely rotten and that the vessel was unseaworthy.

The situation seemed hopeless, but White quickly developed a plan to re-plank the ship, and then directed the digging of a channel through the sand to admit the tide to the stranded vessel. He was entirely successful in both these operations, and within a few days the ship was afloat and on its way to New York. This seagoing episode revealed the problem solving capabilities of White's mind, and foreshadowed the self-confident attitude that he would display as an engineer.

It is impossible to calculate exactly the significance of this long voyage for White. It most probably affected his character in a general way by expanding his awareness of the western world. In any case, it gave him exposure to some of the accomplishments of other nations, contributing to his sense of the possibilities to be realized in his own country.

In the fall of 1812, at the age of 22, he returned in better health to clerk in Colonel Carpenter's store, where he remained for two uneventful years. In early 1814, as the British stood poised for an invasion of New York, he raised a company of volunteers and received a commission as Lieutenant in Colonel Philetus Swift's regiment, General Peter B. Porter's brigade of New York volunteers.
His regiment participated in the battles around Fort Erie, near Buffalo. While serving in occupation of the Fort, he was wounded severely in the leg by an enemy mortar shell. After recovering, he led his company in the capture of a British reconnoitering party, displaying courage and leadership in the process. When the war ended in the spring of 1815, he returned to Whitestown and his position as clerk in Colonel Carpenter's store.

By 1815, White was a well-educated young man of 25 with travel and leadership experience. However, he probably expected to live the routine life of a clerk in his hometown, for he could not have imagined the great opportunity that soon was to open for him on the Erie Canal. By chance, he was uniquely prepared to learn the engineer's art, and his progress was remarkable.  

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6See Canvass White's inventory of property taken from him by the British, dated February 15, 1815, Canvass White Papers.
Chapter Two
The Erie Canal Experience

In a moment of pride and patriotism, a historian of the Erie Canal once wrote that "just as Washington, Hamilton and Jefferson built a nation in a land where there were no statesmen, so Wright, Geddes and White built a great canal in a land where there were no engineers."\(^1\) The Erie is recognized as the birthplace of the American engineering profession, and as a seminal event in the history of transportation technology. Before the Erie Canal, Americans had relied on European experts, usually British or French, and a handful of self-styled proprietor engineers, who had limited success on a number of small projects. The proposed 363 mile route of the Erie Canal dwarfed the scale of any attempted to that time, and multiplied the logistical and technological problems beyond the experience of any American.\(^2\)

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The interior water route of New York State had been well-travelled since colonial times. The Hudson and Mohawk Rivers, and the neighboring lakes, provided a natural pathway to the Great Lakes that was interrupted by only a few difficult portage areas. In 1792, the Western and Northern Inland Lock Navigation Companies obtained a charter permitting them to make improvements along the Hudson and Mohawk, and to construct a short canal between the Mohawk and Lake Ontario. After passing through a series of incompetent engineers, the companies managed to employ William Weston, an experienced English engineer who had worked in both Pennsylvania and Massachusetts. Weston helped the companies to make some improvements between 1795 and 1799 while training several assistants, including Benjamin Wright. 3

Enthusiasm for the scheme subsided during the first decade of the nineteenth century, and it was not until 1810 that interest was renewed in improving the Hudson River-Great Lakes route. In that year, the New York legislature appointed a canal commission, which consisted of Stephen Van Rensselaer, DeWitt Clinton, Samuel Young, Joseph Ellicot and Myron Holley, to study the proposal and

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to have surveys and plans made. The commissioners searched for experienced engineers but settled for the limited skills of New Yorkers Benjamin Wright and James Geddes. Wright and Geddes were experienced boundary surveyors, and this qualification led them to further responsibilities. In addition, Wright had acquired a small amount of engineering experience as an assistant to Weston. During 1811, they made a series of rough surveys, known as running levels, of several routes, but failed to develop specific plans and recommendations. The canal commissioners' continuing attempts to attract an English engineer were interrupted by the War of 1812, and the project stalled.

In 1815, the commissioners renewed their search and once again turned to Weston. He declined their offer, preferring to remain in England, where there was also a demand for experienced engineers. Undaunted by their inability to attract a foreign engineer, the canal commissioners at last decided to rely totally on native talent. In a report prepared in March of 1816, they declared that there was "every reason for preferring our

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4 ASCE, Biographical Dictionary of American Civil Engineers, 125; Morison, From Know-How to Nowhere, 39; Whitford, History of the Canal System, 76.
own countrymen if the requisite scientific and practical knowledge can be found." The engineering responsibilities fell naturally to Wright and Geddes, who began the enormous task of marshalling local resources. Although they lacked technical knowledge, they managed to creatively solve problems as they came upon them, with the help of a rising corps of young assistants.

When Wright organized his first surveying crew in 1816, Canvass White secured a position and immediately demonstrated his skills. Within a short time, he became Wright's principal assistant and, by 1817, he was taking charge of the surveying parties during Wright's absence. He had a natural intelligence for engineering and was the only young assistant with any formal education in surveying, mathematics and the natural sciences. At twenty-five years of age, he began a learning experience that was to propel him into a new and challenging profession.

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5 As quoted in Calhoun, The American Civil Engineer, 26; see also Laws of the State of New York in Relation to the Erie and Champlain Canals Together With the Annual Reports of the Commissioners and Other Documents Requisite for a Complete Official History of Those Works, Vol. 1 (Albany, 1825), 117.

6 Calhoun, The American Civil Engineer, 29.
Canals in New York, 1838

The engineering responsibilities on the canal were at first divided on a geographical basis. Geddes had charge of the western division which extended from Lake Erie to the Seneca River near Montezuma. Wright had the middle section, from the Seneca River to Utica; and Charles Brodhead, another surveyor, had the eastern, from Utica to Albany. The engineers and canal commissioners agreed to work first on the middle section, since it was the shortest and the most level.

The surveys run in 1816 and 1817 were necessarily crude because of a lack of experience in engineering surveying and the poor quality of available instruments. Surveys to determine boundaries required only that a course be marked out; canal surveying required the precise determination of changes in elevation along a course. With the possible exception of Wright, none of the engineers had experience with surveying of this kind. The type of instrument used to determine elevations was more complex and sensitive than the one used to establish boundaries. The latter instrument was little more than a compass with a sighting device, which could be rotated to allow the viewer to line it up with any point. The surveyor peered through the sight in the desired direction, and chose a landmark to mark the boundary. The instrument used to determine elevations consisted of a telescope to which was
attached a sensitive leveling tube. The telescope and tube were mounted on a spindle, and held in position by a casting called the leveling head. The bubble in the tube was centered by adjusting the screws on the leveling head. When this was done, the line of sight was truly horizontal. The establishment of a true horizontal line enabled the engineer to determine the difference in elevation between any known point and any other point.

The surveying operation required a number of hands under the supervision of an engineer. First, a crew worked to clear away brush and allow the engineer an uninterrupted line of sight. An assistant with a calibrated rod was then stationed at the first known elevation, usually sea-level or the edge of a river. This first reference point was assigned a value of zero. The leveling instrument was set up at a measured distance from the rod. The distance was measured by laying chains along the ground. After properly leveling the instrument, the engineer looked through telescope. A set of crosshairs placed between the lenses of the telescope allowed him to mark a precise spot on the rod. This established what was called the height of the instrument. For example, assume that the horizontal line fell at five feet on the calibrated rod. The rod man was then sent out ahead of the instrument to a higher elevation, at precisely the same
distance as in the previous measurement. The instrument was rotated while in a fixed position, releveled, and a new reading was taken. Since the rodman was at a higher elevation, the engineer's horizontal sight fell on a lower point on the calibrated rod; assume it fell at two feet. By subtracting the second reading from the height of the instrument, it was possible to establish the elevation at which the instrument stood; in this example, three feet above the first point at the river's edge. The crew then leapfrogged across the countryside from one established elevation to another along the proposed route. When they reached the end of the section being surveyed, they started back in the same manner to check for discrepancies, mistakes or instrument error. This process was called differential leveling.\footnote{I would like to thank Dr. John O. Liebig of the Civil Engineering Department at Lehigh University for sharing with me his knowledge of early surveying practices.}

A careful survey was crucial to the canal's success, and it can be fairly said that the work of 1816 and 1817 was little more than a process of trial and error. Besides a general lack of experience, the engineers were hampered by poor instruments, which often fell out of adjustment. To their credit, they moved cautiously and deliberately,
knowing that costly mistakes would erode public support.
The first spadeful was dug on the middle section at Rome on July 4, 1817 with an auspicious ceremony. The engineers knew that many problems had to be faced, but they were confident that their knowledge would increase with the progress of their labors.

In the fall of 1817, Wright and DeWitt Clinton, who was then governor of New York, decided that it would be extremely useful to send one of the young assistants to England to gather information by interviewing engineers, visiting their completed works, and observing their on-going projects. They approached White in October of 1817 and asked him to leave soon and return before the beginning of the next working season. White was a logical choice because of his experience, increasing knowledge, education and pleasant manner. Curiously, not all the canal commissioners were convinced of the necessity of the trip, so White had to pay his own expenses. Apparently they were blind to its obvious benefits, for the excursion marked a turning point in the project's history.

On October 16, 1817, White sailed from New York on the ship Pacific, bound for Liverpool. In his pocket, he

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8 Canvass White to Hugh White (father), New York, October 17, 1817, William Pierrepont White Papers.
carried letters of introduction from Clinton which enabled him to meet some of Britain's finest engineers. After reaching England, he walked over four hundred miles on the canals of North Wales, accumulating technical and practical information. He was a keen observer who had an eye for detail as well as the ability to ask the right questions. On January 21, 1818 he wrote to his father from Liverpool recapping his experiences. He was extremely impressed with engineering achievements in Britain, particularly the great aqueduct which carried the Ellsmere Canal over the River Dee. 9 This aqueduct was over 1,000 feet long and 121 feet high. Constructed between 1795 and 1805, under the supervision of one of Britain's engineering pioneers, Thomas Telford (1757-1834), it was the most impressive work of the British canal builders. The young engineer reported that the aqueduct consisted of 19 arches of cast iron, about 46 feet in span, each supported by pillars of hewn stone 120 feet high. The waterway, towing path and railing were all of cast iron. 10

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10 Canvass White to Hugh White (father), Liverpool, January 21, 1818, Canvass White Papers.
White was inspired by the self-reliance and innovativeness of the British engineers, for these were just the qualities that were needed on the Erie Canal.

