COPY

Report on
Little River Improvement
submitted to
The Board of Health
of
Haverhill, Mass.

Oct. 21, 1916.

Charles B. Breed
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M. AM. SOC. C. E.
CONSULTING ENGINEER
6 BEACON STREET, BOSTON

Boston, October 21, 1916.

Board of Health of Haverhill,

Haverhill, Mass.

Gentlemen:

Your instructions to me relative to the subject of Little River Improvement are embodied in the vote passed at the regular meeting of the Board of Health held June 15, 1916, which was as follows,-

> "That the services of Charles B. Breed be employed as consulting engineer on the Little River case, and that Mr. Breed submit a report to the Board of Health as to the best method and most feasible manner of abating the alleged Little River nuisance."

Plans Accompanying This Report but Bound Separately.

> Plan of Little River from the Merrimac River to Pentucket Mills, comprising 5 sheets and referred to in this report as Fig. 2.
>
> Profile of Both Banks of Little River from the Merrimac River to Pentucket Mills, comprising one sheet and referred to in this report as Fig. 3.

Conclusions in Brief.

After careful consideration of this problem covering a period of four months, your engineer recommends that a covered conduit of reinforced concrete of two channels each 8 ft. x 12 1/2 ft. be constructed from

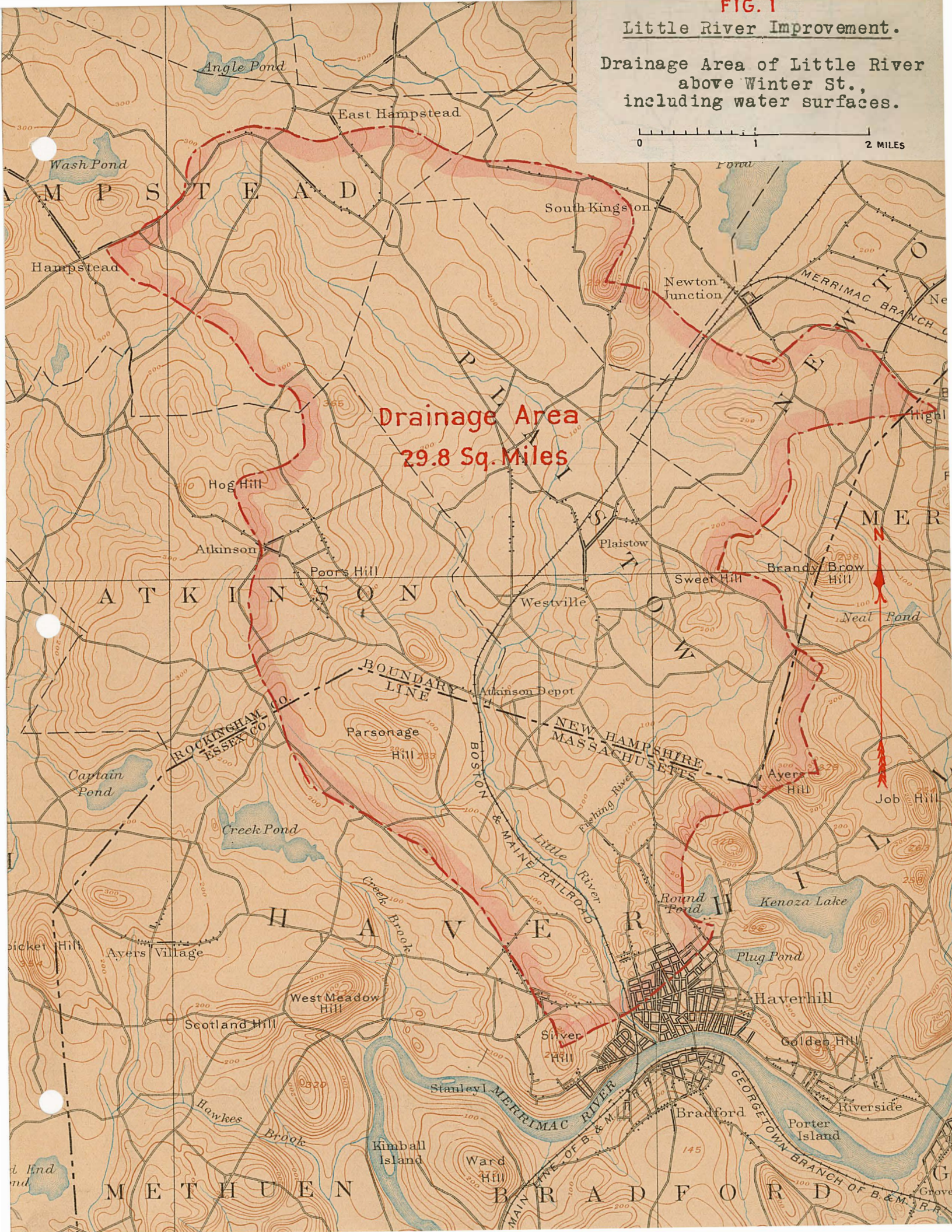
Washington Square arch to a point about 60 ft. south of Winter St. (length 2147 ft.) of the general design shown on Fig. 28 and in the location and at the profile shown on plans accompanying this report and marked Fig. 2 and 3 respectively. It is suggested that a new 30-ft. street be constructed over the conduit from Washington Square to Locke St.

The total estimated cost of this construction, including a 3 ft. cover of earth on top of the conduit and including engineering and all incidental expenses, but exclusive of property takings and any new street construction, is $195,327.

As shown later in this report, the entire proposed conduit from Washington Sq. to Winter St. need not be constructed in one season; a section at a time can be built, thus distributing its cost over a few years if deemed advisable.

Surveys Required.

When the work of investigation was started no complete plan or profile of Little River and vicinity was in existence. The work of making the necessary surveys and drafting the resulting plans was carried out by the City Engineering Department. It required the services of four men for the four summer months. While this work was going on the writer devoted his attention to a careful study of the various phases of the general problem, the probable


FIG. 1
Little River Improvement.
Drainage Area of Little River above Winter St., including water surfaces.
0
1
2 MILES
Drainage Area
29.8 Sq. Miles
Angle Pond
East Hampstead
Wash Pond
Hampstead
South Kingston
Newton Junction
MERRIMAC BRANCH
Hog Hill
Atkinson
Poors Hill
Plaistow
Sweet Hill
Brandy Brow Hill
Westville
Neal Pond
BOUNDARY LINE
ROCKINGHAM CO.
ESSEX CO.
Atkinson Depot
NEW HAMPSHIRE
MASSACHUSETTS
Parsonage Hill
Captain Pond
Creek Pond
BOSTON & MAINE RAILROAD
Fishing River
Little River
Ayers Hill
Job Hill
Round Pond
Kenoza Lake
Plug Pond
Haverhill
Ayers Village
West Meadow Hill
Scotland Hill
Silver Hill
Golden Hill
Stanley
MERRIMAC RIVER
Riverside
Bradford
Porter Island
GEORGETOWN BRANCH OF B. & M. R.R.
Hawkes Brook
Kimball Island
Ward Hill
MAIN LINE OF B. & M. R.R.
METHUEN
BRADFORD

maximum yield of the drainage area of Little River, and to designs and estimates.

General Description of Existing Conditions.

Little River has its source 9 miles north of the business district of Haverhill in the town of Hampstead, N. H., and its outlet into the Merrimac River at Washington Square Park in Haverhill. Its drainage area of about 30 square miles includes part of Hampstead, Atkinson, Kingston and Newton, nearly all of Plaistow, and a large part of Haverhill. (See U.S.Geological Survey Map, Fig. 1.) From the dam at Pentucket Mills the river flows through the heart of Haverhill for a distance of about half a mile with a flat gradient and crooked alinement. In this city district it is crossed by Winter St., the Boston & Maine Railroad, Locke St., Locust St. and Washington Square, all of which are supported on single span masonry arches except Winter St., which has two arches, one for the main river and the other for the tailrace of the water wheel of the Pentucket Mills. The dam at the mills forms a pond of relatively small area which supplies water for one water wheel in the mill which produces about 35 indicated horse-power. The photographs, Figs. 4 to 17, give a fair idea of the present condition of the river and vicinity, but do not properly show the filthy condition of the river bed on account of the amount of water flowing at the time these particular views were taken.



Fig.4. Northerly portal of Washington Sq. arch looking down-stream.
Photographed by C. B. Breed. July 5, 1916.



Fig.5. From platform at rear of fruit store, Washington Sq. looking up-stream.
Photographed by C. B. Breed. July 5, 1916.



Fig.6. From pedestrian bridge about half way between Washington Sq. and Locust St., looking down-stream. Photographed by C. B. Breed. July 5, 1916.



Fig.7. From point about 200 ft. above Washington Sq. arch, looking up-stream. Showing pedestrian bridge. Photographed by C. B. Breed. July 5, 1916.



Fig. 8.



Fig. 9.

From pedestrian bridge about half way between Washington Sq. and Locust St., looking up-stream. "Simplex Sample System" building is on northerly side of Locust St.
Shows overhang of bowling alley on southerly side of Locust St.

Photographed by C. B. Breed. July 5, 1916.



Fig.10. From Locke St. arch looking down-stream. Showing small wooden building overhanging river on northerly side of Locust St.

Photographed by C. B. Breed. July 5, 1916.

Haverhill Little River Improvement.



← Fig.11.

From point about 100 ft.
above Locke St.
looking up-stream.

Photographed by C.B.Breed.
July 5, 1916.

Fig.12. →

From point about one-third
of the way from the
R.R. bridge to Locke St.
looking down-stream.

Photographed by C.B.Breed.
July 5,1916.





Fig.13. Pedestrian bridge about one-third of the way from R.R. bridge to Locke St. Looking up-stream. Lennox & Briggs building overhanging river on right. Photographed by C. B. Breed. July 5, 1916.



Fig.14.

R.R. bridge looking up-stream from pedestrian bridge.

Photographed by C.B.Breed. July 5, 1916.



Fig.15. Looking down-stream from Winter St.
Shows platform of Haverhill Gas Co. supported on columns in river.
Photographed by C. B. Breed. July 5, 1916.

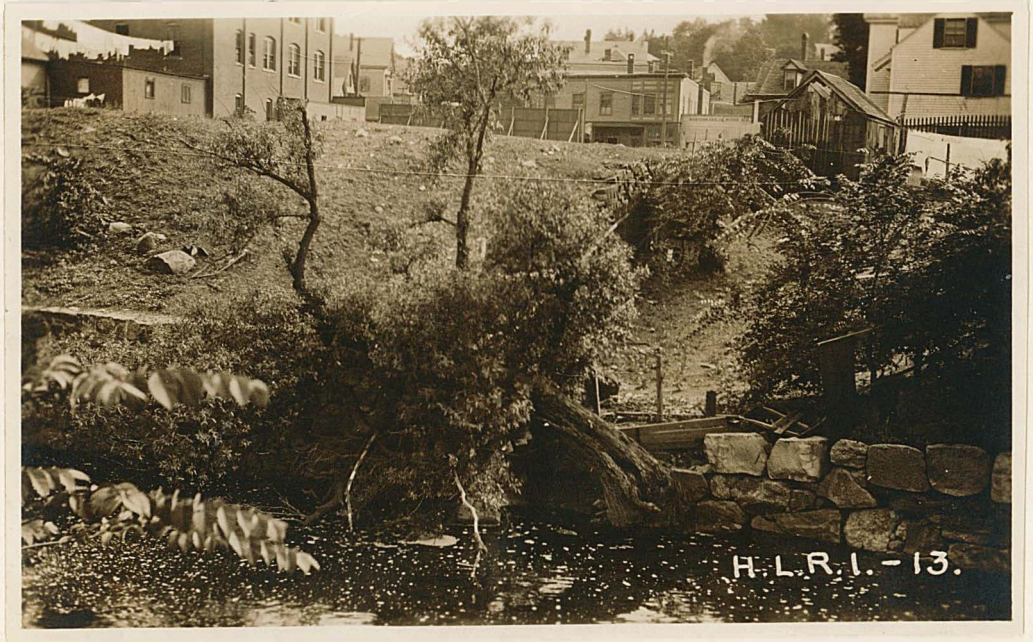


Fig.16. So-called "Public Landing" where tree is shown on the west bank. Just down-stream from Winter St.

Photographed by C. B. Breed. July 5, 1916.



Fig.17. Pentucket Mills Dam from Winter St.

Photographed by C. B. Breed. July 5, 1916.

Little River is a stream with a low normal flow and with a low maximum flow as well. Its drainage area is almost entirely meadow and farm lands, the soil is largely sand or gravel, the district is not hilly or rocky; and as a result the total run-off from this area is small in amount when compared with the rainfall. The effect of a sharp, heavy storm is usually evidenced in the flow of Little River over a period of several hours after its occurrence, the water from such storms being released gradually from this drainage area owing to the character of its soil, vegetation, shape and other physical features. There are also a few small ice ponds and a pond above the dam at Westville which tend to control the run-off from portions of the drainage area.

The favorable location of Little River through the heart of the city formerly led to its use as a drain for all storm water within its natural drainage area,- that which fell within the built-up portion of the city as well as that which ran off from the rural districts north of the city. It was also used as an open sewer for several years. In 1888, when that portion of the sewerage system of Haverhill lying within the natural drainage area of Little River was developed the storm water and sewage were both taken directly into the sewers south of Winter St. North of Winter St., in Wards 5 and 6, the separate system of sewers has been designed and

partially constructed, which delivers the storm water directly into Little River, but none of the sewage is allowed to enter the river north of the dam at Pentucket Mills.

South of the dam, however, many of the industries and dwellings have drains which empty directly into Little River. There are about 90 such drains on the east bank and 25 on the west bank. For the most part these drains are roof and yard drains, blow-offs from boilers, pipes for heating systems and for discharging by gravity the water which may flood the lower floors of buildings contiguous to Little River when the river water is high.