He next passed through northern England and continued his practice of making careful drawings and taking notes. By spring, he was in London waiting to embark for home with two important tasks still to be completed. White was one of the few Erie engineers who realized from the beginning that hydraulic cement would be an important ingredient in the canal's success. This cement had the desirable property of setting hard underwater, and had been known and used in Great Britain for several decades. He received samples of hydraulic cement from John Isaac Hawkins, an English engineer. These were as precious as any drawings in his possession.

Following Wright's instructions, he purchased a number of excellent surveying instruments to replace the unreliable ones used in the first surveys. These instruments proved invaluable as they greatly increased the accuracy and reliability of the engineers' work. Just

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prior to embarking, White added a model of a canal boat to his collection of notes and materials, and then felt satisfied that he had accomplished his major objectives.12

White's effort was no less than heroic for he brought the technical knowledge of two generations of English civil engineers to America. The know-how that he acquired dramatically improved the Erie's prospects. He arrived home in the spring of 1818 and immediately set to work implementing what he had learned. During the next five years, he was active along the entire length of the canal, and his stature and reputation as an engineer grew.

White was indispensable to Wright after 1818, and the two became lifelong friends and professional associates. Wright and the commissioners came to depend on White for precise survey work in difficult areas, and advice on a range of technical subjects; including the construction of locks, boat building, mechanical invention, and the planning of dams, bridges and aqueducts.

During the winter of 1818, using the chemistry he had learned at Fairfield, he began experiments with several varieties of local minerals that were similar in

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12 The surveying instruments were purchased at 20 Holburn Viaduct, London; see White, "Canvass White's Services," 365. The canal boat model is in the collection of the Buffalo and Erie Historical Society.
composition to the cement rock samples he had been given in England. The commissioners and engineers had decided to use common quicklime mortar in the canal's masonry and to face it with a layer of costly, imported hydraulic cement. White was convinced that this was a poor solution and, fortunately, his experiments had a quick and successful result. His timely discovery of natural cement rock along the line of the canal at Chittenango insured that the lock walls, bridges and aqueducts would be solid and enduring. Without hydraulic cement, the canal would have been in a constant state of disrepair, and public confidence in the work would have been lost. At first, there was a reluctance on the part of the masonry contractors to try the new cement, but by 1819 it was generally accepted. Between 1819 and 1825 over 400,000 bushels were used on the canal, and additional bushels were shipped to other states.\footnote{Laws . . . Erie and Champlain Canals, II, 216-227.}

At the beginning of the 1819 working season, White was singled out for special duties. He had moved to the head of the class of young engineering assistants, which included Nathan S. Roberts, David Thomas, Holmes Hutchinson, John Jervis, William Jerome and David S. Bates. All eventually achieved the rank of principal
engineer on the Erie Canal and went on to have distinguished careers. The commissioners first sent White to "run a test line throughout the long summit in order to correct some errors into which the work was falling between Rome and Utica." This was a significant trust because the success of the summit on the middle section was crucial to the commissioners' efforts to lobby for appropriations to begin the eastern and western divisions. The middle section was the proving ground for the whole project. White was well aware of the tentative nature of legislative support, especially on the part of the downstate representatives, since he boarded with several of them at a rooming house in Albany. He felt that favorable legislation would pass in 1819 if he was "not deceived by appearances and conversation." He carried

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14 For information on the training and subsequent careers of these engineers, see Alvin Harlow, Old Towpaths (New York, 1926), 295-307; and John A. Krout, "New York's Early Engineers," in New York History (July, 1945), 269-77. For a discussion on the progress of assistant engineers, see Calhoun, The American Civil Engineer, 27-30; and Morison, From Know-How to Nowhere, 37-46.

15 Laws ... Erie and Champlain Canals, I, 407.


17 Canvass White to Hugh White (father), Albany, January 27, 1819, Canvass White Papers.
his survey of the summit through Utica and explored possible routes for the beginning of the eastern section.

As soon as this was completed, the commissioners dispatched him to the western division to check the levels run by James Geddes in 1816. On July 3, he began his survey at the Seneca River, moved westward, travelled sixty miles in about fifteen days, and then carefully retraced his steps. He recommended a route that was several miles further south than the one surveyed by Geddes. 18 He was anxious for the commissioners to recognize the value of his services. "I have done a great deal of work this last month which I hope the commissioners will be satisfied with," he wrote to his father. 19 The commissioners chose the route originally proposed by Geddes, who was, after all, one of their senior engineers, but took the time to cite White for his work:

Canvass White, Esq., an engineer, has had the charge of a party which has been engaged for several months in leveling over and surveying different routes for the canal line. These labors he has performed much to our satisfaction. 20

18 Canvass White to Hugh White (father), Rush, near the Genesee River, August 3, 1819, Canvass White Papers.
19 Ibid.
By 1821, White had a voice in major engineering decisions. He was assigned to survey the difficult eastern section, which dropped sharply between Utica and Troy, and he quickly superseded Charles Brodhead as principal engineer for that division. Again, his valuable work did not escape the attention of the canal commissioners, who noted in their report of 1821 that the

... important services pertaining to the engineer's department on the eastern section have, for the last seasons, chiefly devolved upon Canvass White, Esquire; whose usefulness from the beginning has been constantly increasing with the progress of our labors by his continuing assiduity and increasing knowledge.  

The eastern division was the most challenging because the canal followed the twisting course of the Mohawk River from Little Falls, below Utica, to Albany. Crowding hills, narrow gorges and steep declines made it difficult to locate the route of the canal. White, with assistance and support from Benjamin Wright, made several bold proposals to the commissioners concerning the line and features of the eastern section. In 1821, they told the commissioners that, in their opinion, the high ground south of the Mohawk River could not be crossed. They

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21 Ibid., II, 18.
22 Shaw, Erie Water West, 134.
recommended that the canal follow the Mohawk River eastward to Cohoes Falls, near Troy, and then proceed along the Hudson River to Albany. When this plan was adopted, White laid out the entire section and prepared plans for the excavation of the difficult areas.

By 1822 White was a master at the complex and costly job of designing and constructing locks. Along the precipitous eastern division, he designed several series of locks that were praiseworthy. In their report of 1822, the canal commissioners commended his work at Little Falls and noted that he had:

\[\text{. . . by a judicious distribution of his locks, dropped his levels on land giving suitable depth of cutting and requiring little embankment, and thereby avoided damage by the annual floods of the Mohawk.}\]

He also designed an impressive series of sixteen locks at the Cohoes Falls, near the junction of the Mohawk and Hudson Rivers, where the canal dropped 132 feet in the

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24 As quoted in Henry Wayland Hill, A Historical Review of Waterway and Canal Construction in New York State (Buffalo, 1908), 143.
space of 12 miles. There were 27 locks in the thirty miles between Schenectady and Albany; nearly a third of the canal's total.

There were other complications that required great engineering skill on the eastern section. These were solved by the construction of aqueducts that White designed based on his English experience. The first was built at Little Falls to carry a navigable feeder from the north bank to the canal on the south. This aqueduct fed water from the Mohawk to the canal and connected the town of Little Falls on the north bank, with the main line. The second aqueduct was built at Niskayuna, four miles below Schenectady, where the south bank became impassable because of high ground composed of solid rock. Between Niskayuna and the Hudson River, the Mohawk passed through a rocky gorge making it extremely difficult to locate a feasible canal line. In 1821, Benjamin Wright proposed tunneling through the rock. This idea was rejected because of a complete lack of experience in tunnel building and

25 Canvass White to Michael Hoffman (canal commissioner), Princeton, November 18, 1833, Canvass White Papers; see also George Armroyd, A Connected View of the Whole Internal Navigation of the United States (Philadelphia, 1830), 60.

26 Shaw, Erie Water West, 135.
the fear that it would take many years to complete.\textsuperscript{27}

While surveying on the eastern section in 1821, White perceived a solution and recommended that two aqueducts be built to carry the canal around the difficult areas on the south bank of the Mohawk.\textsuperscript{28} His plan was adopted although many thought that it too would add years to the work. The scale of these aqueducts was equal to any in Great Britain, and they were completed in a remarkably short time. The upper aqueduct at Niskayuna was 748 feet long, supported by 16 piers, 25 feet above the river's surface. After crossing, the canal proceeded along the north bank for 12 miles and then re-crossed the river above the Cohoes Falls. The lower aqueduct was 1188 feet long, with twenty-six masonry piers, and has to be regarded as one of the engineering wonders on the canal.\textsuperscript{29} The aqueducts were a bold and innovative solution to a complex set of problems. In all his work on the eastern division, White exhibited those qualities of self-assurance and innovative leadership that would distinguish him during his subsequent career.

\textsuperscript{27}Ibid., 134.

\textsuperscript{28}Laws . . . Erie and Champlain Canals II, 73,74.

\textsuperscript{29}Armroyd, A Connected View, 60.
As White increased in rank and ability, he came into conflict with James Geddes, whom he began to regard as incompetent. During 1819, he had re-surveyed Geddes' work on the western division, recommending changes in location that were not adopted. In the winter of 1822, he was sent to examine the summit level of the Champlain Canal, a branch of the Erie Canal laid out by Geddes, which extended the navigation further up the Hudson River. Geddes' plan for the Champlain Canal was unscientific, almost to the point of being humorous. He built it with many curves to prevent the wakes of heavy boats from washing out the banks. The force of each wave was to be broken against a curved bank of the canal. The result was a snake-like course which impeded the progress of boats.\(^\text{30}\) The meandering canal required additional water, creating a chronic shortage at the summit level. White, Benjamin Wright, Nathan Roberts, David Thomas and Geddes held a meeting in February of 1822 and decided that the only way to increase the water available for the summit was to build a navigable feeder from the Hudson River above Glen's Falls to the Champlain's summit, two miles above Fort Edward. White thought this to be an unnecessary expense and felt that Geddes had been "very much to blame

\(^{30}\text{Harlow, Old Towpaths, 300.}\)
in his management as an engineer."  

As his own knowledge grew, he lost confidence in Geddes, and felt a rising sense of personal ambition. He confided to his father that he hoped Geddes would step aside, but added that "he will not stand in my way any longer." In the spring of 1822, the canal commissioners sent White to lay out the Glen's Falls feeder. The seven mile long feeder served the double purpose of supplying the summit with water, and opening navigation to a higher point on the Hudson River. The sturdy feeder saved the Champlain Canal, and Geddes' reputation.

In the early 1820s, White's talents became known to promoters of public works in other states, and he began to receive offers to examine plans and proposals away from the Erie Canal. While at work on the Champlain Canal's problems in the winter of 1822, he agreed to act as technical advisor to a committee of the Manhattan Common Council investigating the city's inadequate water

32 Ibid.
33 Laws . . . Erie and Champlain Canals, II 112.
supply.\textsuperscript{34} Although he lacked specific experience, his knowledge of hydraulic engineering was invaluable to the committee, since there was still a great scarcity of engineering talent. In the same year, the State of Ohio offered Whites the position of chief engineer for the state's intended works. He declined the offer, preferring to remain on the increasingly prestigious Erie Canal.\textsuperscript{35}

But, beginning in 1823, he found it more difficult to turn away from the many employments offered him, and he initiated a career pattern of accepting a number of simultaneous consulting roles and major appointments.

In the summer of 1823, the chief engineer of the Schuylkill Navigation Company in Pennsylvania, Thomas Oakes, died very suddenly and White was offered the position. He promptly visited the company's works and made a number of suggestions. Rather than becoming involved with the time consuming chores of being on the site, he recommended that the company employ Ephraim Beach,

\textsuperscript{34}Minutes of the Manhattan Common Council 1784-1831 XII, 309-311; as quoted in I.N. Phelps Stokes, The Iconography of Manhatten Island 1498-1909 Vol. 5 (New York, 1928), 1622.

\textsuperscript{35}Canvass White to Hugh White (father), Albany, February 22, 1822, Canvass White Papers.
one of his associates from the Erie Canal, as chief
engineer, and retain him as consultant.\textsuperscript{36}

That same summer, he served as advisor to Samuel
Mifflin, president of the Union Canal Company of
Pennsylvania. Mifflin and his chief engineer, Laommi
Baldwin, were in conflict on a number of issues, and White
was called in to present an unbiased, experienced opinion.
He sided with Mifflin, prompting Baldwin to resign, and
accepted the appointment as chief engineer for the company
in the late fall of 1823. His actions as a consultant
marked him as unique among this country's early engineers,
since the number of men who worked as consultants was a
small fraction of even those who became chief engineers.\textsuperscript{37}

After 1823, the pace of White's activities accelerated as
he received a steady stream of requests for his services.

White's last efforts on the Erie Canal were related
to the completion of the Glen's Falls feeder, and the
issue of the location of the western terminus of the
canal. Black Rock, on the Niagara River, and Buffalo,
situated at the mouth of Buffalo Creek on Lake Erie, were
rivals for the economic benefits to be reaped by occupying

\textsuperscript{36} Canvass White to Hugh White (brother), Reading,
Pa., August 23, 1823, Canvass White Papers.

\textsuperscript{37} Calhoun, \textit{The American Civil Engineer}, 81.
this strategic position. The villages were only two miles apart, but their advantages and liabilities were quite distinct. A great deal of political jockeying went on between the competing factions, but somehow the canal commissioners had the good sense to rely on the judgement of their senior engineers. The engineers had to consider which site would make the best harbor, and which was the better source of water for the western section. In February of 1822, four of the five leading engineers, Benjamin Wright, David Thomas, Nathan Roberts and White, gave an unanimous opinion that the canal should terminate at Buffalo Creek. Geddes alone dissented, allegedly because of ties to Black Rock interests; but his reputation, and the weight of his opinion, had diminished when the canal commissioners censured his work on the Champlain Canal in their annual report of 1822. The commissioners accepted the majority engineers' report and Buffalo became the western port of entry.

White was a leading figure in the great engineering seminar that took place on the Erie Canal. He rose through the ranks like other young engineers, but his progress was

38 Shaw, Erie Water West, 149; see also Laws. . . Erie and Champlain Canals, II, 519.

39 For a complete discussion of the western terminus issue, see Shaw, Erie Water West, 140-163.
marked by a series of brilliant achievements, the technological knowledge that he brought from England was crucial to the Erie's success. He passed quickly from the role of competent assistant to capable leader, and advanced to the head of a newly forming profession. The engineering knowledge and experience that he gained became extremely valuable in an age when there were few engineering texts and no professional schools. Anxious to increase his reputation and his wealth, he maintained an incredible pace for the next several years. Expressing a desire to capitalize on opportunities, he confided to his father that there were, "a great number of canal projects afoot," and that he intended, "to reap some benefits from them while the harvest's ripe." 40

In 1817 the engineers on the Erie Canal faced the problem of obtaining a suitable mortar for the line's hydraulic features. The engineers were led by Benjamin Wright, who was particularly aware of the inadequacy of common lime mortar when used on stonework that was exposed to water.¹ He recommended that hydraulic cement be imported from England, where it had been in use for several decades. The imported cement would be so costly that the engineers proposed merely facing the masonry with it, while laying the stone in common lime mortar.² Such an action, they felt, would greatly add to the stability of the canal.

Hydraulic cement set hard whether exposed to air or water, and it was a key ingredient in the success of the

¹Report of the Joint Committee on Canals and Internal Improvements, on the Petition of Timothy Brown, in Assembly, No. 114, February 11, 1825, Canvass White Papers.

²Ibid.
British canal builders. Cement technology developed in Great Britain in the middle of the eighteenth century with the emergence of the first generation of British civil engineers. Before that time, England satisfied its limited needs for hydraulic cement by importing varieties made in Italy or Holland.

Hydraulic cement was known and used by the Romans in their many engineering projects, especially in the construction of bridges and aqueducts. In the first century A.D., the Roman architect Vitruvius prepared an excellent cement from pozzolana, a light, friable rock, reddish in color, derived from volcanic ash found near the town of Possuoli, at the foot of Besuvius. The rock was pounded and sifted until it had the consistency of a coarse powder. It was then mixed and ground with common limestone and an equal measure of clean sand; water was added to make a paste just before applying. This formula was used with great success for many centuries.

The Dutch, with their long experience in constructing hydraulic works, also developed a waterproof cement derived from a volcanic rock: cellular basalt. This mineral was found near Bockenheim and Frankfort-on:Main in

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3Richard Shelton Kirby and Phillyss Gustave Laurson, *The Early Years of Modern Civil Engineering* (New Haven, 1932), 261.
The Rhine Valley, and brought down the river to Holland. Known as trass, or terras, it was a variety of pozolanic cement. By the late seventeenth century, England was importing a considerable amount of trass from Holland for use in the construction of docks and piers. 4

During the eighteenth century, England began a period of canal building and other internal improvements that greatly increased its demand for hydraulic cement. Volcanic rock was not present in Great Britain, so English engineers experimented with varieties of native limestone rock. The first English civil engineers, like the Americans, were self-taught and lacked formal education in the sciences. One of these engineers, John Smeaton (1724-1792), began a search for local waterproof cement rock in 1756, while supervising the construction of the Eddystone Lighthouse on a dangerous reef off southeastern Cornwall in the English Channel. Smeaton wished to avoid the expense and trouble of importing trass, and he turned naturally to limestone because its general properties as a mortar were well-known to stonemasons. He experimented with a number of limestone aggregates and achieved a partial success when he prepared a mortar from a clayey

4 There is some information on the use of cement in Europe in notes written by White. Unfortunately, the note pages are not dated. Canvass White Papers.
limestone found near Aberthaw on the Bristol Channel. Aberthaw lime eventually became a widely used waterproof cement, but Smeaton was not confident enough to rely on it entirely. He settled for a halfway measure and blended two parts Aberthaw lime, three parts sand, and one part of the reliable trass with apparent success.

The increasing demand for hydraulic cement in England during the second half of the eighteenth century led to further experiments. On June 28, 1796, James Parker was granted a patent for a preparation he called Roman cement. Parker's cement was made from another variety of clayey, or argillaceous, limestone found on the Isle of Sheppy in the estuary of the Thames River. It occurred in pebbles or nodules which came to be called sheppystone. Parker broke the pebbles into fragments and then burned them in a kiln or furnace with enough heat to calcine them. The regulation of the temperature was important, for if too much heat was applied, the nodules fused into a slag and were worthless. The calcined nodules were ground into a coarse powder and mixed with an equal measure of clean sand. A mortar made from two parts water and five parts dry mixture set hard underwater in twenty minutes. Known commonly as Parker's Patent Cement, it was used extensively throughout Great Britain, and became so familiar that its specifications were published in May of
1811 in London's Repertory of Arts series.  

When Benjamin Wright and DeWitt Clinton dispatched Canvass White to England in the fall of 1817, they instructed him to learn about waterproof cements used by that country's engineers. White's introduction to mineralogy and geology at Fairfield Academy proved useful during his examination of cement rock deposits in England and, subsequently, in America. He examined a number of quarries while abroad, talked to engineers and stonemasons, and witnessed the preparation of the cement from natural rock. In addition, he obtained samples of Parker's cement from John Isaac Hawkins, a prominent British engineer who had spent some time in America, before sailing home from London in the spring of 1818.

Realizing the urgency of the problem, White began to search for local deposits of cement rock immediately upon his return. He made a detailed analysis of Parker's cement and noted its composition and general characteristics. Wright was very interested in these experiments and he invited Andrew Bartow, an agent of the canal commissioners.

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6 Ibid.
with some scientific training, to assist in the examination of several stone quarries then operating in Onondaga County. Bartow became intrigued with the cement problem. After making several independent experiments with local limestones, he achieved some measure of success. A nineteenth century historian of Onondaga County gave this account of a demonstration by Bartow:

Bartow took some of the rough stone that he had found and recognized as natural cement rock, to the trip hammer shop of John B. Yates at Chittenango. There he reduced it to a coarse powder, and in the nearby taproom of Elisa Carey, in the presence of Canvass White and Benjamin Wright, he mixed the powder with sand, rolled a ball of it and placed it in a bucket of water. In the morning it had set and was solid enough to roll across the floor.

Bartow claimed this cement to be the equal of Parker's and trass. For unknown reasons, Bartow's results were considered inconclusive, for the same historian who gave the account of the taproom demonstration asserted that White continued his search of stone quarries and his experiments. John B. Jervis, a young engineer on the Erie Canal who was to have a distinguished engineering career, recollected that White conducted a vigorous search and

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8 Ibid., 66.
performed a number of experiments in the summer of 1818; all at his own expense. While there is no reason to doubt Bartow's claim that he was the first to demonstrate the presence of natural cement rock in New York State, the fact that White continued his experiments suggests that he probably searched for a more suitable variety of limestone. Also, he needed to find a reliable method to calcine large quantities of the natural stone, and the means to manufacture a consistently good mixture.