A few of the buildings near the river discharge their sewage or industrial wastes directly into the river, notably from the office building at the corner of Washington Sq. and Emerson St. owned by Clarence S. Coombs, from the stores and dwellings owned by Ezra W.B. Taylor on Emerson St., from the stores and dwellings in the two buildings owned by Levi L.H. Taylor on Emerson St., from the morocco factory of Lennon & Briggs just below the railroad bridge, and from the Pentucket Mills. These cases are treated separately later in this report.

It appears to be a well-established practice for residents along the river bank, operatives in the mills and storekeepers over and along the river to use it as a convenient depository for garbage, slops, empty cans, bottles,

boxes, rags, ashes, and in fact practically all kinds of refuse which collects in such establishments. The result of such misuse of the river is obvious. It has become a filthy brook, offensive to the senses of sight and smell. The river is today in a sense an open sewer; it is a detriment to the immediate vicinity and, because of the possibility of spreading disease, is a menace as well to the whole city.

For many weeks, in the summer months particularly, the flow of Little River is very small, with the result that the sewage and mill wastes settle over the uneven bottom of the river, which when uncovered gives off offensive odors. In its present condition Little River tends to prevent or delay commercial development along its banks.

In the half mile of its course below the Pentucket Mills dam the river flows in a channel beneath streets upon the lines of which buildings have been constructed in such a manner as to cut off the view of the river from the public so that few people have any adequate conception of its condition. Examination of the river bed shows that, particularly from the railroad bridge to Washington Square, there is an accumulation of sewage and other filth. These conditions are plainly shown in the following photographs, Figs. 18 to 24.

The largest sewer of the city, which receives the flow from one-third of the entire sewered portion of the city,



Fig.18. Northerly portal of Washington Square Arch looking down-stream.
Photographed by A. S. Keen. Sept. 21, 1915.



Fig.19. From a point about 100 ft. above Washington Square Arch looking up-stream.
Photographed by A. S. Keen. Sept. 21, 1915.

Haverhill Little River Improvement.



Fig.20. From a point about 100 ft. above Washington Square Arch looking up-stream.
Photographed by A. S. Keen. Sept. 21, 1915.



Fig.21. From a point 250 ft. above Washington Square Arch looking toward Locust St.

Photographed by J. M. Snow. Oct. 4, 1916.



Fig.22. Between Locust St. and Locke St.,looking up-stream.
Shows Locke St. sewer under arch.

Photographed by J. M. Snow. Oct. 4, 1916.

Haverhill Little River Improvement.



Fig.23. From a point about 300 ft. above Locke St. looking up-stream.

Photographed by J. M. Snow. Oct. 4, 1916.



Fig.24. From a point about 200 ft. down-stream from R.R.bridge, showing Lennox & Briggs tannery on the right.

Photographed by J. M. Snow. Oct. 4, 1916.

has its outlet on the shore of the Merrimac River only 10 ft. from the outlet of Little River, and as the tide makes in on the Merrimac River and follows up Little River, and when the wind is also favorable, some of the floating sewage matter from this and other city sewer outlets floats back into Little River, which acts as a tidal estuary of the Merrimac. This nuisance is augmented by the fact that the outlet of the river is below mean low water in the Merrimac River, in consequence of which backwater extends for 1500 ft. up the river and transforms it twice a day into a tidal estuary extending up into the business center of Haverhill. The deposition of sewage into the Merrimac from the cities of Lawrence and Lowell adds materially to the general filthy condition of the Merrimac.

The unsanitary condition of Little River has been repeatedly alluded to in the reports of the Haverhill Board of Health, as well as in the reports of the City Engineer and of the State Board of Health.

GENERAL METHODS OF ABATING THE EXISTING NUISANCE.

Two methods of abating this nuisance are apparent -

(1) Stop misuse of river by policing, and carry sewage and factory wastes into existing City sewers.

(2) Carry the river through the city in a covered conduit, and the sewage and factory wastes into existing sewers.

(1) The first method means to put a stop to the misuse of the river by residents and operatives of industries adjacent to the river and connect all sewers and factory waste drains now emptying into Little River with the existing city sewerage system, installing proper sewage ejectors to lift the sewage from those basements which are too low to empty by gravity into the present city's system.

If it is possible, through policing methods, to put a stop to the throwing of refuse into the river and if the sanitary sewers and factory waste drains are removed then the only material liable to be offensive to health, sight or smell will be that which comes into the river above the dam and that which flows back up the river from the Merrimac when Little River is acting as a tidal estuary. The objectionable material which comes down the river from above the dam is very small in amount and does not contain any sewage matter or factory wastes. The nuisance from backing up of sewage matter from the Merrimac River appears to be a real nuisance and will grow worse as years go on, rather than better, because as the city grows an increasing amount of sewage will flow into the Merrimac both from the Haverhill sewers as well as from cities farther up the river. When it becomes necessary, however, to extend all of the existing sewer outlets to deep water in the Merrimac River the nuisance from this source will doubtless be lessened,

although it is probable that there always will be some of this unsanitary condition so long as sewage material is deposited anywhere in the Merrimac River. Such effects of course will always be to a more or less degree evident along the city's shore and on the bed of Little River in the form of odors, scums and deposits objectionable to sight. Little River, however, is the only inlet from the Merrimac River into the city proper and therefore the only way in which this unsanitary condition can be brought directly up into the business district. Even if the throwing of objectionable material from buildings along the shores of Little River could be prevented by policing, the nuisance just referred to would still exist.

Experience, however, in other cities has shown also that it is impossible to prevent the misuse of such streams by policing. It seems therefore clear that the only positive cure of the present objectionable conditions is to carry Little River through the city in a covered conduit, and this appears to be the solution adopted under similar conditions in other cities.

The construction of the Jones Falls conduit in Baltimore in 1913 was for the purpose of curing a condition much like that which exists in Little River. The two projects are very similar in character, although the former is much larger in extent and expense. The Mill Brook conduit in Worcester and the Stony Brook conduit in Boston are both

examples of where it became necessary to carry existing natural streams through cities in covered conduits to prevent nuisances. Many cities have had to meet this problem, and in almost every instance it is solved by constructing a conduit for the filthy river flow.

Concrete Pavement on River Bed.

The bed of the river through the city is rough. It can be improved by constructing from wall to wall a concrete floor of such a shape that it will be more self-cleaning than the present rough bed is. Such an improvement, however, would not fully cure the present nuisance, and would cost several thousands of dollars. It would not prevent the river being used as a dumping ground, as the present channel is used. It is true that it could be more easily cleaned, but would require just as constant policing, any amount of which experience elsewhere has shown will not prevent the misuse of such a stream. This method is therefore not recommended as a cure of existing conditions, although it would be a decided improvement upon present conditions.

The following letter expresses the opinion of the State Board of Health on this matter as well as its recommendations on the project as a whole.

"Aug. 13, 1913.

"To Mr. Louis C. Lawton,
City Engineer, Haverhill, Mass.

Dear Sir:-

The State Board of Health has considered your application for advice as to a proposed plan for improving the condition of Little River, which you describe as follows:-

> I desire to obtain the advice of your Board relative to a proposed plan for improving Little River in this city from Washington Square to Winter Street.
>
> On account of the rough and irregular character of the present river bottom refuse material collects at various places, which during the dry summer season, when the water is low, and the bed is exposed, becomes objectionable.
>
> Our plan is to construct a smooth concrete pavement in the bed of the river, sloping to a central depression, on a true established grade. With this pavement properly constructed, the dry weather flow would be confined to the center, and the surface of the concrete could be easily kept clean . . . . . .

In response to this application the Board has caused Little River in the portion of its course in which it is proposed to improve the channel, this portion being included between Winter Street and Washington Square, to be examined by one of its engineers and has considered the plan presented.

The results of the examination of the river show that at the present time the channel of the stream throughout its length between Winter Street and Washington Square is bordered for the most part by rough stone walls which are in many places out of repair, while the bottom is very irregular, being covered with stones and especially with large quantities of detritus, including tin cans, wooden boxes and much other refuse.

The water of the river above Winter Street is used for manufacturing, a large part of the flow at the present season of the year being used in the various processes in the mills along the stream, and at the time of the examination the entire flow of the stream below Winter Street was

highly colored with manufacturing waste. By carrying out the plan suggested the bottom of the channel would be materially improved, and by reconstructing or repairing the side walls the channel could be brought into such condition that - if floating matters are kept out of it and the bottom is kept free from detritus - its sanitary condition would be satisfactory; but the experience with similar channels flowing through densely populated districts has been that they are used to a very great extent as places of deposit for such materials as are now found in the channel of Little River, including much foul organic matter, and it is very difficult, if not impracticable, even with careful inspection and frequent cleaning, to keep such channels in proper condition.

In the opinion of the Board the best practicable plan of preventing efficiently further nuisance from the channel of Little River will be to cover the channel completely with a suitable structure capable of carrying off the flow of the stream at times of extreme freshet. The cost of such a channel will of course be much greater than the cost of improving the bottom of the stream alone, and - since it is very desirable that a material improvement in this stream should be made at the earliest possible time - it is advisable to improve the bottom of the channel by covering it with concrete as proposed, and in carrying out this work to provide, so far as practicable, for the final covering of the channel throughout its length from Winter Street to Washington Square. Until the channel is covered the Board recommends that its use as a place of deposit for refuse of any kind be prevented, so far as possible, and that the channel be cleaned at the necessary intervals to maintain it in a satisfactory sanitary condition.

The Board further recommends that foul manufacturing waste and other polluting liquids be disposed of into the sewers and the pollution of the stream be prevented."

The conclusions reached by your engineer, while they accord with the recommendations embodied in the above letter, were in no way influenced by it, for the existence of this communication from the State Board of Health was not discovered by him until after his plans and report were practically completed.

(2) Methods Considered for Carrying Little River through the City in a Covered Conduit.

Two methods have been worthy of consideration -

(a) Taking the River through a conduit constructed in Essex St.

(b) Taking the River through a covered conduit constructed in the present river bed from Winter St. to the Washington Sq. arch.

(a) Taking River through a Conduit Constructed in Essex St.

While consideration was given to abandoning the present location of the river and taking it through a large straight conduit constructed in Essex St. from Winter St. to the Merrimac River, its interference with existing sewers, water pipes, public service pipes and conduits, and its expense, made the abandonment of this idea necessary. It has become apparent that whatever construction is done should be accomplished along the present location of the river, even though it is in places quite crooked in alinement.

(b) Taking Little River in Covered Conduit constructed in Present River Bed from Winter St. to Washington Square.

This method appears to be the only complete cure of the present unsanitary conditions. It is the means to which the City must eventually resort. The nuisance in the river

is not one that is liable to grow any less as years roll on, but will grow more serious. Expenditures for makeshifts and for constant cleaning of the river bed which might somewhat relieve the present unsightly conditions, will be largely wasted, for a covered conduit must eventually be constructed, and if the nuisance has grown to the extent evident today it certainly requires relief and the only real cure of conditions should be applied.

A small plan and profile of the river and the proposed conduit are shown in Figs. 25 and 26, which are miniature copies of the large plan and profile (Figs.2 and 3). They are introduced in the report merely to make it more complete when it is not accompanied by the larger drawings.

In the design of this covered conduit it has been necessary to give very careful consideration to the effect it will have on the water level at the tailrace of the Pentucket Mills, so that in low water conditions the head on the water wheel at the mill will not be any less than under the present conditions and so that in the unusual high water conditions water will be discharged through this conduit as rapidly as through the present channel and will therefore not back up in the Pentucket Mills any higher or run off any slower than it does under present conditions. To meet these conditions satisfactorily to the owners of the Pentucket Mills the designs for the pro-

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PROJECT Haverhill Little River Improvement

SUBJECT Little River from Washington Square Park to Winter St.

SHEET NO.

DATE, September 1916

COMPUTED BY

CHECKED BY

Scale, 1"=300'



Fig. 25

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Profile of Center Line of Little River showing Proposed Conduit

SHEET NO.....

DATE, September 1916

COMPUTED BY.....

CHECKED BY.....

Scale : 1" = 300' Hor
1" = 10' Vert.

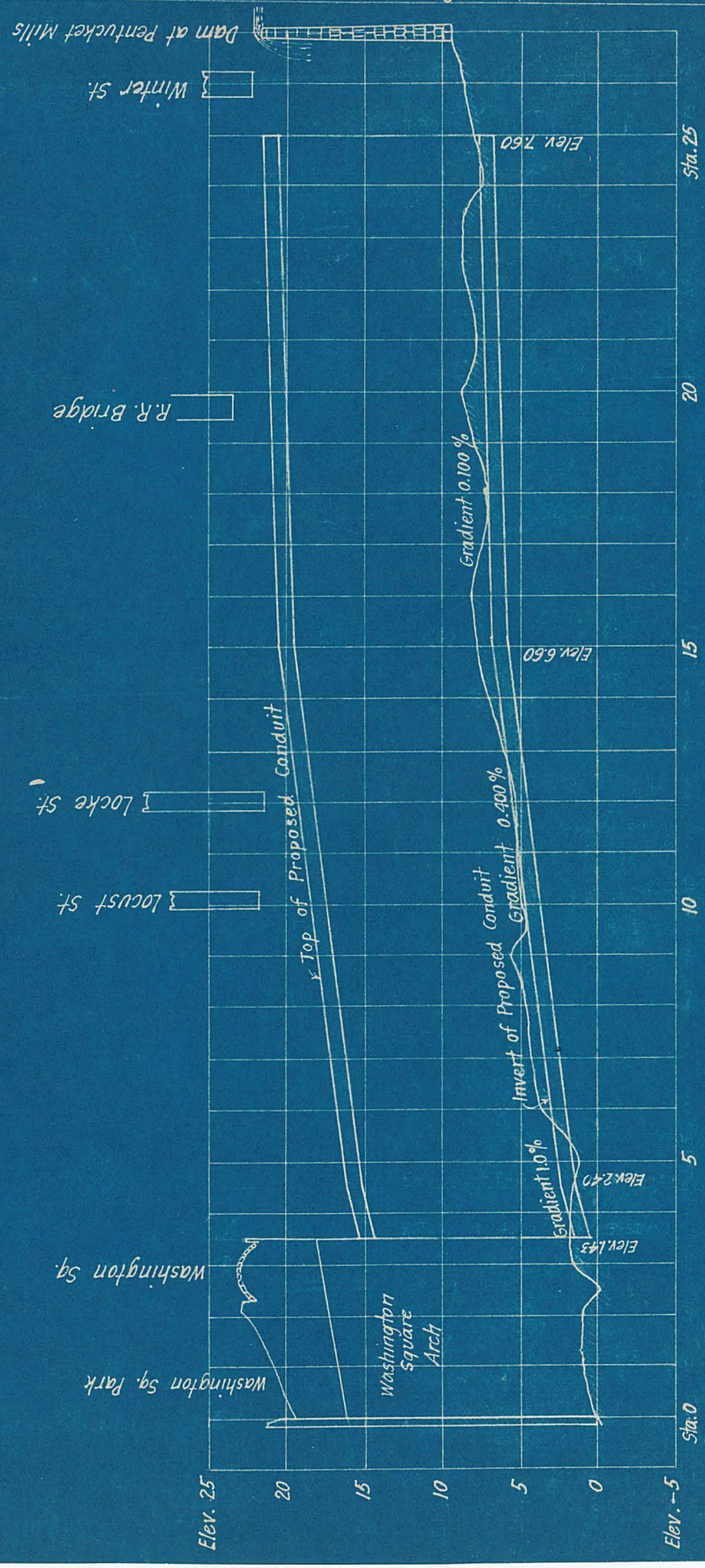


Fig. 26

posed conduit have been submitted to Mr. Richard A. Hale, engineer for the Pentucket Mills, and after several conferences the recommended design has been approved by him for the Pentucket Mills. A copy of his letter of approval follows:-

"Lawrence, Mass.,
October 19, 1916.