The quarry searches in the summer of 1818 resulted in the discovery of several cement rock deposits in Onondaga County. White's analysis of the stones revealed that their important characteristics were the presence of clay and oxide of iron in the limestone formation. Cement rock proved to be in abundant supply, and was even encountered during excavation of the canal channel between Rome and Syracuse. Modern geologists have estimated that natural cement rock and other limestones occur in a ten mile wide band, at varying depths, across New York, from Buffalo to Port Jervis. White had no trouble locating several varieties with which to experiment.


10 A.A. Bartow to the Honorable Canal Commissioners (undated manuscript), M.S. 1-2, A.A. Bartow Papers.
He finally selected a variety of indurated rock that he classified as argillo-feruginous limestone, and devised a way to manufacture it with consistent quality. The rock was calcined by placing it in a kiln with alternating layers of wood, or on an iron grate with wood underneath. As with Parker's cement, it was important to control the heat so that the stone did not fuse into a slag. An equal amount of clean sand was added to complete the dry mixture.

White recognized the value of Bartow's work and the two struck an agreement in the fall of 1818 to patent waterproof cement. The proportion of Bartow's contribution was reflected in his willingness to accept only one quarter interest in the patent. White drafted the patent which included a detailed, scientific analysis of the components of argillo-feruginous limestone, and its specific gravity. He made the bold claim that his patent extended to all minerals from which waterproof cement was manufactured. The patent was issued on February 1, 1820; and amended on February 17, 1821.12

11 Canvass White to A.A. Bartow, New York, April 16, 1823, A.A. Bartow Papers.

Owing to skepticism, especially among the masonry contractors, common quicklime mortar was used on the canal at the beginning of the 1819 working season. White's waterproof cement was slowly introduced along the line, but quickly gained acceptance when its superiority was demonstrated. Fortunately, there were ready facilities for manufacturing cement near the site where natural cement rock was discovered. The first batches were prepared during fall and winter of 1818-1819 in Sullivan, Madison County, at the gypsum grinding mill of John B. Yates. Yates had recently constructed the mill at the falls of the Chittenango Creek to grind gypsum, which was used to make plaster and fertilizer, and was itself only recently discovered. White directed the operation by choosing the stone and by supervising its proper calcination.¹³

From the very beginning, White found it difficult to enforce his patent. Natural cement rock existed in abundance and experienced masonry contractors all along the line were able to prepare an acceptable waterproof cement from local deposits. This was alright in itself, but when contractors charged the state for services and material, they were encouraged by the canal commissioners

¹³Harley J. McKee, "Canvass White and Natural Cement, 1818-1834," in Concrete International (June, 1979), 41.
to ignore the cement patent, and omit the four cents per bushel owed to the patentee. In their annual report of 1820, the commissioners seemingly took credit for the discovery, claiming that the cement had been discovered in the progress of their own exertions. A legislative committee later concluded that "... the manner in which they announced the discovery was well calculated to lull contractors into a belief that the discovery was common property."  

White was extremely disappointed by the canal commissioners' action for he hoped to earn a personal fortune from this discovery. Over five hundred thousand bushels of the cement were used on the canal without regard for the patent. Since triple damages were awarded by law for patent violation, White was entitled to approximately sixty thousand dollars. His only recourse was to sue every contractor and test his patent in the courts. In the spring of 1823, he brought suit against one of the contractors, Timothy Brown, in United States District Court, Northern District. The opinion of the canal commissioners was either presented nor solicited,

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14 Report of the Committee on Canals and Internal Improvements, In Assembly, No. 196, April 2, 1824, Canvass White Papers.
15 Ibid.
so the court focused on the validity of White's claim to have discovered a new material. The defense argued that White could not patent a mineral, especially one that was well-known and abundant. Judge Skinner agreed with this. However, he concluded that the patent was not granted for the discovery of the mineral, but for the discovery of its useful properties and the art of exploiting them. He ruled that the making of waterproof cement was an art; that the cement, when made, was a manufacture; and that it was a composition of rock, sand and water prepared in a particular way. The judge referred to the analogous situation with drug and medicine patents, which are not issued for materials, but only for the manner of combining them. A jury subsequently awarded White seventeen hundred dollars in damages.16

The court's decision greatly alarmed the contractors. Led by Brown, they petitioned the legislature for relief, claiming the canal commissioners, acting as agents of the state, had informed them that the patent was unenforceable. They had supplied the cement in good faith without allowing the four cents per bushel due to the patentee. Further, the recent decision of the court threatened them with financial ruin. In February of 1824,

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16 Ibid.
the Committee on Canals and Internal Improvements in the Assembly requested a report from the canal commissioners, and a declaration whether they had made any agreements to protect contractors from White's patent. A.C. Flagg, chairman of the Canal Committee, also asked Benjamin Wright to respond to a list of questions concerning the cement. On March 8, 1824, Wright answered and stated that White's cement was used in 1819 despite a great deal of reluctance on the part of the canal commissioners. They had made no provision for the importation of hydraulic cement despite his written recommendations in 1818 and, again, in early 1819. Wright also informed the committee that the commissioners did not give White, or any other individuals, directions to search for hydraulic cement. Wright's testimony indicated that the commissioners had been very negligent in this regard. He made it clear that hydraulic cement was crucial to the stability of the canal, and that White's discovery had been of incalculable benefit to the state.\textsuperscript{17}

\textsuperscript{17}Ibid.

The canal commissioners submitted their report on March 18, 1824, still committed to the idea that the patent was not sustainable. They claimed, however, that no understanding existed between them and the individuals who

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supplied waterproof cement. The commissioners argued that if an understanding had existed, they would have aided Brown in his defense. If such had been the case, they declared, "... the result of said suit would have been very different."\(^{18}\)

Samuel Young wrote the commissioners report in which he asserted that White's patent violated the principles of United States' patent law. He informed the committee that the patent law enacted in February of 1793 provided that patents may be issued for "any new or useful art, machine, manufacture, or composition of matter not known or used before."\(^{19}\) And, by amendment in April of 1800, it further stipulated that every person applying for a patent must make an oath that the discovery has not been used or known before in this or any foreign country. Young told the canal committee that waterproof cements made from varieties of limestone had been known and used in Europe for years. He pointed out that several European texts on mineralogy contained detailed descriptions of argillaceous limestone and its properties. Although varieties of this limestone were known in these texts by several names,

\(^{18}\)Ibid.

Young claimed that their descriptions applied so perfectly to cement rock found in New York that "... had the authors of those treaties had specimens of our water-lime before them, their delineations could not have been more correct." 20

Young quoted from two texts to substantiate his charges. He chose a passage from Philip's Mineralogy, published in London in 1796, that described the mineral in language remarkably similar to that used by White in his patent. This text also contained a reference to its use as a waterproof cement. 21

In an attempt to prove that this information was also available in the United States, Young cited the first comprehensive text on mineralogy published in America: Parker Cleaveland's, Elementary Treatise on Mineralogy and Geology. 22 Cleaveland, a professor of mathematics and lecturer on mineralogy and geology at Bowdoin College, introduced European systems of classification in the geological sciences to America, and tried to shed some light on the location of native formations. Young

20 Ibid.
21 Ibid.
22 Parker Cleaveland, Elementary Treatise on Mineralogy and Geology (Boston, 1822), 187.
carelessly cited the second edition of Cleaveland's book, which did contain a description of argillaceous limestone and its use as a waterproof cement, but was published in 1822, two years after the patent was granted. Had he been more astute, he could have cited the first edition, published in 1816, which also contained a reference to this mineral and its use as a waterproof cement, as well as information on how to calcine the stone and prepare the mortar.  

Young's poor research probably went unnoticed. He presented a strong argument against White, and insisted that the natural cement rock found in New York was identical to that known and used in England. According to the laws of the United States, he argued, the patent was void.  

The Committee on Canals and Internal Improvements in the Assembly responded to the opinions of the canal commissioners by informing them that the matter had already been decided in court. A.C. Flagg, chairman of the committee, lamented the fact that the commissioners had

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23 Parker Cleaveland, Elementary Treatise on Mineralogy and Geology (Boston, 1816), 160-61.

not presented their opinions in defense of Brown in court. Flagg realized that not all the canal commissioners were in agreement with Young. His own conclusion was that White deserved credit for introducing the cement, which was of unquestioned value to the state.25

Additional support came from DeWitt Clinton who wrote to Flagg on March 30, 1824 stating that, in his opinion, the mineral used by White was different from any used in England. He also reminded Flagg of White's many services to the state, including the valuable trip he made to England at his own expense.26

The Committee on Canals and Internal Improvements remained faced with finding a practical solution that rewarded White, and saved the contractors from ruin. Flagg felt that the canal commissioners had mislead the contractors when they claimed in their annual report of 1820 that hydraulic cement had been discovered in the progress of their own exertions. "The contractors," he said, "had much reason to infer that they would not


26 Ibid.
subject themselves to damage by furnishing this cement." 27 He asked the legislature to compensate White for cement already used on the canal, in order to quiet his claims against the honest and industrious contractors. 28

Throughout the litigation, White realized that his chances for receiving quick remuneration were diminishing. On April 16, 1823, he wrote to Bartow lamenting the decreasing value of the patent because of "... the number of persons who had been engaged in manufacturing cement for the commissioners, also the number that owned land on which the cement is found." 29 He further told Bartow that he was considerably in debt, his health was poor, and his spirits low. White had reason to believe that Brown intended to carry his appeal to the United States Supreme Court, and he realized that he could not expect to receive any payments until the long court battle was over. 30 In addition, he would have to raise legal

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27 Report of the Canal Commissioners on the Petition of Brown, Beecher and Others, In Assembly, No. 168, march 18, 1824 (Flagg's opinions are appended), Canvass White papers.

28 Ibid.

29 Canvass White to A.A. Bartow, New York, April 16, 1823, A.A. Bartow Papers.

30 Canvass White to A.A. Bartow, New York July 12, 1823, A.A. Bartow Papers.
fees, and devote personal attention to the suit at a time when his schedule was becoming increasingly hectic.

The Joint Committee on Canals and Internal Improvements in the New York Assembly received Flagg's report, and agreed that the contractors should be indemnified, and White rewarded. On February 11, 1825, the joint committee issued its own report after reaching an agreement with White. 31 White accepted $10,000 in return for dropping his actions against the contractors on the Erie Canal. This was only one-sixth the amount he could have received had he successfully prosecuted each contractor. Further, he agreed to abandon his patent claim in the state of New York. 32

White was probably compelled to accept this poor bargain because he needed cash. By 1825, he was active as both an entrepreneur and an engineer, and there were obvious advantages to having money in hand. In addition, he became doubtful of the eventual success of his effort given "... the strong public prejudice against patents,

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32 Ibid.
and the glorious uncertainty of the law."\textsuperscript{33}

On January 20, 1827, he resubmitted the patent, only half convinced that it could somehow be enforced in other states.\textsuperscript{34} This act was practically futile, since knowledge of hydraulic cement spread throughout the states almost as quickly as it had along the Erie Canal. Deposits of natural cement rock were discovered near internal improvement projects in many localities. During the late 1820s, White became so involved in his engineering activities that he simply abandoned what seemed a time consuming and profitless effort.