"Professor C. B. Breed,
Consulting Engineer Haverhill Board of Health,
Boston, Mass.

Dear Sir:-

As Engineer for the Pentucket Mills I have made a thorough examination of the design for the proposed twin channel conduit recommended in your report to the Board of Health of the City of Haverhill dated October 21,1916, and as a result of my investigation, and with the authorization of the owners of the Pentucket Mills, the M. T. Stevens and Sons Company, I hereby approve your design and am satisfied that it properly conserves the interests of the Pentucket Mills.

Yours truly,

(Signed) Richard A. Hale,

Engineer for Pentucket Mills."

The proposed conduit will have practically no effect upon the existing buildings or walls along the bank of the river below Winter St. All of the drains from those buildings which discharge only water will be connected directly to the proposed conduit. In fact the few existing sewers and factory waste drains could also be made to discharge into the conduit, but it is deemed advisable, for

reasons explained later, to connect all such drains with the existing city sewers which can all be done in a practical manner.

The present abutters along the river will not be deprived, by the construction of the conduit, of any of the advantages it now presents to them. On the other hand, the complete covering of this filthy stream will be a considerable improvement to the entire locality through which it flows.

If all of these objectionable materials are thus kept out of the proposed conduit there can never in the future be any objection to discharging all of the flow of Little River directly into the Merrimac River at the shore line. The State Department of Health now requires the city to extend any new sewer outlet to deep water, and in the future it may require the extension of the existing sewers which have their outlet at the shore of the Merrimac River, but such requirement will not apply to the Little River Conduit if sewage is not admitted to it.

In the future Haverhill may even be required to filter or to chemically treat all of its sewage, and when that time arrives no revisions of the work proposed in this report will be necessary, for the flow from the Little River conduit, will be pure enough to be permitted to discharge directly into the Merrimac. At that time the storm water now carried by the Essex St. sewer and by other combined sewers which lie within the natural drainage area of Little River

can also be diverted through storm water drains into the Little River conduit and thus eliminate large quantities of water from the filter beds.

Removal of Sewer Outlets in Little River.

The buildings from but three properties now discharge sewage into the river, the Coombs and the two Taylor properties on Emerson St.

(1) Coombs Building, corner of Washington Sq. and Emerson St.

At the present time all of the sewage from this building empties into Little River through one opening in the wall 18" x 24" in size. The basement level of the building is about 9 1/2 ft. below the grade of Emerson St. The Emerson St. sewer is about 5 ft deep. Obviously toilet fixtures in the basement of the Coombs building cannot drain by gravity into the Emerson St. sewer, but all sewage above the first floor level can be connected with the Emerson St. sewer, and the basement fixtures can be drained to the well of a sewage ejector which can be installed in the basement of the Coombs building and which will automatically pump the sewage into the Emerson St. sewer. These ejectors are thoroughly reliable; they are successfully used in the basements of most of the large department stores, hotels and theatres of Boston and other cities.

(2) Ezra and Levi Taylor's Business Blocks, Emerson St.

The condition in these buildings is similar to that in the Coombs building, except that the sewage is discharged through three 8" sewers into Little River. Here, again, the sewage from above the first floor can be taken by gravity into the Emerson St. sewer and the basement sewage pumped into the Emerson St. sewer by means of sewage ejectors.

Removal of Injurious Factory Wastes from Little River.

(1) Lennox & Briggs Tannery.

Certain factory wastes which are acid in character injuriously affect the concrete of which the proposed conduit is to be constructed. This is true of the wastes which are discharged from all of the higher level drains from Lennox & Briggs tannery. The discharges from the two lower level drains at this point are alkaline, which will not have any deleterious effect upon the materials of the proposed conduit. It is proposed to connect the upper drains, those with acid discharges, to a sewer which discharges by gravity into the Duncan St. sewer and to permit the other two (low-level) drains to discharge into the conduit.

(2) Pentucket Mills.

The only other case of factory wastes discharging into the river is that at the Pentucket Mills. The prob-

ability is that these discharges enter the river so far above the end of the proposed conduit as to be diluted so much that they will not be injurious to the concrete of the conduit, but if further investigation or experience shows this not to be the case, these injurious materials can be drained to a sewage ejector which will automatically discharge them into the Winter St. sewer.

Yield of Little River Drainage Area.

The maximum discharge of Little River of which any knowledge is available is about 700 cu. ft. per sec. At several other times it has reached 600 cu. ft. per sec. Under all such high water conditions the Pentucket Mills are flooded, and when the water in the Merrimac is also high this flooding is serious. Twice in the past 30 years the Merrimac has risen so as to flood Washington Square Park as shown in Fig. 27. The proposed conduit has been so designed that at its upper end its floor is a little lower than the bed of the present river so as to insure a free run-off from the tailrace of Pentucket Mills and thus cause no damage to the water power of that industry. It has also been designed so that it will discharge 1200 cu. ft. per sec. and not cause backwater effect at the Pentucket Mills which will be any worse under any stages of the Merrimac than that which has already been caused by floods no greater than 600 to 700 cu. ft. per sec. In other words,



Fig. 27. Washington Square Park - March 4, 1896.

Photographed by Postmaster Lot McNamara.

assuming that no greater floods occur in the future than those which have occurred during the past 50 years, then the Pentucket Mills will never again be flooded as badly as they have been in the past.

A smaller conduit, of course, could have been designed to carry say 700 cu. ft. per sec. with the same backwater effect at the Pentucket Mills as under existing conditions, but after an exhaustive study of all data available it appeared to be advisable to provide for floods somewhat greater than those which have actually occurred since records have been kept at Haverhill.

The backwater effect in the case of a rectangular conduit 14 ft. wide and 12 ft. high is shown in Figs. 48 and 49 in the appendix for discharges of 600 and 1200 cu. ft. per sec. Backwater curves for the proposed conduit would be practically like these curves.

Cross-Section of Proposed Conduit.

Two different typical sections for the proposed conduit are shown in Figs. 28 and 29, the former being a conduit with twin channels and the latter a single channel conduit. Both designs have practically the same discharge capacity. (See Tables I and II in Appendix).

The twin section is about 2 1/2 ft. wider than the single conduit and will cost about 8 per cent more; but it has the following advantages over the single conduit.

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PROJECT Haverhill Little River Improvement

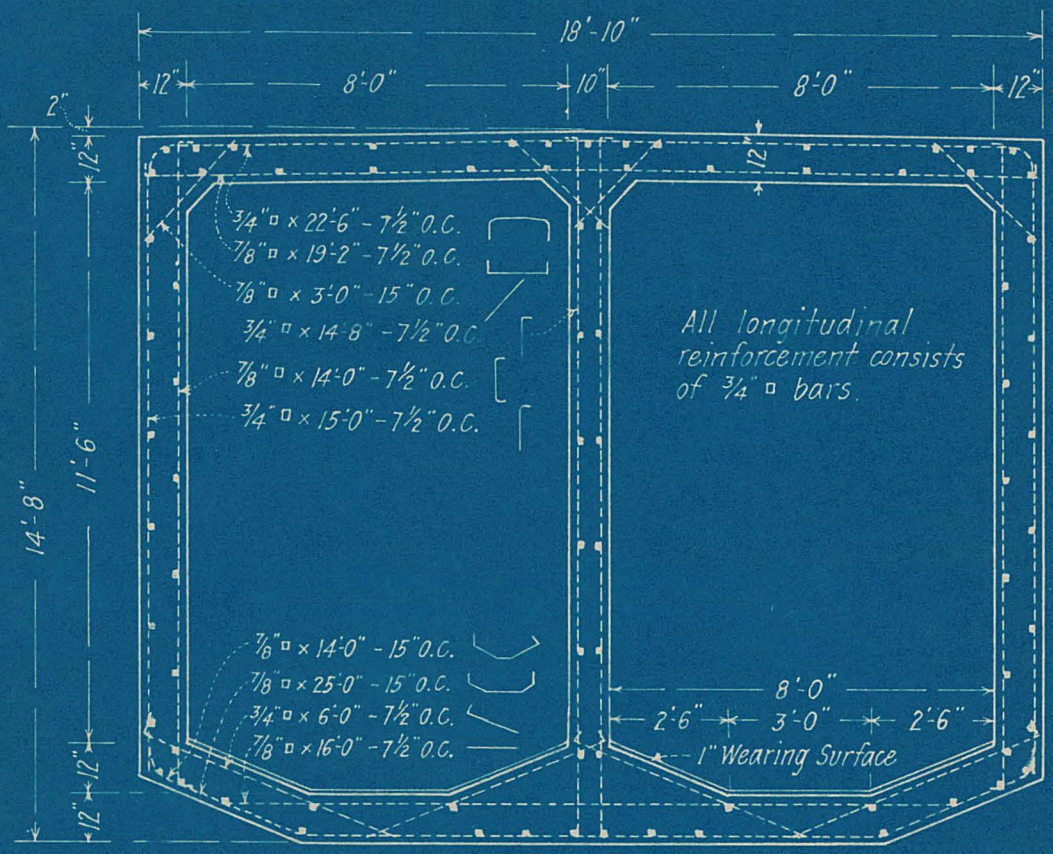
SUBJECT TYPICAL DESIGN OF SECTION OF PROPOSED DOUBLE CONDUIT

DATE, Sept. 2 1916

COMPUTED BY C. B. B.

CHECKED BY

Scale, 1/4" = 1'



— Estimated Quantities —

Concrete	2.8 Cu. Yds.
Steel	900 Lbs.
Forms	87 Sq. Ft.
Granolithic	17 Sq. Ft.

Quantities are for one lin. ft. of conduit.

Fig. 28

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SUBJECT TYPICAL DESIGN OF SECTION OF PROPOSED SINGLE CONDUIT

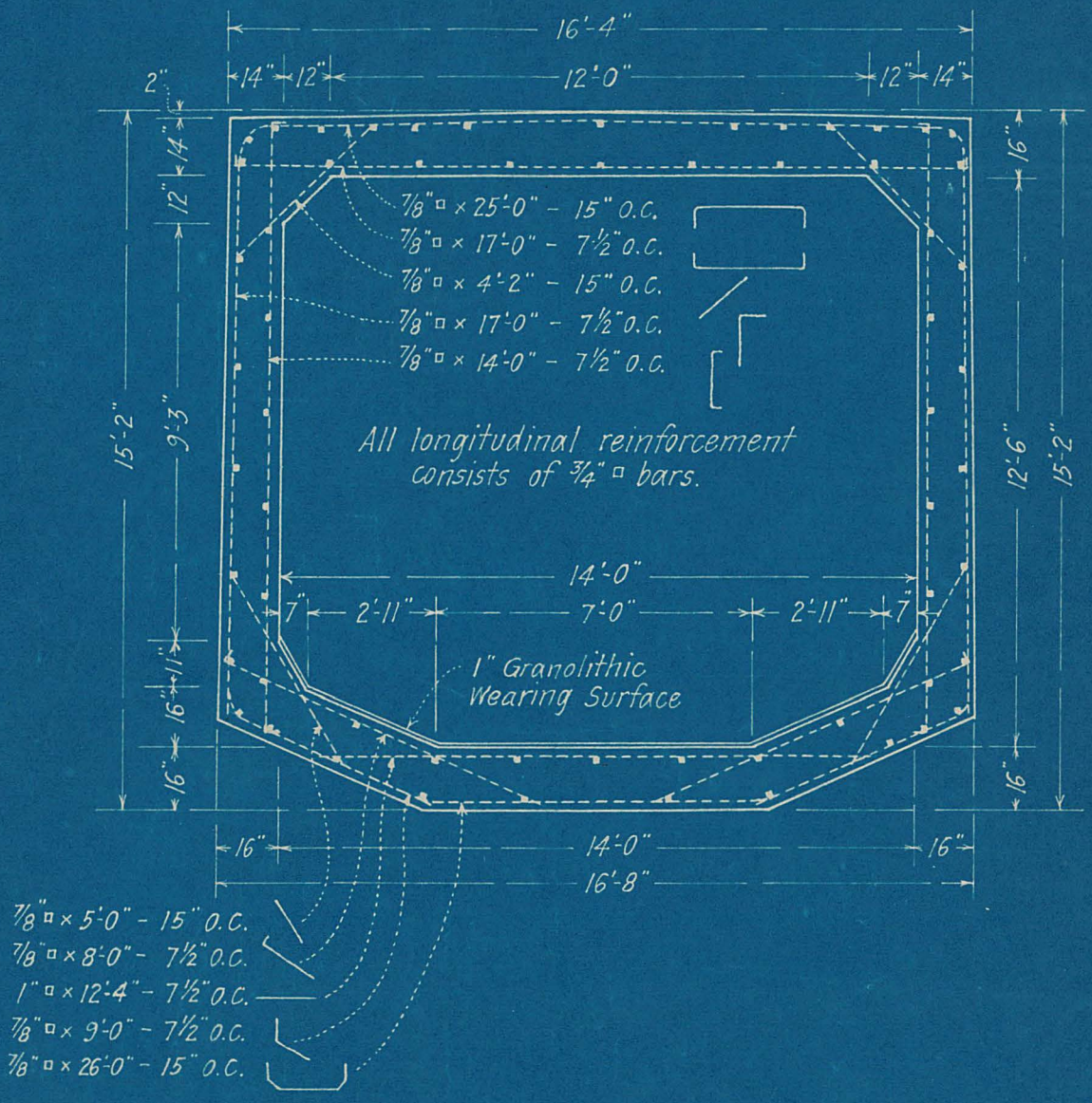
SHEET NO.

DATE, Sept. 2 1916

COMPUTED BY C. B. B.

CHECKED BY

Scale, 1/4" = 1'



Estimated Quantities

Concrete	2.63 Cu. Yds.
Steel	850 Lbs.
Forms	61.5 Sq. ft.
Granolithic	15.5 Sq. ft.

Quantities are for one lin. ft. of conduit

Fig. 29

One side can be constructed at a time while the natural flow of the river is carried in the other half of the present channel. Its floor can be designed of such shape that velocities great enough to scour the channel clear can be obtained even when the water flowing in the river is relatively small in amount. All of the flow can be taken through one of the twin channels under ordinary conditions, which will give sufficient velocity to keep it clean, the second channel coming into use only in high water conditions. At the upstream end of the conduit stop planks should be provided, so that if the conduit should become silted up the entire flow of the river can at any time be diverted through one channel, thereby producing a velocity of flow sufficient to thoroughly clean the channel. By means of these stop planks also the flow can be directed so that any needed repairs can be made in either side of the conduit.

The advantage of the single over the double conduit appears to be principally in the fact that it will cost about $12,000 less, which cost would probably be somewhat offset by increased maintenance to keep the channel cleaned should it become silted. It is not expected, however, that much of this cleaning would be required because at every sharp, hard storm the flow through the conduit would reach a velocity sufficient to scour it. These storms, however, might come at such long intervals

that some cleaning of the conduit might be required; and as the single conduit is larger in cross-section at the lower stages of the river the velocities will be lower and hence the liability to silting greater.

Taking all things into consideration, the twin section, Fig. 28, is recommended.

The conduit has been designed of reinforced concrete of strength sufficient to support a street and its heavy traffic. Six different conditions of loading have been considered in this design, covering all the possible conditions which could prevail; these are fully enumerated in the Appendix. The inside dimensions will be uniform and without any obstruction whatever throughout its entire length, and the lining will be a smooth concrete. Where column supports for existing buildings have been built, such supports will be carried directly on top of the conduit, necessitating special design for the roof at these places. The inspection can be made through conveniently located manholes.

The Locke St. sewer, which now passes directly through the Locke St. arch and interferes with the flow of the river at higher stages, is to be carried under the proposed conduit by means of a so-called inverted siphon, which is a thoroughly practical construction for these conditions.

At the streets the conduit will be carried directly under the existing arches without interfering with any of the

present structures, and along its entire course it will lie inside the existing walls of the river. To assist further in understanding the location this proposed conduit will occupy with reference to existing structures, typical cross-sections have been prepared and are shown in Figs. 30 to 44, inclusive.

Foundations and Construction Features.

Borings were made in August, 1916 by The Charles R. Gow Co. of Boston, under the direction of your engineer, at a cost of $320. Twenty-four holes were driven in the river bed at intervals throughout the entire length from Winter St. to Washington Square, with the uniform result that the foundation for the conduit will in all places be either gravel or a mixture of sand and gravel, except in the vicinity of Winter St., where sand prevails for a depth of 30 ft.

Fig. 50 in Appendix shows the location where each boring was made and Figs. 51 to 54 give in detail the materials encountered at each boring. An arrow is drawn in red on each boring showing where the bottom of the conduit will come and the materials which will be encountered.

These results of borings indicate clearly that no piles will be needed throughout the entire length of the proposed construction. It will, however, beadvisable to drive a row of splined H.P. sheet piling into the sand of

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PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

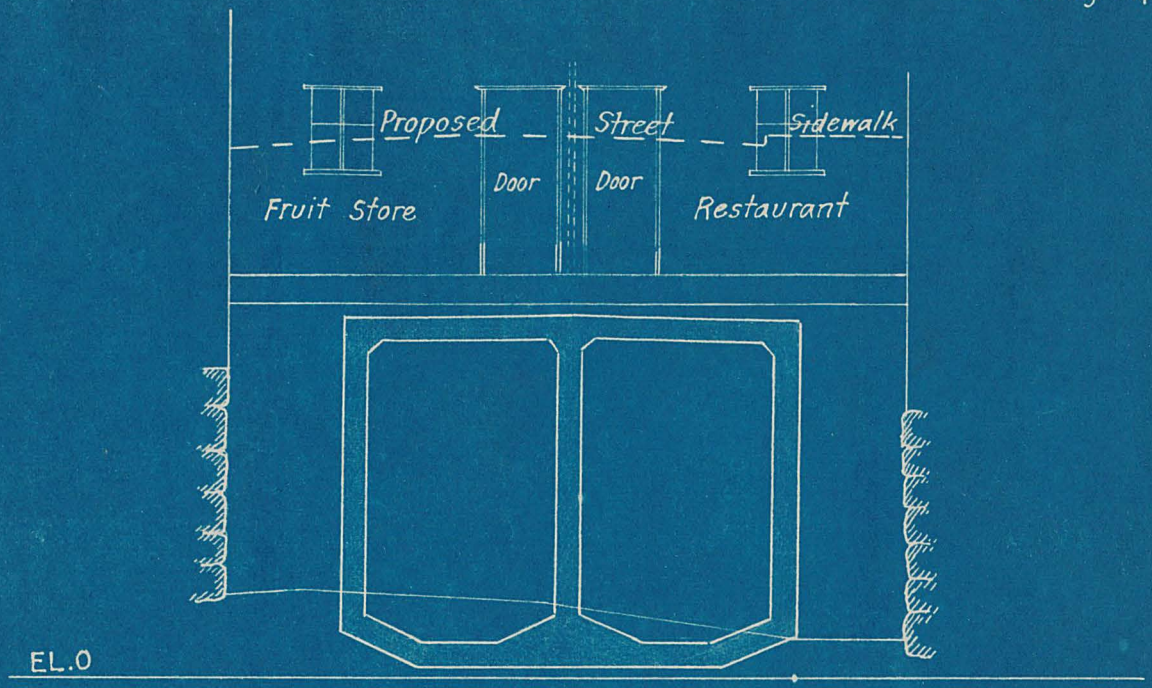
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DATE, August 1916

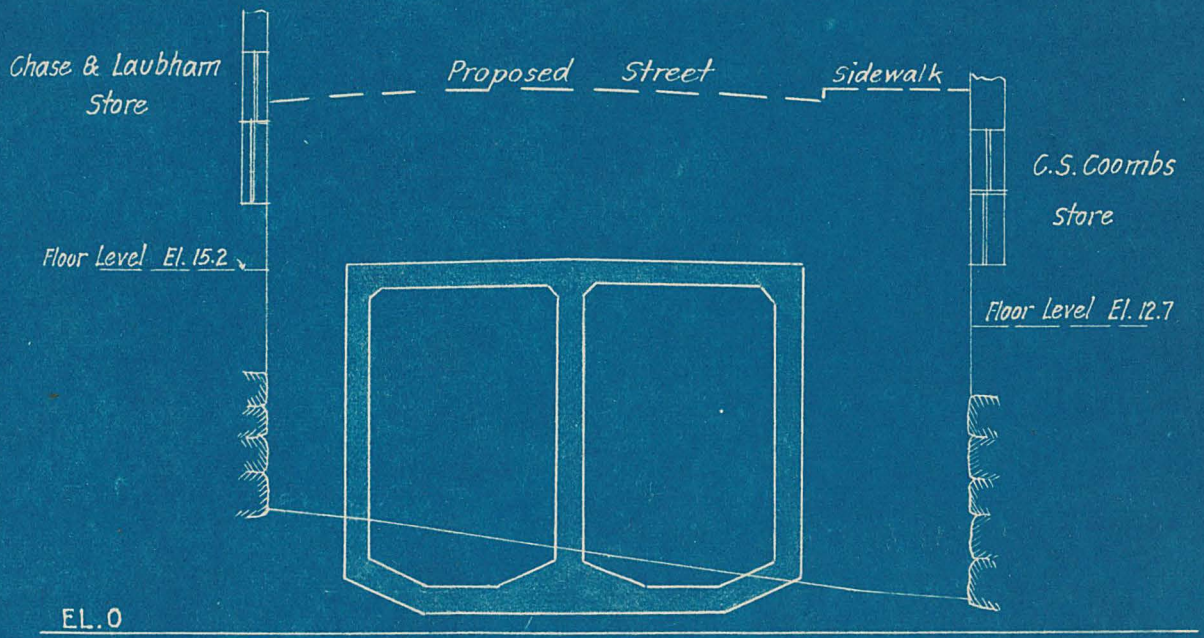
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Scale, 1" = 8'
Looking Upstream



STA. 3+53 AT UPSTREAM SIDE OF WASHINGTON SQ. ARCH



STA. 4+00 ABOUT 50 FT. UPSTREAM FROM WASHINGTON SQ. ARCH

Fig. 30

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PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

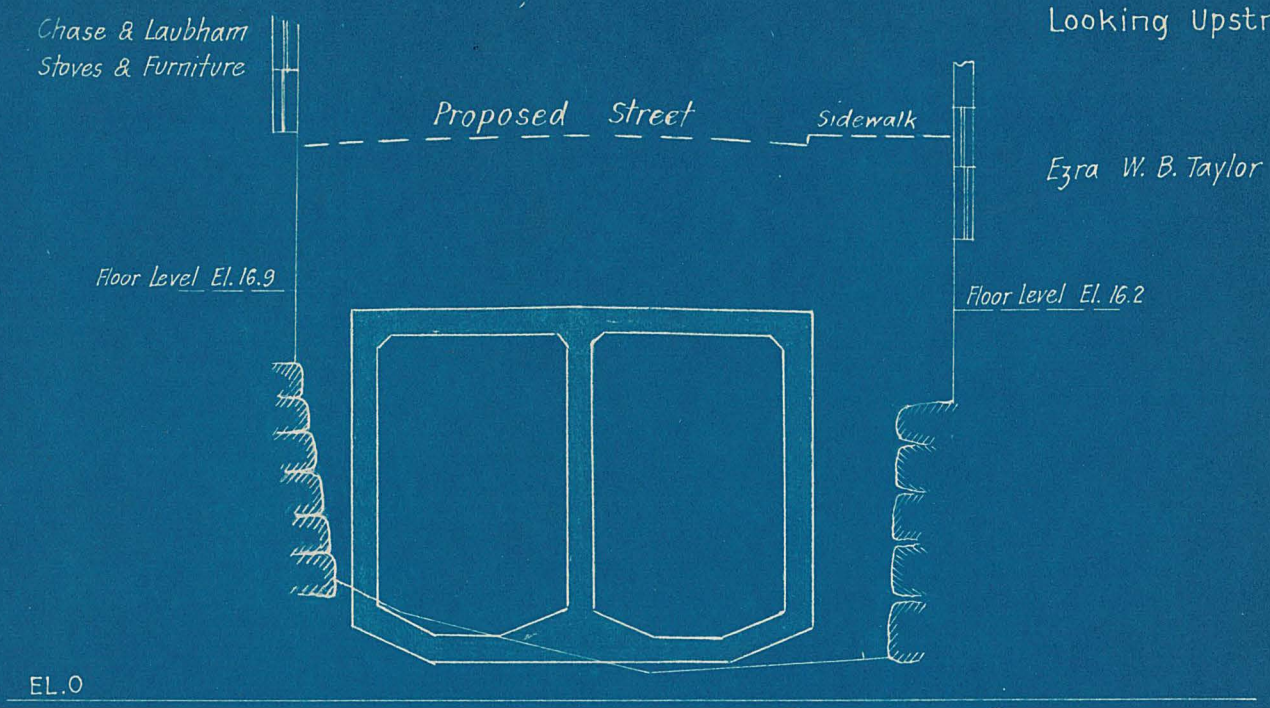
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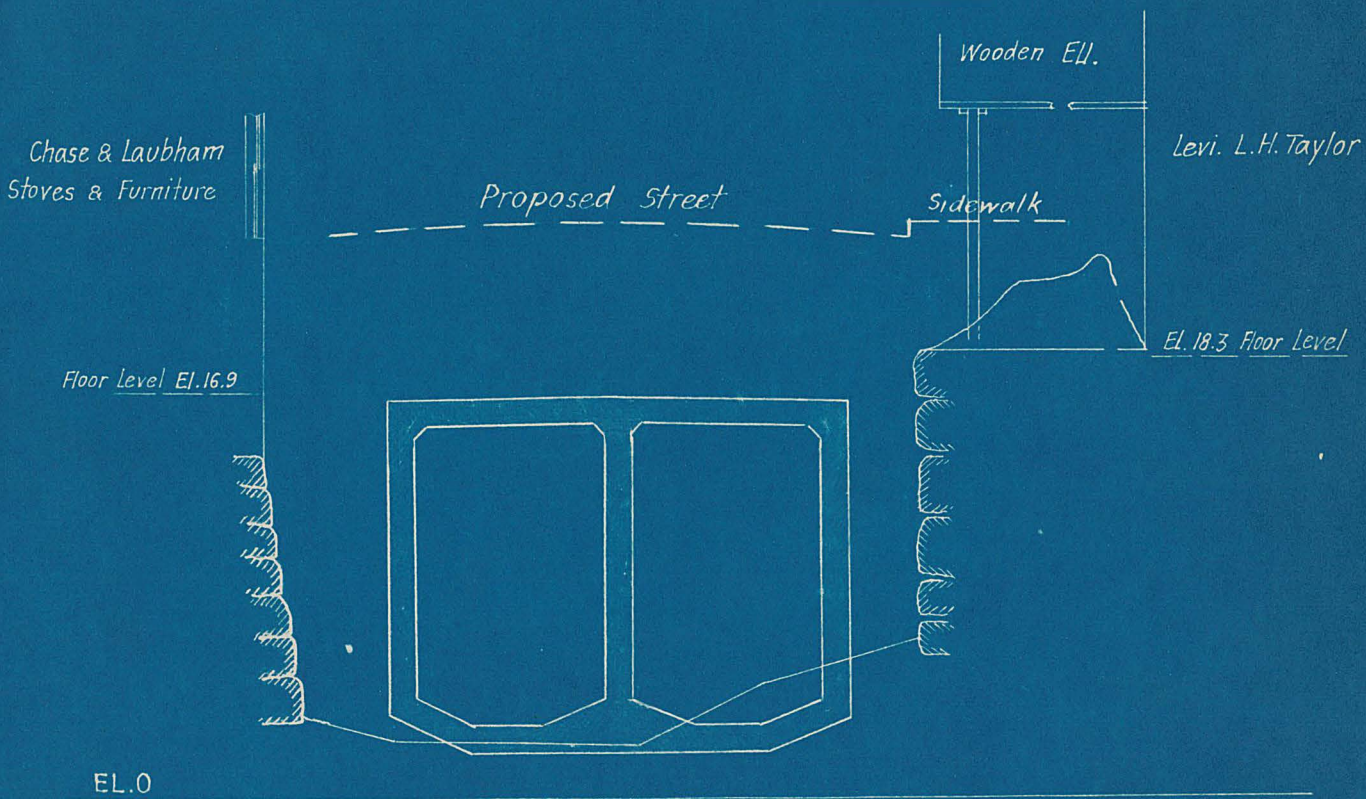
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Scale, 1" = 8'
Looking Upstream