Unfortunately, the action of the New York Assembly was more of a mediation than a decision. White's patent was sustained by a lower court that did not hear the strong argument presented by the canal commissioners. It is possible that White accepted the state's offer because he feared a reversal and an entire loss in a higher court.

Without the full argument being presented in court, it is difficult to establish the validity of White's patent. Did he discover the properties of a uniquely American mineral, or did he bring a European discovery to

\textsuperscript{33} Canvass White to Hugh White (brother), New York, December 10, 1825, Canvass White Papers.

\textsuperscript{34} Copy of a Specification submitted to the patent Office January 20, 1827, in White's own hand, Canvass White Papers.

53
America? Although his cement was similar to varieties used in England, it was not necessarily identical. From a strictly legal point of view, this was the crux of the issue. However, it cannot be denied that his discovery was based on technical knowledge that he had gained while in England.

The technology of hydraulic cement was extremely important to the success of this country's first major public works projects. White certainly deserved credit for his hard work and timely success. Unfortunately, he made a discovery that was easily repeated using a variety of similar aggregates. This, the action of the canal commissioners, and the popular prejudice against patents combined to deny him the reward he deserved for his remarkable accomplishment.
Chapter Four

New York City's Water Supply Problem

In the early 1820s, the reputations of the Erie Canal engineers began to grow. There was still a tremendous shortage of engineers, but no shortage of plans and schemes. Early in 1822, Canvass White agreed to act as consultant to a committee of the New York Common Council, which sought a solution to the city's long standing water supply problem. As he was to discover, the city's problem was not confined to a lack of technical know-how.¹

By 1798, recurring epidemics of yellow fever and extensive damage by fires had convinced many that water available on the island was contaminated and insufficient for a growing population. On July 2, 1798, Dr. Joseph Browne, an astute physician, recommended a plan to the Common Council for taking water from the Bronx River in Westchester County. He correctly reasoned that clean water was essential to limiting the devastation of seasonal epidemics.

epidemics. His plan was to bring water from the Bronx to the Harlem River by enlarging natural streams and constructing a short, open canal. Cast iron pipes would convey the water over the Harlem to distributing reservoirs on Manhattan. Browne recommended that the work be done by a private company chartered for the purpose, and estimated the expense at $200,000.²

The Common Council approved of the plan, but decided that a more experienced opinion was needed. They immediately hired William Weston, the English engineer who had worked in northern New York, to examine the ground and review Browne's proposal. On March 11, 1799, Weston told the Council that in his opinion the Browne plan would work. The Council then submitted a bill to the Legislature seeking the authority and powers necessary to construct a municipally owned waterworks.³ It was at this point that unscrupulous politicians cast a dark shadow over the health of the city's inhabitants.

On March 30, 1799, the Legislature passed an act which put the water supply responsibilities in the hands of a private corporation. Aaron Burr and the Republican

³Ibid., 20.
faction in New York directed this new company, but they had selfish motives rather than the public welfare in mind. Their real interest was to create a bank, since they were denied financial opportunities by the local banks, which were then controlled by the rival Federalists. Their purpose was accomplished by the clever phrasing of a clause in the company's charter that allowed the directors to use any surplus capital raised in any manner that was not unlawful. The Manhattan Company, later known as the Manhattan Bank, had little interest in extensive plans to furnish water, and from the first considered that responsibility to be a nuisance. 4

The act of incorporation gave the Manhattan Company the powers it needed to carry out the Browne proposal; and it was clear that the Common Council, and the city's inhabitants, expected it to do so. At the least, all anticipated some improvement and great expectations arose when the company set to work almost immediately. However, the company's plans were limited. In the summer of 1799, they sank a large well, twenty-five feet in diameter, at the corner of Reade and Center Streets, and pumped water into a newly constructed reservoir on Chambers Street. Soon after, the company laid six miles of wooden mains

which enabled it to supply water to about four hundred families. After this initial burst of activity, it became obvious that the company was only interested in performing the minimal services necessary to maintain its charter. By 1808, it had laid twenty miles of bored-wooden mains and was furnishing some two thousand customers with water. This satisfied only a small portion of the demand and most New Yorkers continued to depend on nearby wells. To make matters worse, the company's water was poor in quality, and there were frequent service interruptions.\(^5\)

The powerful position of the Manhattan Company was not seriously challenged for almost twenty years, despite its poor record and a dramatic worsening of the water problem. Between 1800 and 1820, the city's population increased from 60,489 to 123,706, and its suffering increased proportionally.\(^6\) The Common Council, with a lamentable lack of leadership, managed only weak attempts to improve the situation.

In 1818, in contrast to the paralysis in New York, Philadelphia initiated construction of its Fairmount Park dam and waterworks on the Schuylkill River. In 1819, they

\(^5\)Ibid., 22.

began laying a system of iron distributing pipes that would eventually carry water to all parts of the city. The Manhattan Company, however, opposed the formation of the type of city-owned corporation that was successfully bringing fresh water to Philadelphia.

In 1819 the Common Council was stirred to action by public outcries against the Manhattan Company. In August, a water committee led by Robert Macomb presented a plan for supplying the city with water from the Rye ponds in Westchester County. These ponds were the source of the Bronx River, and Macomb's plan was similar to the one proposed by Browne and Weston twenty years earlier. The Council gave Macomb approval to carry out his plan, but nothing further was done.\(^7\)

Devastating fires and bad tasting water continually reminded New Yorkers that a serious problem existed. On December 24, 1821 the Council appointed a new water committee led by the city's new mayor, Stephen Allen. The committee considered Macomb's plan, but realized that it was unqualified to make a practical judgement. In March of 1822, the committee asked Canvass White to join them in an examination of the Rye Ponds and the Bronx River. White's

\(^7\)Ibid.
contributions to the Erie Canal served as evidence of his engineering abilities, and the committee was delighted to have the service of an American expert.

On April 1, 1822, the water committee reported the results of their examination to the Council. The ponds were ideally situated in an elevated position thirty miles from the city. White's measurements determined that the ponds discharged 1,000,000 gallons into the Bronx River every twenty four hours. The young engineer was convinced that they would be an excellent source. Since the committee considered itself incompetent to carry the matter further, it recommended that White be retained to conduct a careful survey, and to prepare plans and estimates. The Council agreed and appropriated $500 for White's salary.

Because of his responsibilities on the Erie Canal and his inexperience with water supply systems, White made no progress during 1822. On November 25, 1822, the water committee told the Council that they daily expected White to commence his survey. With the scarcity of engineering

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10 Stokes, Iconography, 1626.
talent, they had little choice except to wait.

In February of 1823, a group of promoters presented a radically new plan to the Common Council. They proposed to build a canal from Sharon, Connecticut to the city for the double purpose of water supply and transportation. The Council approved the plan with the feeling that competition was healthy, and the notion that any progress would be welcome. The Legislature granted the promoters a charter in spite of the opposition of the Manhattan Company. The city was reluctant to invest municipal funds in the project, however, because the Council was not completely convinced that the plan was feasible. The New York and Sharon Canal Company found it difficult to engage an engineer to confirm the practicality of the plan and prepare reliable estimates. Lack of engineering assistance and poor administration accounted for the company's weak performance. Although it accomplished nothing, the company became a complicating factor in the city's continuing water problem.11

In January of 1824, White made his long delayed report to the water committee of the Council. The delay can be attributed to White's inexperience with the many

aspects of a water supply system and his desire to be thorough. He reiterated his belief that the Rye ponds and the Bronx River could fully meet the city's needs. Philadelphia's experience had shown that a daily supply of 27 gallons per capita was ample. This amount included water used for street sprinkling and manufacturing. White calculated that a minimum, daily supply of 3,000,000 gallons was available from the Bronx alone; and that this could be increased to 6,600,000 gallons if storage reservoirs were built. The reservoirs could be easily formed by damming the outlet of the two Rye ponds. An additional supply could be obtained by diverting the Byram, Sawmill and lesser rivers in the vicinity into the reservoirs. Short canals or tunnels could be built for this purpose. White examined the high ground that separated the Croton River from the Bronx River and concluded that it would be impractical to bring the Croton into the reservoir system. In his opinion, water from the Croton would have to be brought to the city by an aqueduct built along the Hudson River.\footnote{Edward Wegmann, The Water Supply of the City of New York 1685-1895 (New York, 1896), 14.}

The preparation of accurate and reliable estimates was one of the most important tasks of the engineer. The
members of the water committee were as anxious to know the plan's cost as they were its feasibility. White presented four variations of the same scheme with accompanying estimates. Plans 1 and 2 called for a dam across the Bronx River, and a canal from the dam to the Harlem River. The canal would terminate at a reservoir to be built on the north bank of the Harlem River at Macomb's Dam, near the termination of present day Seventh Avenue. Water from the reservoir was to be pumped to a receiving reservoir on city. The difference between plans 1 and 2 was the location of the canal from the Bronx River to the Harlem River, and the height to which the water had to be pumped to feed the reservoir on Manhattan. Plan 1 was estimated to cost $953,011.95; and plan 2, $921,711.13

Plan 3 and 4 were more ambitious and more ingenious. White proposed a gravity supply system that completely avoided any mechanical pumping. A dam across the Bronx River near the Westchester Cotton Factory would raise the water level to a height of 62 feet above the proposed distributing reservoir on Manhattan. Plan 3 called for the construction of a closed, brick tunnel, 5 feet in diameter, from that point on the Bronx to the high ground above the Harlem River. The distance from the Westchester

\footnote{Ibid.}
Cotton Factory to the Harlem River was only 13 1/4 miles. Water could be carried across the Harlem River by aqueduct, or through cast iron pipes laid under the roadway of a bridge. The system of receiving and distributing reservoirs on Manhattan was the same as in plans 1 and 2. Plan 4 substituted an open canal for the brick tunnel and was estimated at $987,535.95. Plan 3, strongly recommended by White, was estimated to cost $1,949,542.65.14

According to White's estimates, the daily supply of water from these plans was sufficient for a population of about 250,000 persons. The city's population in 1820 was 123,706 and White reasoned that water enough for twice that many people was ample provision for the future.15