STA. 5+00 ABOUT 150 FT. UPSTREAM FROM WASHINGTON SQ. ARCH



STA. 5+50 ABOUT 200 FT. UPSTREAM FROM WASHINGTON SQ. ARCH.

Fig. 31

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SUBJECT Present and Proposed Cross Section

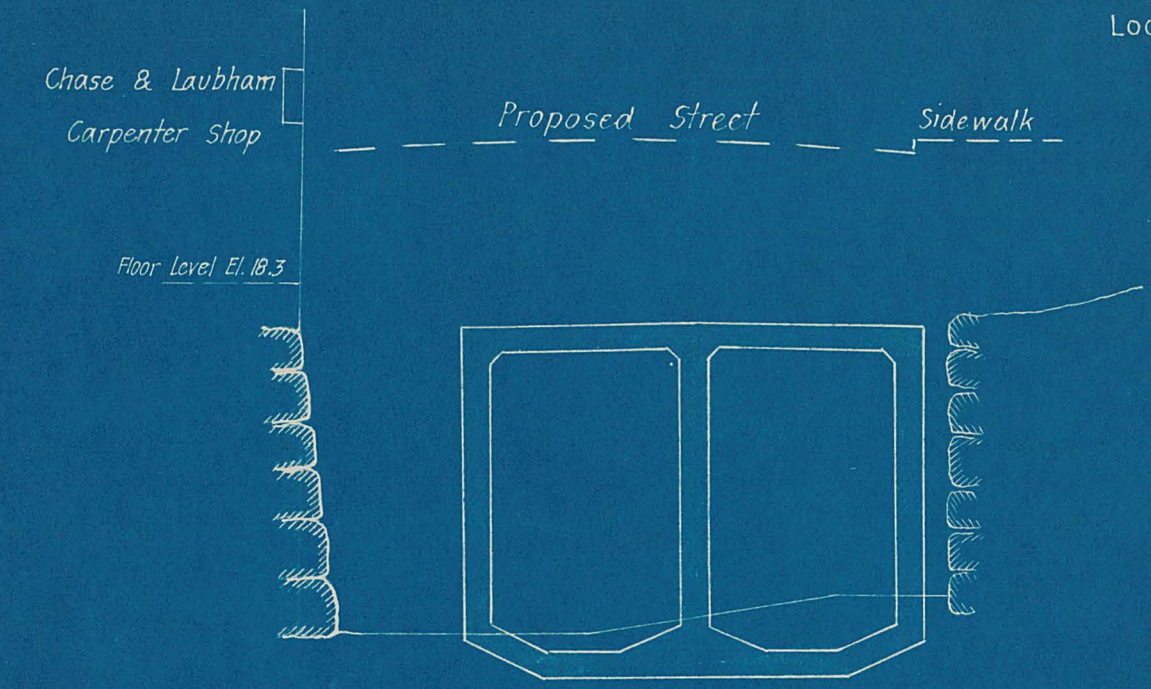
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DATE, August 1916

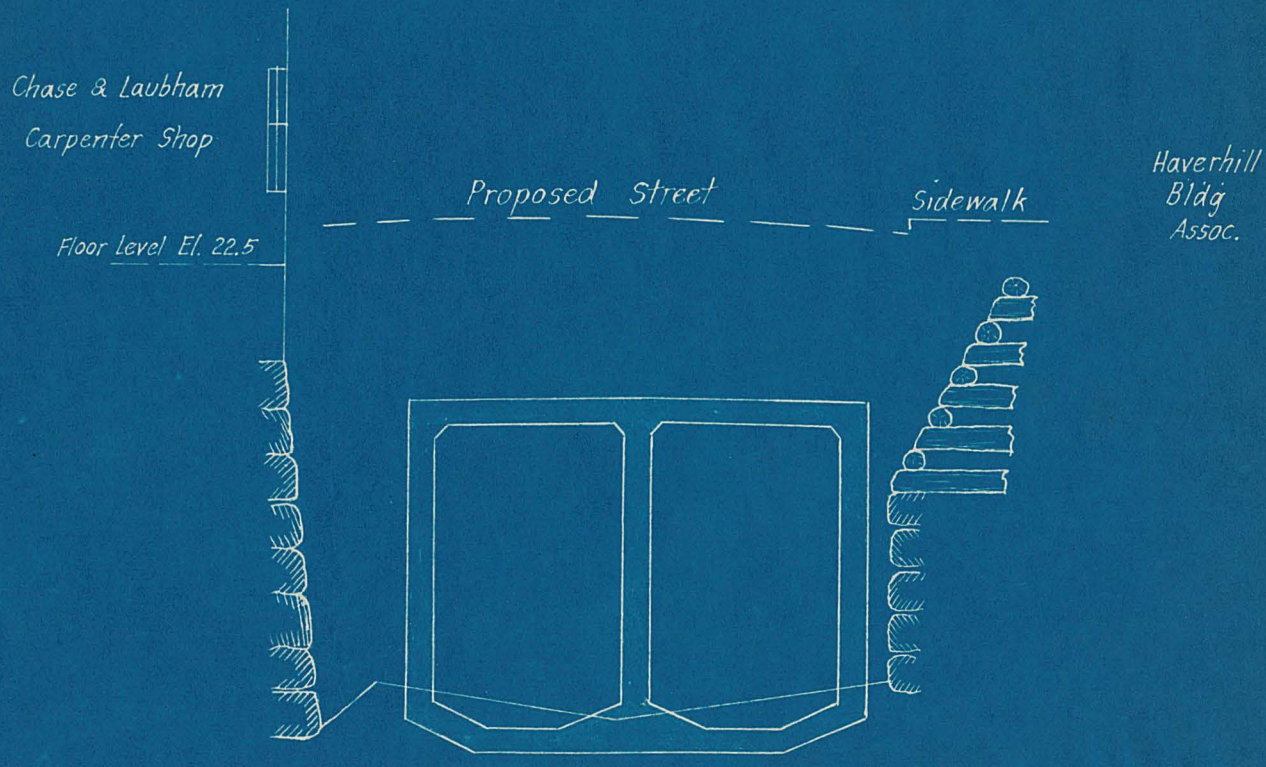
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Scale 1" = 8'
Looking Upstream



STA. 6+00 ABOUT 250 FT. UPSTREAM FROM WASHINGTON SQ. ARCH



STA. 6+50 ABOUT 50 FT. DOWNSTREAM FROM FOOT-BRIDGE

Fig. 32

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6 BEACON ST., BOSTON

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SUBJECT Present and Proposed Cross Section

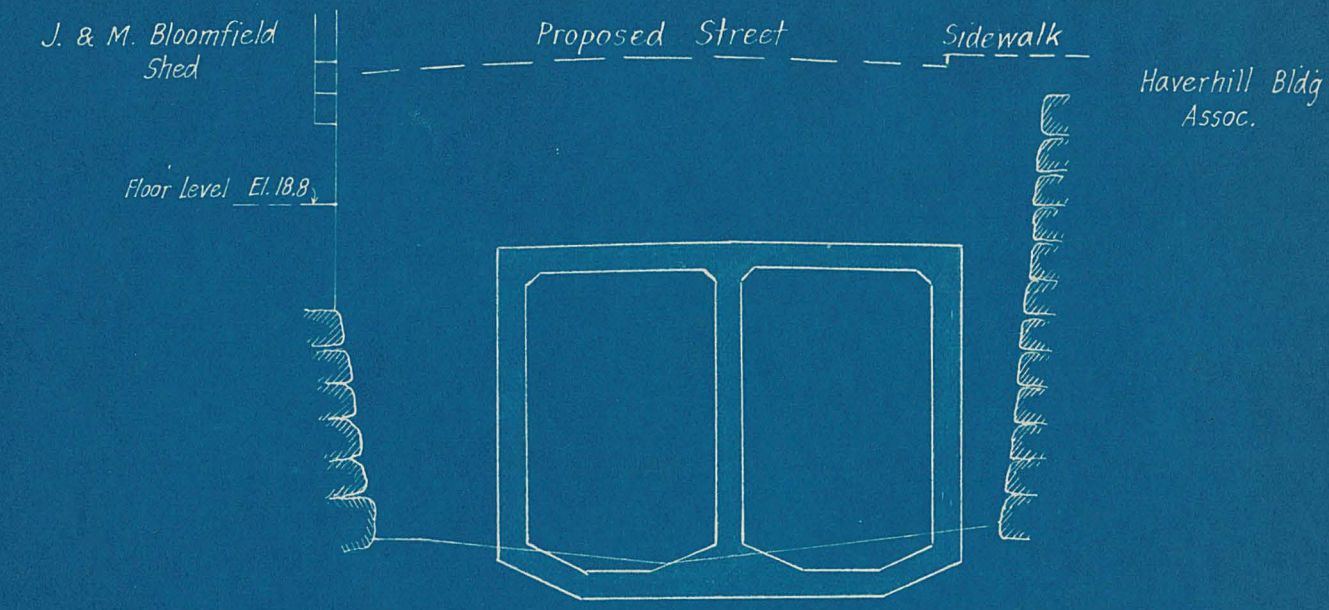
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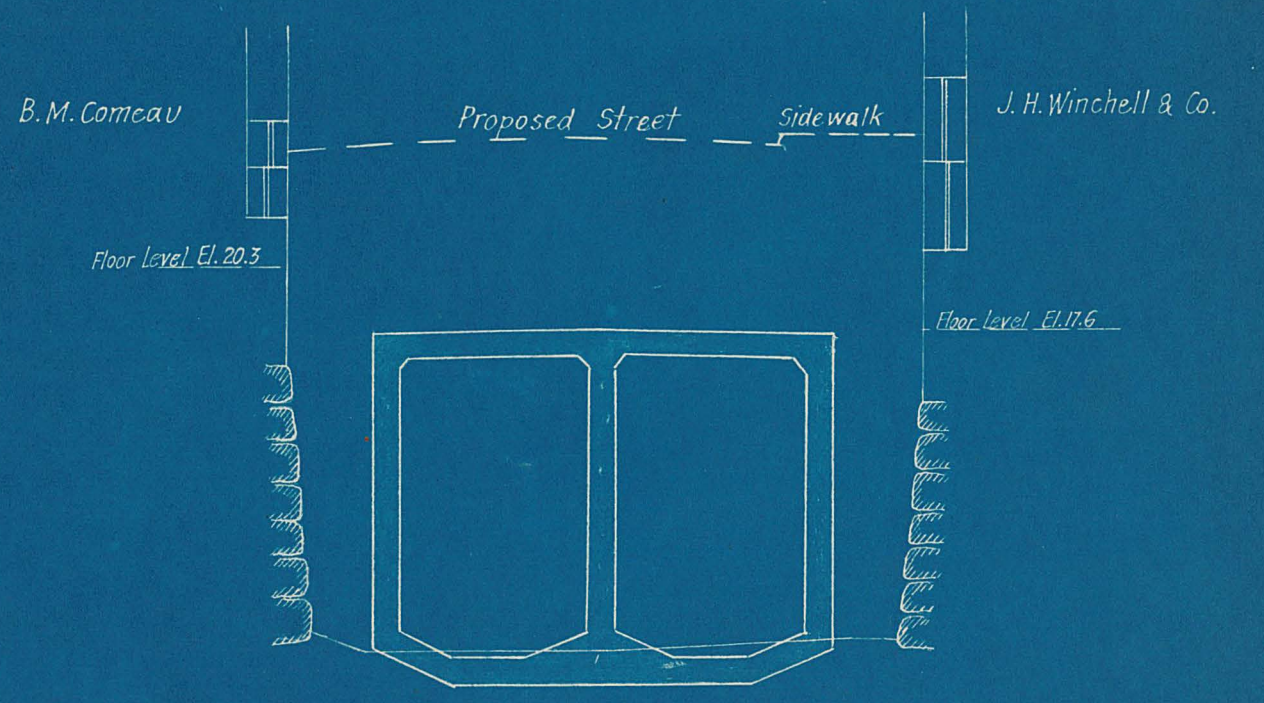
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Scale, 1" = 8'
Looking Upstream



STA. 7+00 JUST UPSTREAM FROM FOOT-BRIDGE



STA. 8+00 ABOUT 100 FT. UPSTREAM FROM FOOT-BRIDGE

Fig. 33

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

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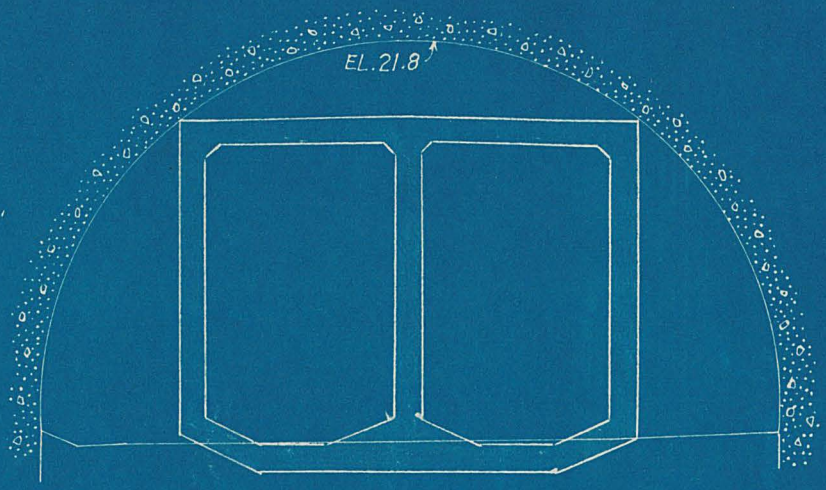
DATE, August 1916

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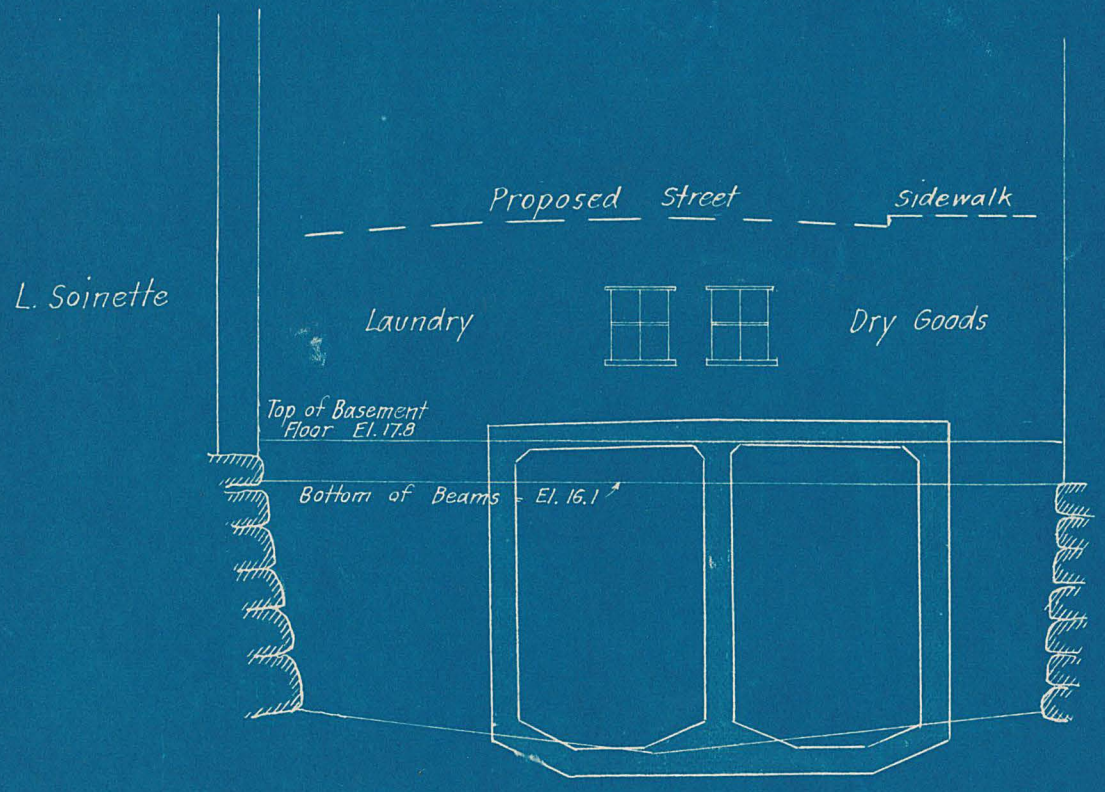
Locust St. Southerly Street Line

Scale, 1" = 8'
Looking Upstream



EL. 0

STA. 10+00 LOCUST ST.



EL. 0

STA. 10+50 ABOUT 10 FT. UPSTREAM FROM LOCUST ST.

Fig. 34

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6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

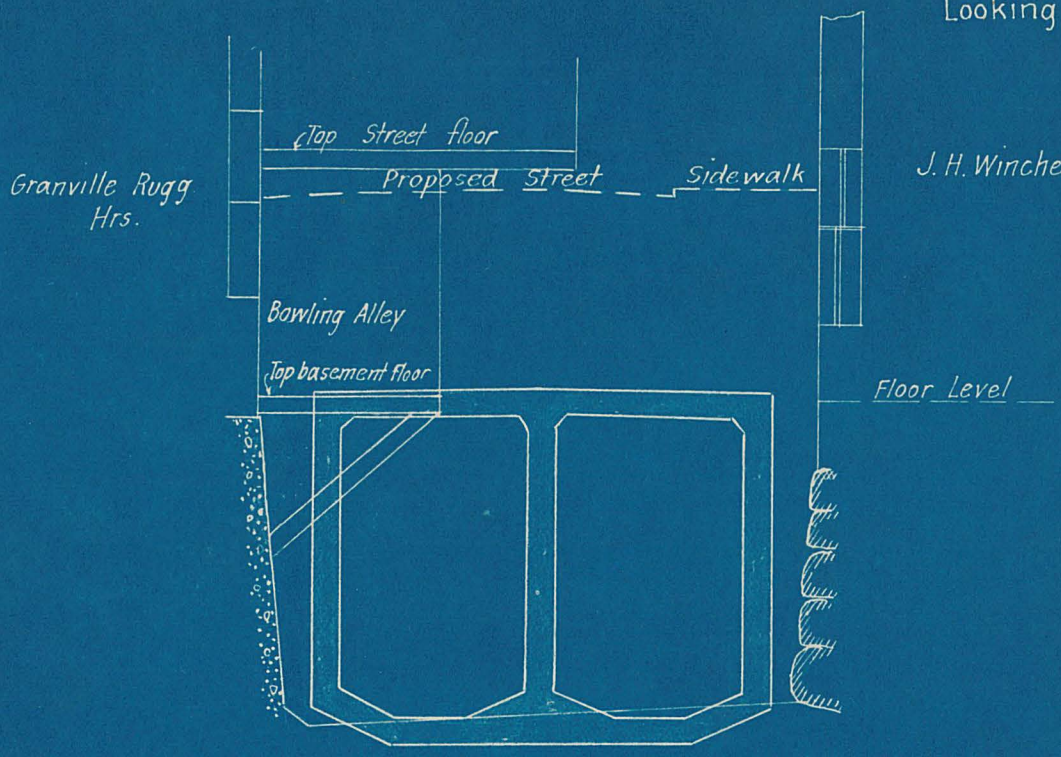
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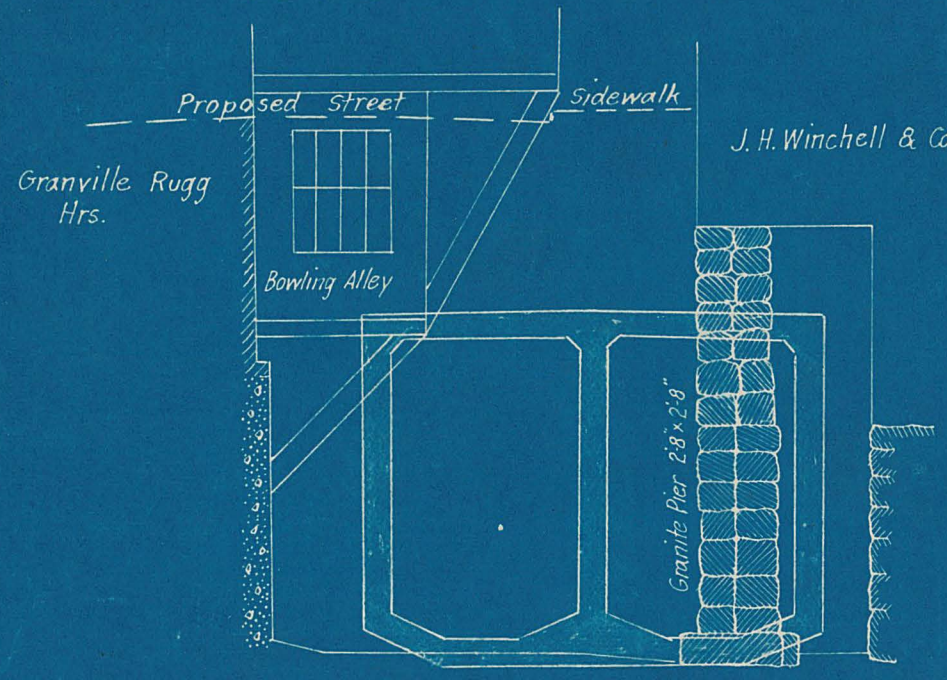
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Scale, 1"= 8'
Looking Upstream



EL. 0

STA. 9+50 ABOUT 40 FT. DOWNSTREAM FROM LOCUST ST.



EL. 0

STA. 9+62 ABOUT 30 FT. DOWNSTREAM FROM LOCUST ST.

Fig. 35

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PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

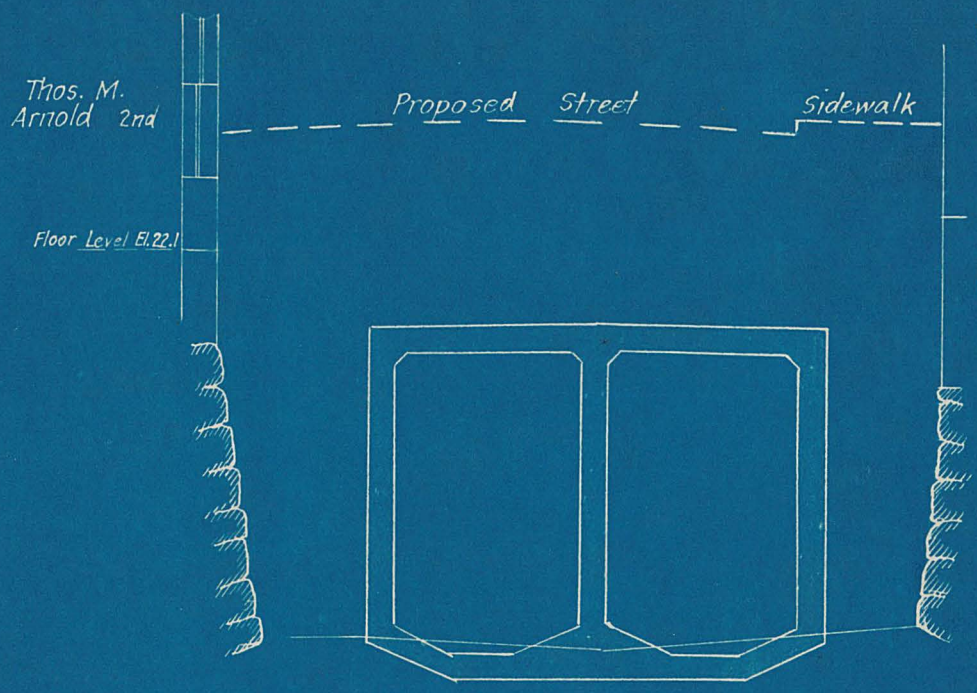
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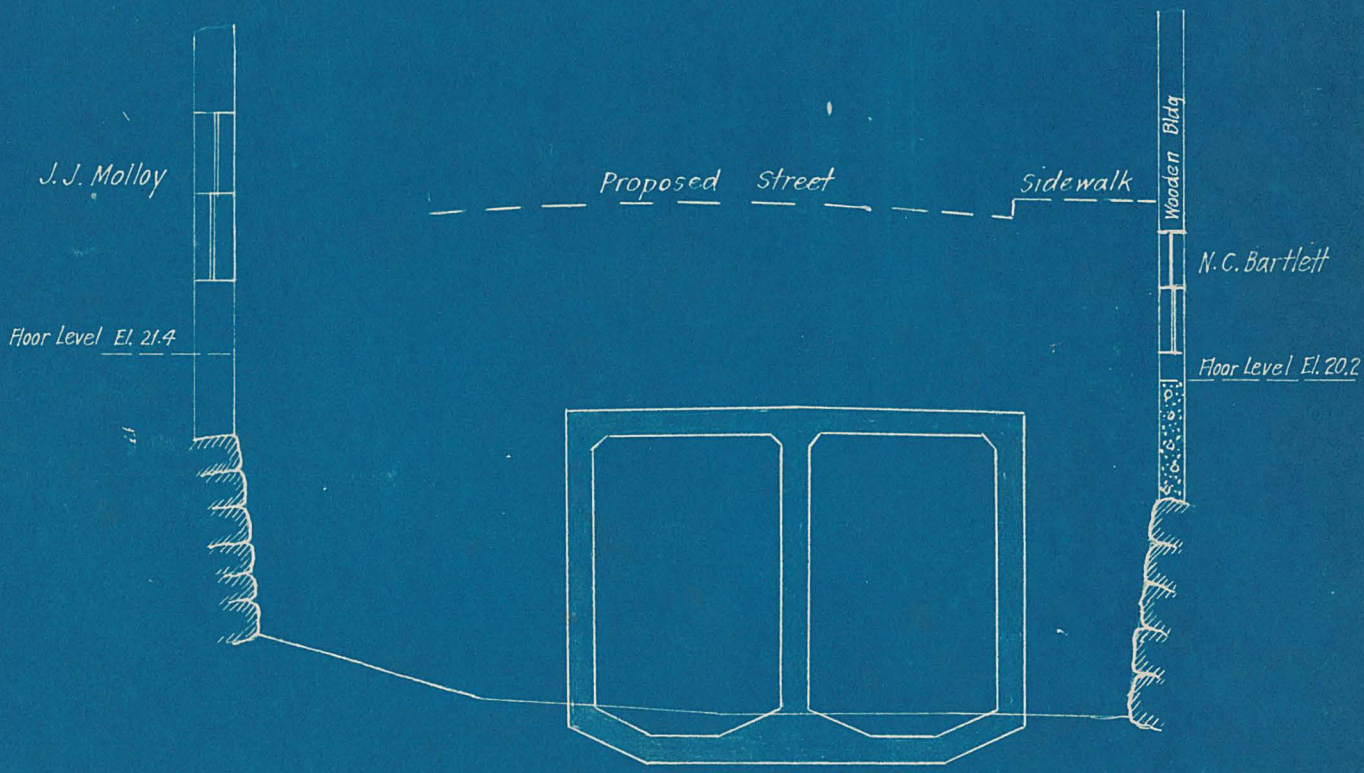
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Scale 1"= 8'
Looking Upstream