On April 12, 1824, the water committee presented White's plan to the Common Council. The Council thought the recommended plan too expensive to be developed by the city and again turned to private enterprise. A group of New York residents, led by John Griscom, subsequently petitioned the Legislature for a charter to incorporate a waterworks company to carry out White's plan. They drew

14 Ibid., 15; see also Stokes, Inconography, 1635.
15 New York City population figure taken from Blake, Water for the Cities, 108.
vigorous opposition from both the Manhattan Company and the Sharon Canal Company, who saw their own chartered privileges threatened.16

The Manhattan Company sheepishly claimed that its water and service were improving. This bluff was necessary because the company's directors realized that their banking activities were contingent upon maintaining a chartered waterworks. Their strength was obviously political, since everyone complained about their bad water and poor service. Even as late as 1830, the Manhattan Company was only able to provide service to one third of the city's populated area.17

The Sharon Canal Company presented a more formidable opposition. The company's directors claimed that their charter included exclusive rights to water sources in Westchester County. In addition, they sought an expansion of their charter to include provisions that would make it easier to raise capital. The proposed New York Water-Works Company had to overcome spirited resistance and failed to obtain a charter during the 1824 session of the Legislature.18

16 Blake, Water for the Cities, 111.
17 Weidner, Water for a City, 22.
18 Blake, Water for the Cities, 111-115.
The one great advantage possessed by the New York Water-Works Company was the experience and reputation of White. The public sensed that the new company could bring results. The Sharon Canal Company, lacking engineering talent, was never able to put a firm plan and estimate before the public. The Manhattan Company, lacking extensive plans, had little need for engineering skills. Public opinion was clearly against the company because of its poor record and its continued efforts to stifle competition.19

On March 25, 1825 the Legislature passed an act incorporating the New York Water-Works Company. Benjamin Wright, chief engineer of the Erie Canal, became president of the new company. White was named chief engineer. The New York Evening Post expressed public sentiment when it declared that for the first time: "Neither zeal nor ability of any kind will be wanting."20 Confidence was so great that the company had no trouble attracting investors. White immediately set to work finalizing his plans and estimates, while the company's directors contracted with individual property owners for water

19 Ibid., 114.
20 New York Evening Post, June 20, 1825.
rights in the vicinity of the Rye ponds. 21

It seemed for a time that the water problem would be solved. Unfortunately, the charges made by the Sharon Canal Company were true. The New York Water-Works Company had no water rights in Westchester County. In their enthusiasm, the promoters of the new company had not bothered to examine their charter carefully. 22 After realizing the defect, the company immediately attempted to amend their charter to include rights similar to those of the Sharon Canal Company. 23

News of the defective charter caused a great deal of unrest among the company's investors. Benjamin Wright pleaded for patience, and asked the investors to wait for White's final report, which would calm their fears about the project. The stockholders were not concerned with engineering or reports. The charter problem caused them greater concern; and on December 13, 1825, they voted to dissolve the corporation. 24

On January 18, 1826, in the midst of this turmoil,

22 Ibid.
23 Ibid., 116-118.
24 Ibid., 117.
White made his final report to the board of directors. He assured them that the plan was practical and could be completed within his estimates. He slightly revised the figures he had prepared in 1825 for the Common Council, and now determined that by following his plan, 9,100,000 gallons could be taken from the Bronx River daily. This was sufficient for a population of 450,000 persons. White maintained his preference for the gravity supply system with the closed, brick tunnel. The open canal seemed objectionable because White thought the water could be easily contaminated by run-off. His estimate of engineering expenses was as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 1/4 miles of closed brick tunnel at $31,174 per mile</td>
<td>$413,055.50</td>
</tr>
<tr>
<td>Bridge over the Harlem River</td>
<td>$45,000.00</td>
</tr>
<tr>
<td>9 miles of 24&quot; cast iron pipe at $65,205 per mile</td>
<td>$586,845.00</td>
</tr>
<tr>
<td>4 reservoirs</td>
<td>$38,000.00</td>
</tr>
<tr>
<td>Sub total</td>
<td>$1,082,900.50</td>
</tr>
<tr>
<td>5% for contingencies</td>
<td>$54,145.02</td>
</tr>
<tr>
<td>Distributing reservoir near city</td>
<td>$187,954.48</td>
</tr>
<tr>
<td>Total</td>
<td>$1,325,000.00</td>
</tr>
</tbody>
</table>

This estimate was lower than one projected in White's initial report. His intention was to assure the stockholders that the project was both practical and well within the means of the company.25

Unfortunately, White's attempt to calm the

stockholders was ineffectual. They lacked confidence in the company's charter, not in his engineering ability. The Sharon Canal Company lobbied actively to prevent any further expansion of its rival's charter. On January 28, 1826 an anonymous letter in the *New York Evening Post* asked if White was ignorant of the fact that "... the New York and Sharon Canal Company has a right to all waters, and the directors of the Water Company have not?" The public debate over water rights caused the citizens of Westchester County to become alarmed at the proposed diversion of their major streams. Their concern led to efforts to block the plans of both companies and gain control of their own waters. This further dimmed the prospects for any expansion of the New York Water-Works Company's charter. 26

On July 13, 1826, having failed to obtain the necessary amendments, the company's directors voted to abandon the project and dissolve the corporation. The stock was promptly liquidated with little loss to the investors, and early in 1827 the company relinquished its charter. 27

A period of confusion followed the demise of the New

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York Water-Works Company. Reports of low water at the Westchester Cotton Factory raised doubts about the dependability of the Bronx River. Improvements in deep well drilling created false hopes that an easy solution was at hand. For a short time, there was a diminished interest in expensive plans to bring water from remote sources.  

Destructive fires, serious epidemics and general condemnation of the Manhattan Company's service were evidence that a serious problem still existed. In December of 1831, the Common Council approved a resolution calling for municipal ownership of a waterworks. This was a decisive action that reflected the city's impatience with the failure of private corporations. The Council petitioned the Legislature to appoint a board of water commissioners with the powers necessary to carry out White's Bronx River plan. The quiet opposition of the Manhattan Company and the Sharon Canal Company, and a general prejudice in favor of private enterprise combined to defeat the proposal.  

A particularly bad epidemic of Asiatic cholera during the summer of 1832 again stirred city officials to action. 

\[28\] Ibid., 118-119.  
\[29\] Weidner, Water for a City, 27.
A newly appointed water committee of the Common Council engaged DeWitt Clinton Jr., a civil engineer, to re-examine the ground in Westchester County and make recommendations. On December 22, 1832 Clinton reported his preference for the Croton River over the Bronx River, and suggested that an open aqueduct be built to carry its water to the city. From that point on, the Croton River was the focus of the city's plans, and the Bronx was never again given serious consideration. 30

The city did not forget the value of White's early investigations. The water committee asked his opinion of the Croton plan and inquired whether he would take charge of the work. White declined the city's offer because of his involvement in several projects and the deteriorating condition of his health. He told the committee that in his opinion the Bronx was still preferable and would be more than adequate. The Croton plan involved unnecessary expense and presented a number of significant engineering obstacles. 31 The committee, however, pressed forward with the plans suggested by Clinton.

It is difficult to judge White's plan since it was

30 Ibid., 28-29.
31 Canvass White to the New York Water Commissioners, undated manuscript (probably March, 1833), Canvass White Papers.
never carried out. There is no reason to doubt his ability; and, had politics not interfered, New Yorkers might have been spared two decades of bad water. The Croton system was not completed until 1846, almost 25 years after White made his initial surveys. The only question about the practicality of White's plan was whether the Bronx was a sufficient source. White never intended to rely on the river alone, and his earliest reports include suggestions for ways to augment the supply by constructing reservoirs and diverting secondary streams. White himself considered bringing the Croton River to the reservoirs made from the Rye ponds, but thought that it was not practical or necessary. He never claimed that it was not feasible. His mistake was to underestimate the growth of the city's population; but this is neither surprising or condemning.

At least one interested witness to the construction of the Croton Water-Works saw the ingenuity of White's plans. In a Description of the Canals and Railroad of the United States, H.S. Tanner noted that the 41 mile Croton aqueduct ran nearly parallel to the Bronx River for almost 25 miles. It then cut across country to the high ground above the Harlem River close to the route originally

32 (New York, 1840), 59-70.
surveyed by White. The construction of the aqueduct was a massive undertaking that required difficult cuts, tunneling, and the erection of long spans. Originally estimated at $4,718,197, the project exceeded $10,000,000 before completion.

According to Tanner, the Croton River at its southeast bend was at a higher elevation than the Bronx, although the two were separated by a high ridge. Tanner proposed piercing the ridge by tunnel and canal to allow the Croton's waters to be carried by the Bronx, which formed a natural channel to within 8 miles of the Harlem River. Seven miles separated the two rivers, making 15 miles of excavation and construction rather than 41.33

White's plan offered the economy that came from using natural forces in an engineering system. This was one of the most remarkable characteristics of America's early engineers. White was especially adept at comprehending the forces and features of a geographical region, and fitting them into the plan that accomplished his purpose. Although never put into operation, White's plan represented the only solid engineering effort before the Croton system. He established a level of professionalism and integrity that was in sharp contrast to the self-interested actions of

33 Ibid., 68.
the Manhattan Company and the ineptness of the Sharon Canal Company.
Chapter Five
The Union Canal in Pennsylvania

The Union Canal was for Pennsylvania what the Erie Canal was for New York: a training ground for engineers. Canvass White led the corps of young engineers on the Union to several great accomplishments, and prepared them for decades of professional service to the government and for private companies. White arrived to take charge of the canal in 1823 accompanied by three capable, young assistants from the New York Canal: Sylvester Welch, George T. Olmstead and Simon Guilford.¹ Fresh from the Erie experience, these men freely shared their knowledge with newly recruited Pennsylvanians, such as William Lehman, W. Milnor Roberts, Benjamin Aycrigg and Solomon White Roberts, who quickly rose through the ranks. Former Union Canal engineers built the extensive state-owned canal system, the Allegheny Portage Railroad, the Lehigh Canal and a number of private canals and railroads. Though

not as commercially successful as the Erie, the Union Canal was a seminal event in the history of transportation technology in Pennsylvania.

By accepting his first major appointment away from the Erie Canal, White inherited a stalled project with a long history of disappointments. The object of the canal was to connect the Schuylkill and Susquehanna rivers, diverting the latter's trade from Baltimore to Philadelphia. In 1762, a group of Philadelphians formed the Schuylkill and Susquehanna Canal Company. This early effort was crippled by a complete lack of experience, but the company did manage to conduct a crude survey that established Reading on the Schuylkill and Middletown (several miles below Harrisburg) on the Susquehanna as the terminal points.