EL. 0

STA. 11+00 HALFWAY BETWEEN LOCKE ST. AND LOCUST ST



EL. 0

STA. 11+50 30 FT. DOWNSTREAM FROM LOCKE ST.

Fig. 36

CHARLES B. BREED
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PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

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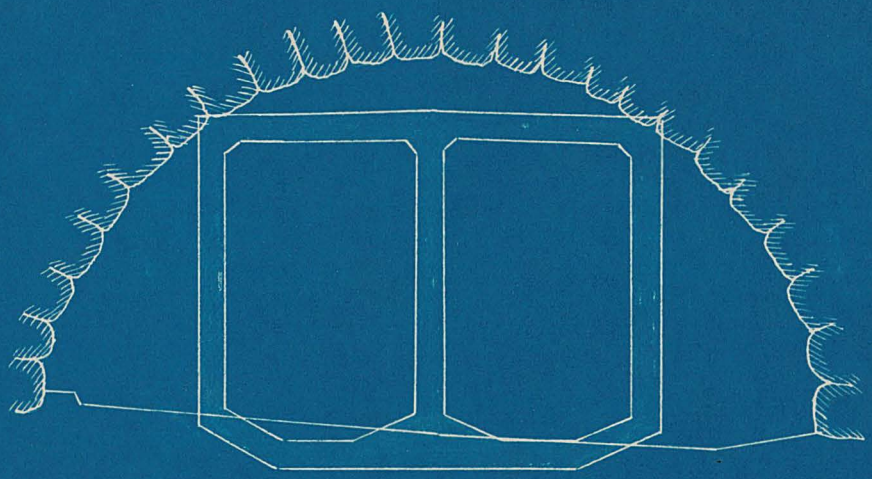
DATE, August 1916

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Scale, 1"= 8'
Looking Upstream

Locke St Southerly Street Line

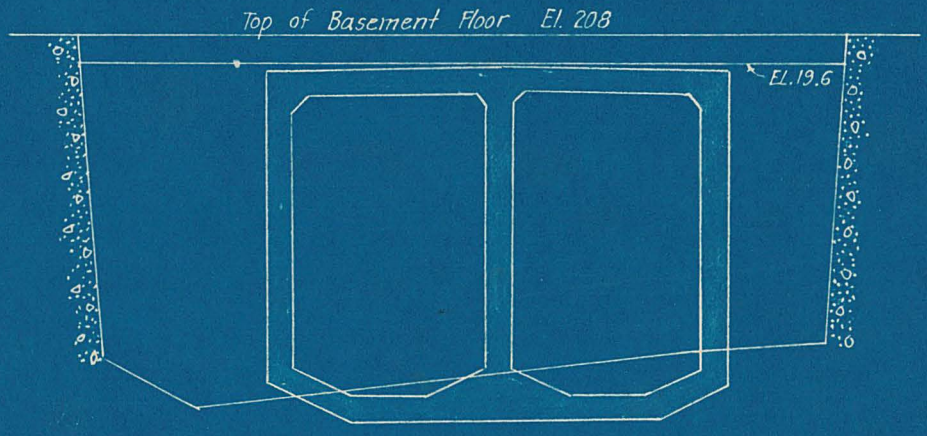


EL. 0

STA. 12+00 LOCKE ST.

Essex Associates Bldg.

Top of Basement Floor El. 208



EL. 0

STA. 12+50 ABOUT 10 FT. UPSTREAM FROM LOCKE ST.

Fig. 37

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PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

SHEET NO.

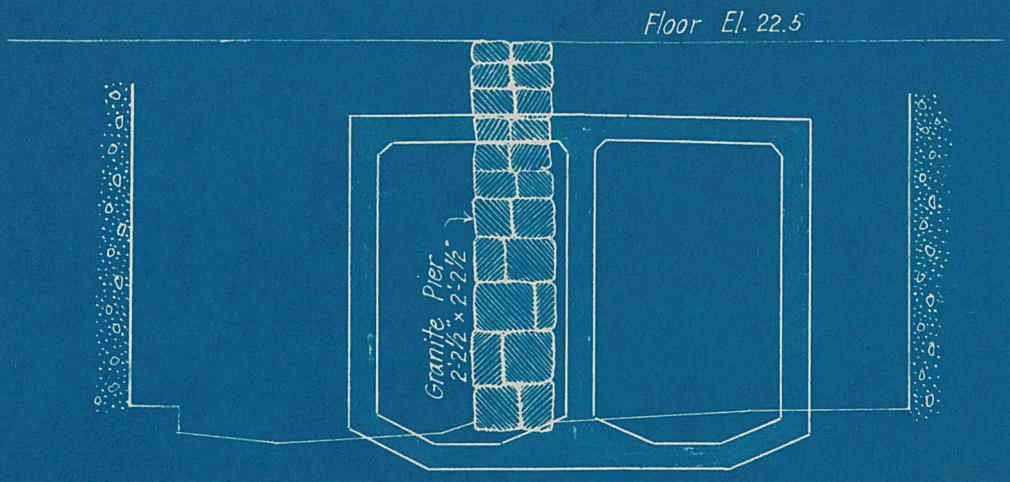
DATE, August 1916

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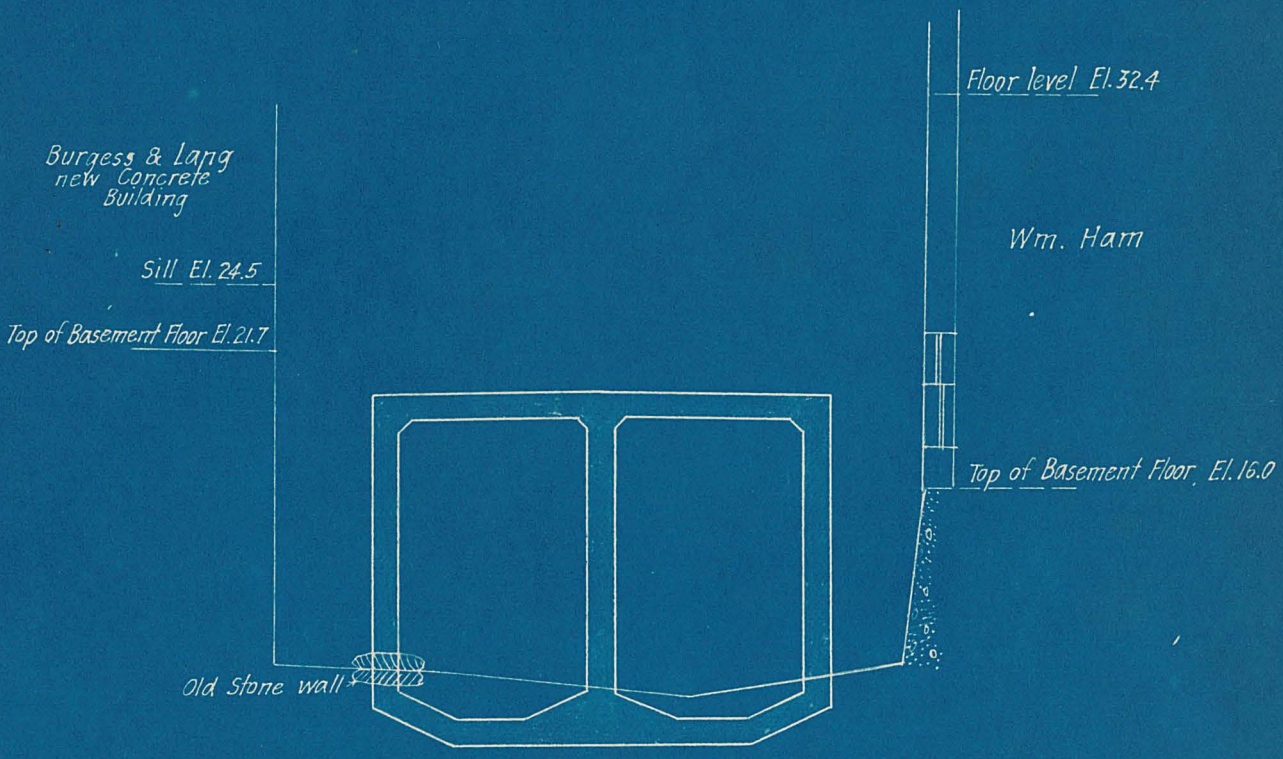
Scale 1" = 8'

Looking Upstream



EL. 0

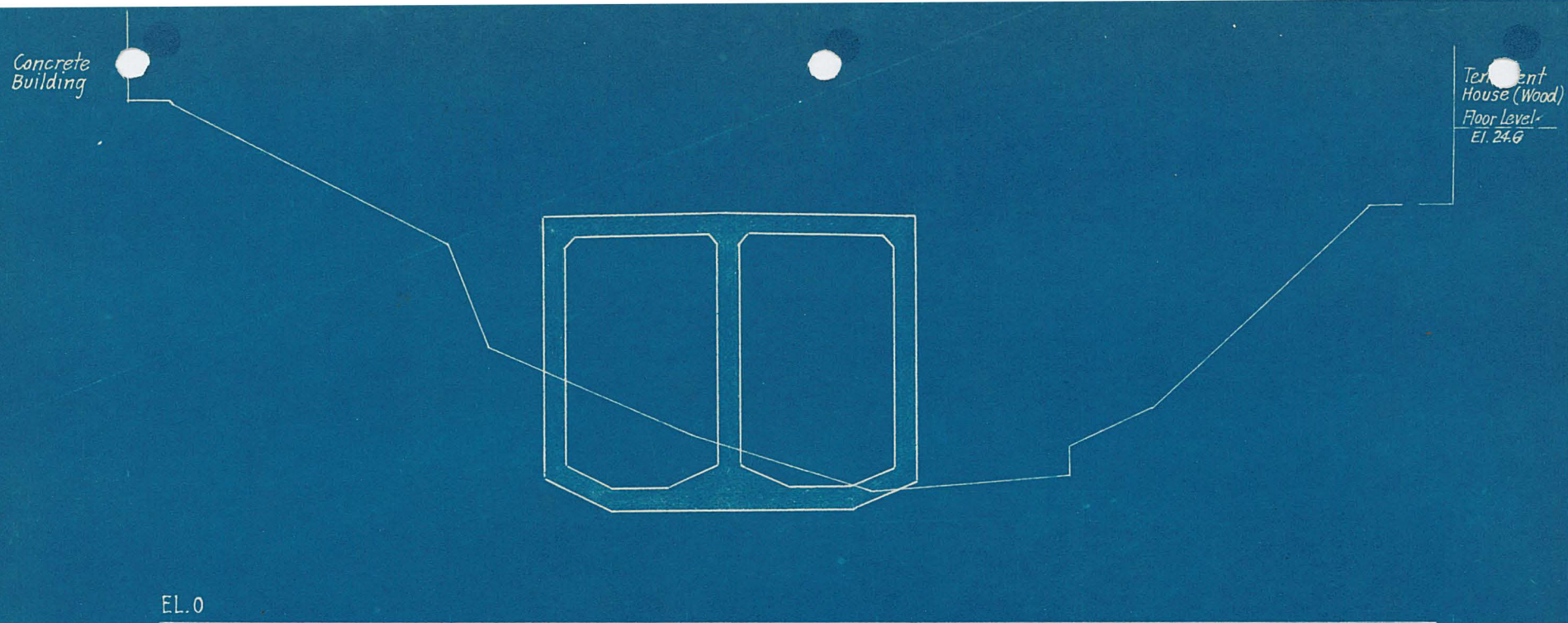
STA. 12+54.5 AT ONE OF PIERS UNDER TILTON BUILDING