The rapid pace of events during the next several decades prevented any further progress. In 1791, Philadelphians organized an expanded project to make the city an outlet for the trade on three major rivers. They revived the Schuylkill and Susquehanna Canal Company and formed the Schuylkill and Delaware Canal Company in an attempt to join the rivers by a network of canals, giving Philadelphia a vast hinterland. These companies accomplished little, mostly due to their inability to attract a foreign engineer, and the project remained
dormant for another two decades. In April of 1811, the two companies merged to form the Union Canal Company, since the principal stockholders in each were the same men. The reorganization had little effect and the project remained stalled, despite the company's serious efforts to find an English engineer.²

By the summer of 1821, Philadelphians, aware of the successful beginning of the Erie Canal, were anxious to compete by completing their own water connections to the west. In the fall of 1821, Samuel Mifflin, heading a group of Philadelphia businessmen who took over the Union Canal Company, renewed the search for a competent engineer. Inspired by the New Yorkers' example of relying on native Americans, he hired Laommi Baldwin, a Massachusetts engineer then working in Virginia, as the company's chief engineer.

Baldwin had originally studied law, but became interested in engineering in 1806 while assisting his father in the construction of the Middlesex Canal between Boston and Lowell. This early canal, only 30 miles long, suffered from many deficiencies, in spite of valuable assistance from William Weston, the experienced, English

engineer who acted as consultant on a number of early American projects. Baldwin benefitted from contact with the experienced Weston, and in 1807 continued his education by touring civil engineering projects in England.

Although capable, Baldwin had an arrogant sense of professionalism that led him into claiming wide authority within the project as a professional right and resented Mifflin's interference in what he considered engineering matters. The central issue was nothing less than the size and capacity of the canal. Mifflin and the board favored a narrow canal prism, and locks that passed only one boat at a time. They favored a prism 36 feet wide at the surface and 24 feet wide at the bottom, with locks 8 1/2 feet wide and 75 feet long. Their decision was prompted by reports that it would be difficult to deliver an adequate amount of water to the summit level, and a desire to save money by holding down construction costs. Baldwin argued that European experience demonstrated the economy of locks that passed two boats at once. He felt that the canal would easily become choked with traffic, and that this would deter Susquehanna River boatmen from considering Philadelphia markets. In the fall of 1822, he resigned
Mifflin immediately began a search for an engineer that better suited the company and found an ideal candidate in Canvass White. White visited the canal in 1823, inspected ongoing construction, and accepted the company's offer to become chief engineer. Baldwin had parting words for his successor: "I presume he will trim his sails so as to please the president. Otherwise I fear for him." White had no problems meeting the company's expectations for two reasons. First, he greatly desired to start an independent career, and this was his first major opportunity. And, unlike Baldwin, he received his training and work experience in a large organization where engineers had limited authority.

White brought his own professional style to the company and managed to make major changes in the original plan, while retaining the support of Mifflin and the board. After closer inspection of the ground in 1823 and 1824, he saw an opportunity to improve the water situation at the summit. Supplying water to an elevated summit was the most difficult problem for early canal engineers. A

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4Ibid., as quoted on 98-99.

5Ibid., 99.
great supply was necessary, since water was drawn from the summit to fill locks on the sloping eastern and western divisions. The Union's 7 mile summit, almost 500 feet above tidewater and more than 311 feet above the starting point at Reading, passed through a poorly watered area.\textsuperscript{6} The original route of the western division ran along the valley of the Quintapahilla Creek and then over a steep ridge that separated the creek from the valley of the Susquehanna River. In 1824 White proposed changing the direction of the western division by tunneling through the ridge at the western end of the summit and carrying the canal to the Swatara River, a tributary of the Susquehanna. He realized that the water situation was desperate and hoped that the larger Swatara River would guarantee a dependable supply. The tunnel was the first phase of a complete, more complex plan that White submitted to the board.

Like Baldwin, White believed that the fate of the canal lay with his judgement and knowledge, not the boards'. With resignation, he accepted the company's restrictions on the size of the canal prism and locks, but quietly resolved to leave the project if his plans for the

\textsuperscript{6}H.S. Tanner, \textit{A Description of the Canals and Railroads of the United States} (New York, 1840), 110.
summit were rejected. Mifflin and the board demonstrated great confidence by approving White's plan, for they cannot have remained ignorant of the risks. In 1824, only one tunnel existed in the United States, a 400 foot shaft through a low ridge on the Schuylkill Navigation near Pottsville. The proposed tunnel on the Union had to be drilled 729 feet through extremely hard rock, making it the most difficult yet attempted. The tunnel plan drew comment from the Acting Committee of the Pennsylvania Society for the Promotion of Internal Improvements:

A work of this kind is almost unknown in our country... Many, favorably disposed toward the design, have regarded it with doubt, and have considered its completion as uncertain.

White moved ahead confidently, unaffected by the doubts of local observers. He named Simon Guilford resident engineer, but remained personally involved during the

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7 Canvass White to Hugh White (father) Lebanon, Pa., November 10, 1824, Hugh White Papers.

8 Alvin Harlow, Old Towpaths (New York, 1926), 87.

9 Paper read at a meeting of the Acting Committee of the Pennsylvania Society for the Promotion of Internal Improvements, held at Philadelphia, August 26, 1826, copy in the Canvass White Papers.
important phases of construction.¹⁰

In 1825, he re-surveyed the area to determine exactly the line of the tunnel and boldly set crews to work from both ends. The simultaneous excavation created a feeling of suspense among local residents and interested persons already impressed by the novelty of digging a long tunnel. Teams of 12 men used hammers, hand drills and explosives to clear the 18 foot high by 12 foot wide shaft and averaged 2 feet per day.¹¹ Progress was steady, but doubts lingered. As late as March 24, 1827 White found it necessary to reassure one of his principal assistants, William Lehman, that the two excavations would meet according to plan.¹²

Satisfied with progress at the tunnel, White turned to the difficult problems associated with bringing water from the Swatara to the summit. This was especially problematic because the river was 81 feet in elevation below the summit. Canal engineers preferred to feed water to the line from sources higher in elevation. White knew


¹¹Ibid.

Canals and Railroads, 1830 (detail of map)

completed     under construction

from: Christopher T. Baer, Canals and Railroads of the Mid-Atlantic Region, 1800 - 1860
(Wilmington, Delaware: 1981).
that this was impossible on the Union Canal and so he chose to rely on the Swatara and an elaborate waterworks, or pumping system. He located the waterworks at the junction of the canal (the western division) and the river, 4 1/2 miles from the western end of the summit. The works consisted of forcing pumps powered by waterwheels 36 feet in diameter. The pumps threw water up 92 feet into a trunk feeder that began on a hill above the river. The gravity trunk feeder conveyed water 4 1/2 miles to the summit level. For insurance, White placed two anthracite coal steam engines at the waterworks to be used in case of accident to the wheels.\(^{13}\) Like other early civil engineers, he felt that artificially produced mechanical power was not as reliable, or economical, as waterpower.

White's plan to channel water to turn the large wheels accomplished the kind of double purpose that pleased the company's managers. During construction of the canal between 1823 and 1825, the company discovered anthracite coal in the mountains at the head of Swatara. Josiah White, proprietor of the Lehigh Coal and Navigation Company, had recently demonstrated anthracite's superiority over soft coal. He was then developing a

\(^{13}\)Cocke, "Notes of a Trip to the Union Canal," 14.
market in Philadelphia by sending river boats down the Lehigh and Delaware Rivers. The Union Canal Company's directors saw an opportunity to enter a profitable side business, and they turned to their engineer for advice. White responded by tying together the waterworks with a plan to extend navigation up the Swatara. In 1825, he laid out a 7 1/2 mile long navigable feeder, 20 feet wide and 4 feet deep, from a spot upriver called Wiedman's Forge to the waterworks. The feeder reached the waterworks at a height of 35 feet above the river.\textsuperscript{14} The volume of the feeder and the height of the drop created an artificial cascade of tremendous power.

The second part of White's plan to extend navigation towards the coal fields was tied to his concern for the water supply. Early in the summer of 1827, he decided to test the canal by letting in water. Using the one wheel then completed at the waterworks, he pumped water to the summit level and anxiously waited the results. To his satisfaction, the embankments and lock walls held firm, but there was a critical loss of water along the entire summit due to sinkholes and the filtering quality of the limestone. Modern engineers, with their knowledge of hydrology and soil mechanics, have devised methods to deal

\textsuperscript{14}Ibid.
with limestone related problems; White's only option was to increase the water supply.\textsuperscript{15}

On July 7, 1827, he reported the problem to the board of managers and presented his plan to improve the situation. He first told them that it was necessary to line the entire summit with wooden planking tied securely to timber braces laid on the bottom and sides of the canal. Apologistic for the unexpected delay and late expense, he explained that it was impossible to determine the extent of the problem except by the "... actual experiment of letting in the water and this could not be done until after the feeders were completed."\textsuperscript{16} The board had little choice but to place its faith in White's judgement. Moving quickly in anticipation of the canal's opening in the spring of 1828, he completed the planking by December.\textsuperscript{17}

Planking the summit was a stop gap measure designed to protect more against sinkholes than leakage. White


\textsuperscript{16}Canvass White to Samuel Mifflin, Easton, Pa., July 7, 1827. Union Canal Company Papers.

\textsuperscript{17}George Armroyd, \textit{A Connected View of the Whole Internal Navigation of the United States} (Philadelphia, 1830), 125.
believed that leakage and the heavy consumption of water caused by locking boats singly would combine to put a tremendous strain on the Swatara. Demonstrating the same type of innovative strategy that resulted in the successful tunnel, he designed a huge dam across the Swatara at a place where the river passed through a gap in the mountains. The rocky sides of the gap formed a natural foundation on which White built the largest dam yet constructed in the United States. Completed before 1832, the dam spanned the entire 430 foot gap and was more than 45 feet high. The dam consisted of two sections: one of log cribbing filled with stones, and the other, an earthen embankment. There were 12 cast iron release gates which were raised and lowered by screws from the top of the dam.¹⁸

The huge dam created a reservoir that extended 6 miles and covered more than 700 acres.¹⁹ It ended the water supply problem and provided an additional benefit, since the reservoir served as the next link in the feeder line to the coal fields. White continued the navigable


¹⁹Armroyd, A Connected View of . . . of Internal Navigation, 126.
feeder from Wiedman's Forge to the dam, where boats locked up to the reservoir. A short canal from the northern end of the reservoir to the village of Pine Grove brought the line within 4 miles of the coal mines. The total length of the Swatara navigation system was 23 miles. It was an ingeniously integrated system that took advantage of natural forces and formations. Displaying great versatility, White completed a gravity railroad from Pine Grove to the mines. The Swatara system enabled the Union Canal Company to successfully enter the profitable anthracite coal market, and greatly stabilized the canal's water situation.

White spent only a portion of his time in residence at the canal during his tenure as chief engineer. Between 1823 and 1827, he became involved with major projects in several states, taking advantage of the many opportunities for experienced engineers. He made periodic inspections of ongoing construction and provided his assistants with information and advice. While away, he kept up a steady stream of correspondence filled with instructions on various topics, sometimes writing several letters to the same person in one day. His presence was required from time to time when unexpected problems arose, and when stockholders and company officials needed assurance.

By December of 1830, White was extremely busy and
anxious to "... make a final arrangement of all matters connected with the Union Canal." Soon after, he ended his formal agreement with the company, but remained associated as consulting engineer through several years of continued improvements. In August of 1831 he responded to a request by William Read, the company's new president, to visit the canal and suggest a plan for the enlargement of the trunk feeder. This was the first in a series of visits between 1831 and 1834 during which White examined expansion plans developed by his former assistants. In 1832, Read asked him to prepare a detailed report that outlined maintenance procedures and estimated their cost. White submitted the report in December of 1832 and warned the company not to neglect minor errors. In this same vein, he cautioned them about the error of cutting expenses in the engineering department:

It is certainly a mistaken policy to attempt what is erroneously called economy in the salaries of persons employed to discharge an important trust.

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21 William Read to Canvass White, Philadelphia, August 9, 1831, Canvass White Papers.

22 Report to the President and Managers of the Union Canal Company, Philadelphia, December 20, 1832; addressed to William Read, Union Canal Company Papers.
In regard to practical matters, he advised them to keep the present summit feeder in good repair, and to remove some projecting rocks in the tunnel so that two boats could pass at once. Also, he recommended that water be pumped to the summit level during winter when the canal was closed so that the planking would not be exposed to damaging frost. Read repeatedly contacted White during the following years concerning a variety of topics.

The Union Canal was more of an engineering than a commercial success. White led the engineering corps to two technological firsts, the longest tunnel and most massive dam yet constructed in the United States, in a heroic effort to complete a difficult assignment. The engineers trained on the canal met many challenges and learned their art well. George Olmstead, Nathan Roberts and Sylvester Welch built the Allegheny Portage Railroad. W. Milnor Roberts and Sylvester Welch followed White to the Lehigh Canal. From White they learned a valuable trade and a manner of professional deportment that became characteristic of modern civil engineers.

The canal proved too narrow to be a rousing commercial success. Baldwin was somewhat vindicated, but it is not clear whether he could have delivered an

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23 Ibid.
adequate water supply to the summit. Also, Baldwin's plan to build a flight of locks to carry the western division over the high ridge to the Susquehanna might have proved disastrous. Throughout his subsequent career, White was regarded as an expert on spacious locks, and there is little doubt that he would have preferred larger locks on the Union. However, he understood the limitations imposed by the geography, and his employers, and worked to develop a complete plan that took advantage of what nature offered. His achievement on the Union Canal must be measured against the difficulties presented by the local landscape, and perceived as a seminal event in the history of American civil engineering.
Chapter Six
Career Developments and Conclusions

The pace of White's career rapidly accelerated during his years as chief engineer for the Union Canal Company. His schedule became increasingly hectic as he accepted a number of simultaneous major appointments, acted as a consultant to projects in several states, and initiated two entrepreneurial engineering schemes of his own. "I am so much driven with work," he complained in 1830, "that I hardly have time to sleep and do not get as much as nature requires."¹

In 1824, the year in which he began intensive work on the Union Canal, he became principal engineer for the Connecticut River Company and directed construction of their locks and short canal around the Enfield Falls in the Connecticut River, just above Hartford. That same year, he acted as consultant to the Connecticut River Company's rival, the Farmington Canal Company. The Farmington Canal intercepted trade on the Connecticut

River above the falls and directed it to New Haven. His work for competing companies probably displeased the managers of each, but neither company was willing to do without his services. Also in 1824, he completed several tasks on the Erie Canal and devoted considerable time to a study of New York City's water supply problem.

In the summer of 1825, White and Benjamin Wright inspected the Lehigh Coal and Navigation Company's improvements in the Lehigh River from Mauch Chunk to Easton, at the request of the company's managers. This contact led to White's appointment in 1827 as chief engineer during construction of the company's canal system. Completed in 1829, the Lehigh Canal was spacious and solidly built. It served as a major anthracite route into the twentieth century.

White expanded his activities during 1826 and continued work on projects already in progress in New York, Connecticut, New Jersey and Pennsylvania. He managed to interest several investors in his plan for an

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industrial complex of mills and waterways at the Cohoes Falls in the Mohawk River, near the junction of the Erie and Champlain canals. On March 28, 1826, the company received its charter from the legislature. White became president, but was unable to lead the company because of his many other commitments, and the project faltered. 4

In July of 1826, White conducted surveys for the state of Pennsylvania to determine the line of the state-owned canal westward along the Juniata River, a tributary of the Susquehanna, to the Allegheny Mountains. He may have been the first to suggest some sort of portage railroad over the mountains. Impressed by the completeness of his reports, his skill, and his integrity, the Pennsylvania legislature offered him the position of chief engineer for all the state's proposed works. 5 He politely declined, explaining that he was fatigued by a heavy work schedule and suffering from a bout with his recurring illness. 6 Just as likely, he did not wish to


5 Canvass White to Hugh White, Morristown, Pa., July 17, 1826, Canvass White Papers.

6 Ibid., see also White, "Canvass White's Services, 359.
limit his earning potential by devoting all his energies to only Pennsylvania's public works.

By 1827, White could justly claim to be the most sought after engineer in America. When the federal government needed a chief engineer for its own Chesapeake and Ohio Canal, none other than Henry Clay recommended that they get White:

- no man is more competent, no man is more capable, and while your faith in his ability and fidelity increases, your friendship will grow into affection.

The Chesapeake and Ohio was an ambitious canal, designed to connect the headwaters of the Potomac River with the Ohio Valley. The terrain presented many difficulties and the government's military engineers had little experience in civilian projects. On March 30, 1827, Major General Macomb, chief engineer in the War Department, contacted White and asked him to review the government's plans and cost estimates. Its not clear whether Macomb offered him an appointment as chief engineer, but it seems unlikely,

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7White, "Canvass White's Services," 364.

since White disapproved of the scheme and considered it impractical. His judgement proved correct for the Chesapeake and Ohio was neither an engineering or commercial success.

In May of 1828, White found time to accompany a group of Philadelphia businessmen on an inspection tour of their recent investment: the Louisville and Portland Canal at Louisville, Kentucky. This short, 2 1/2 mile canal carried steamboats around a treacherous falls in the Ohio River. White became personally interested because of the large locks the company planned to build, and he returned in August of the same year to supervise their construction. He later accepted a permanent appointment as consulting engineer, and in 1829 he was listed as one of the directors of the company.9

During 1829, he completed the Lehigh Canal, continued making improvements on the Union Canal and organized a new business venture. In February of 1830, after much preparation, he signed a contract with the federal government to deliver stone to the Delaware Breakwater at

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Cape Henlopen. The breakwater was the first major harbor improvement attempted in the United States. William Strickland, the noted American engineer and architect, headed the project in cooperation with the government's engineers in the War Department. Supplying stone was a difficult feat since individual stones had to be cut quite large. White's role included devising the means to quarry large stones and arrange for their transport and proper deposit at the site. Each stone weighed at least 2,700 pounds and measured more than 25 cubic feet. An elaborate tally system, crude weighing and loading methods, and the general inexperience of all combined to limit progress. White had received an exclusive contract for stone in 1830, and he did well, considering the many difficulties. In 1831, however, the government settled on a new policy of contracting with many small suppliers, prompting him to abandon further efforts. 11

The last major project of White's career was the Delaware and Raritan Canal which linked New York and Philadelphia by an inland water route. Begun in 1831, it

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10 Canvass White to R. McIlvaine, Louisville, Kentucky, February 15, 1830, Canvass White Papers.

promised to be the crowning achievement of his career, for it connected the two largest commercial centers in the United States. Built on an almost perfect design, the spacious, 75 foot wide canal required only 14 locks, 100 x 24 feet, over its 42 miles. It represented White's conception of an ideally located and constructed artificial waterway.

The Delaware and Raritan, however, was among the first canals to face stiff competition from a railroad. In fact, a joint stock company managed construction of the canal and its rival, the Camden and Amboy Railroad, at the same time, completing the canal in 1834 and the railroad in 1837. Within a decade of its completion, the railroad eclipsed the canal and reduced it to secondary role.

White did not witness the outcome of the competition between canals and railroads. He died on December 18, 1834, at the age of forty four, in St. Augustine, Florida where he had fled in a last minute attempt to recover his rapidly failing health. At the time of his death, the apex of the canal era, he was at the top of his new profession. His reputation, however, like that of other

\[\text{12} \text{H.S. Tanner, A Description of the Canals and Railroads of the United States (New York, 1840), 86-87.}\]

\[\text{13} \text{Ibid., 87.}\]
early canal engineers, has diminished over time as the railroads have come to dominate our perception of technological progress in the nineteenth century. There is the sense that canals belonged more to the fading, agricultural age than the modern industrial one. White's career demonstrates that canal engineers launched the technological revolution in the United States, and they generated a momentum that has carried to the present day. In fact, many canal engineers, including White's students John Jervis, Simon Guilford, Sylvester Welch and William Lehman, passed quite easily into the railroad age and made significant contributions.

During the last several years of his life, White increased his own involvement with railroads. Between 1831 and 1834, he laid out the Camden and Amboy Railroad and received offers to head several other proposed railroads. His declining health and failing energies, however, prevented him from accepting new appointments, and he passed them to his assistants.

White's career spanned almost exactly the first great period of canal building in the United States. On the Erie Canal, he had helped to marshall resources and knowledge from this country and England, and apply them to achieve a breakthrough that had a profound impact. From 1818 to 1834, he made important contributions to the growing body
of American technological knowledge, and acted as both an innovator and teacher. Just as importantly, he imparted a confident, self-reliant attitude by his own example that bolstered a rising generation of civil engineers faced with new and challenging problems.
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Vita

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