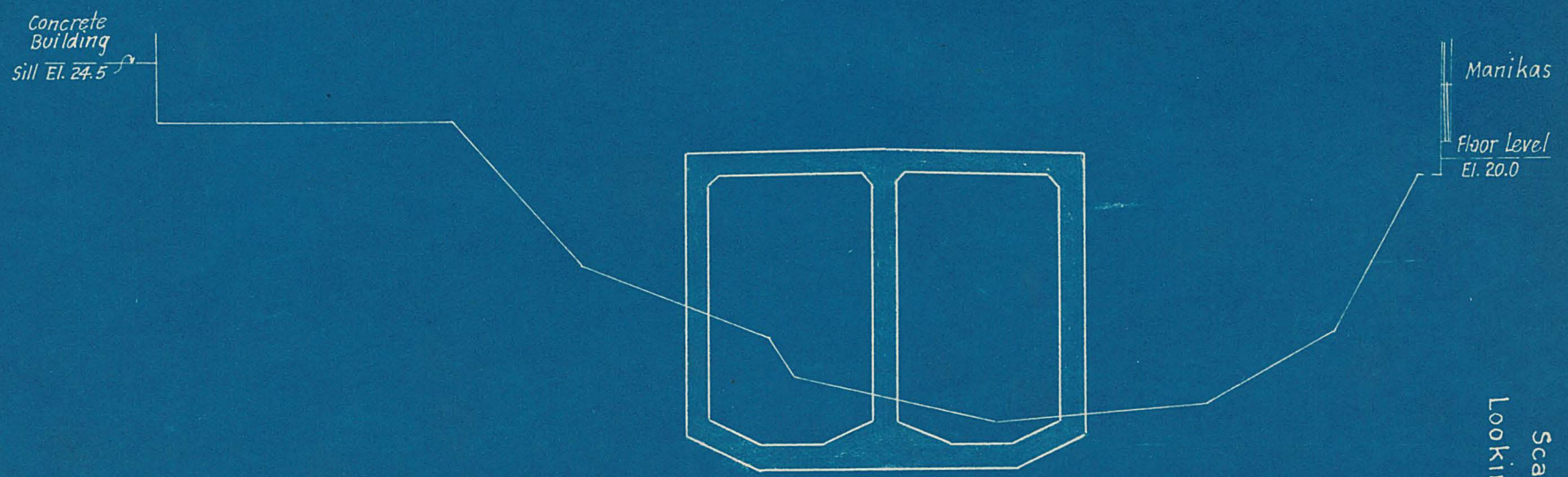
EL. 0

STA. 14+00 160 FT. ABOVE LOCKE ST.

Fig. 38



STA. 15+00 OPPOSITE ABOUT MIDDLE OF NEW CONCRETE BUILDING OF HAVERHILL TRUST CO.



STA. 15+50 OPPOSITE ABOUT MIDDLE OF NEW CONCRETE BUILDING OF HAVERHILL TRUST CO.

Scale, 1" = 8'

Looking Upstream

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

DATE August 1916

SHEET NO.

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Fig. 39

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

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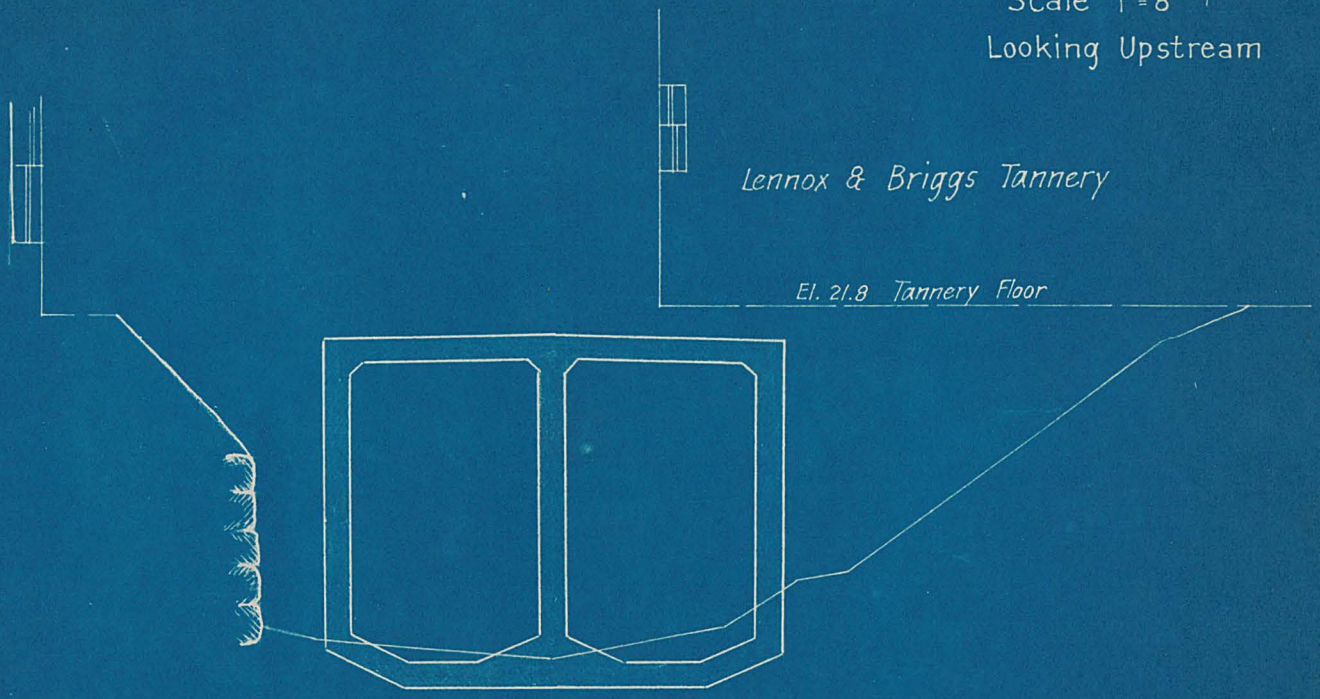
DATE, August 1916

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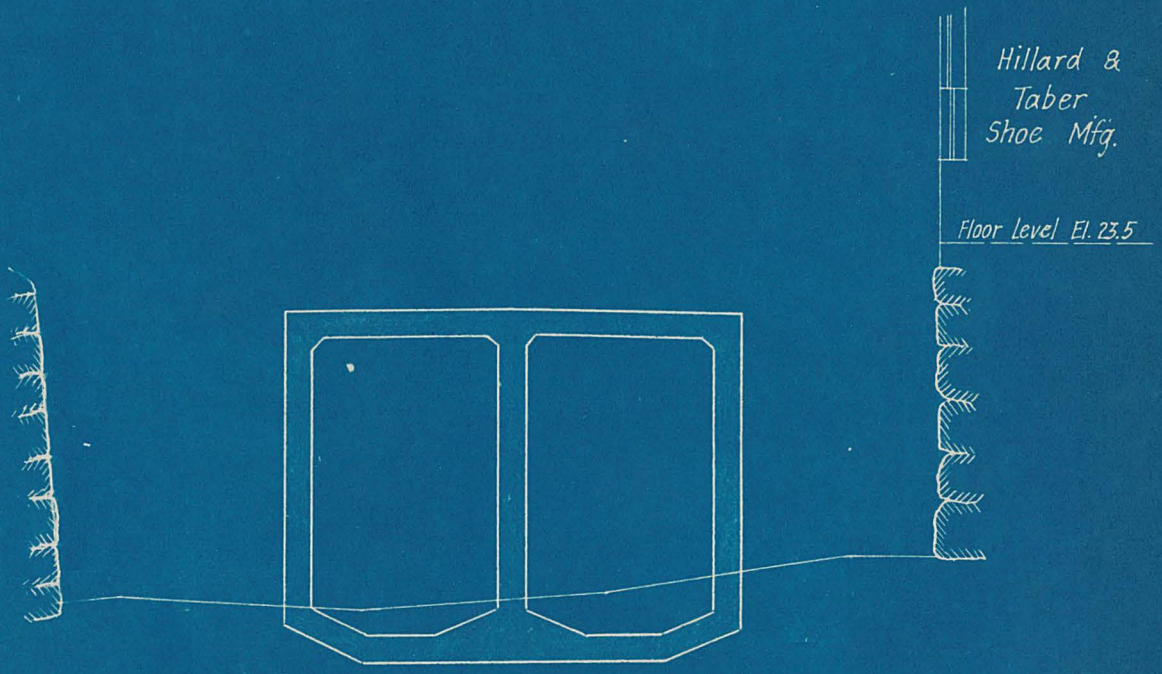
Scale 1"=8'

Looking Upstream



EL. 0

STA. 17+50 OPPOSITE LENNOX & BRIGGS TANNERY



EL. 0

STA. 19+00 ABOUT 50 FT. DOWNSTREAM FROM RAILROAD BRIDGE

Fig. 40

CHARLES & BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

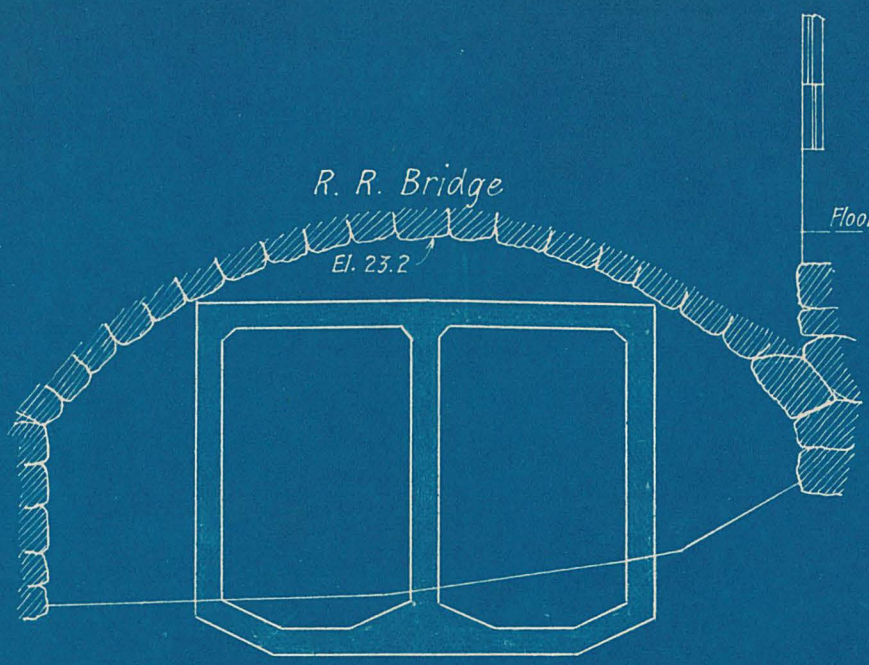
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DATE, August 1916

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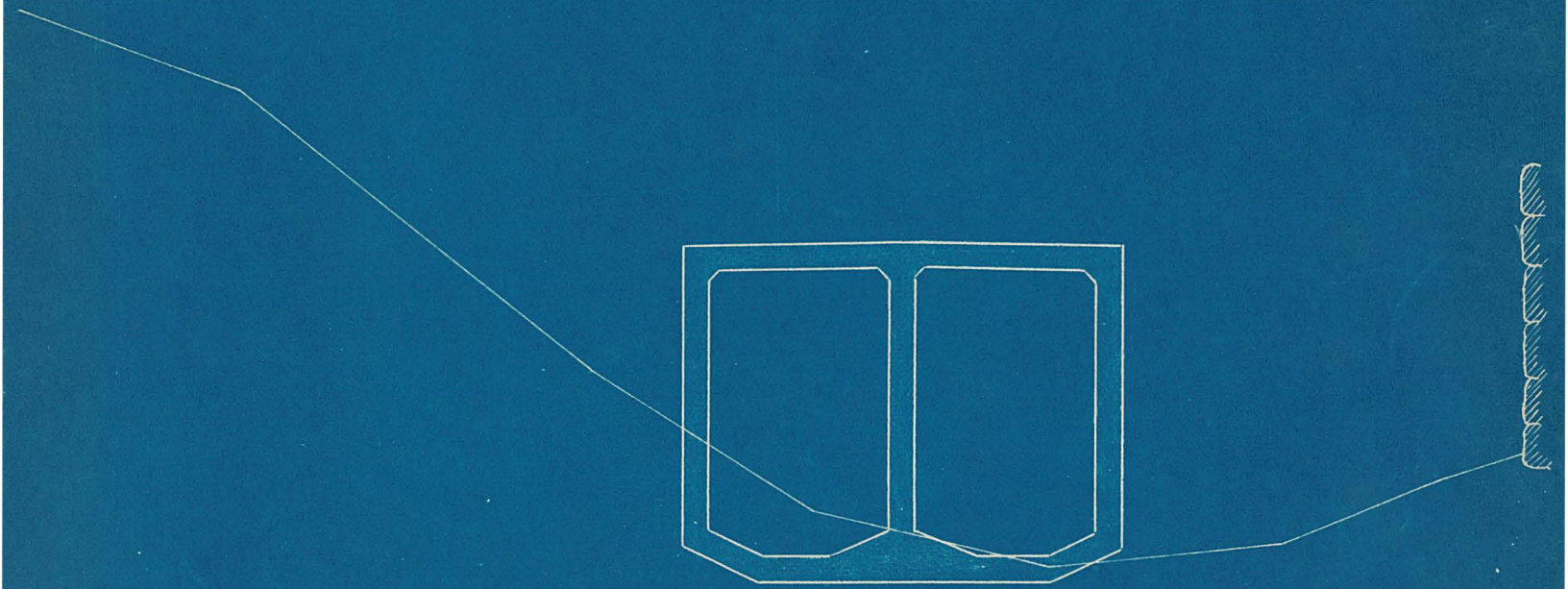
CHECKED BY.....

Scale, 1"=8'
Looking Upstream



EL. 0

STA. 19+50 AT SOUTH SIDE OF RAILROAD BRIDGE



EL. 0

STA. 20+50 ABOUT 50 FT. UPSTREAM FROM RAILROAD BRIDGE

Fig. 41

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

SHEET NO. 1

DATE, August 1916

COMPUTED BY

CHECKED BY

Scale, 1" = 8'
Looking Upstream

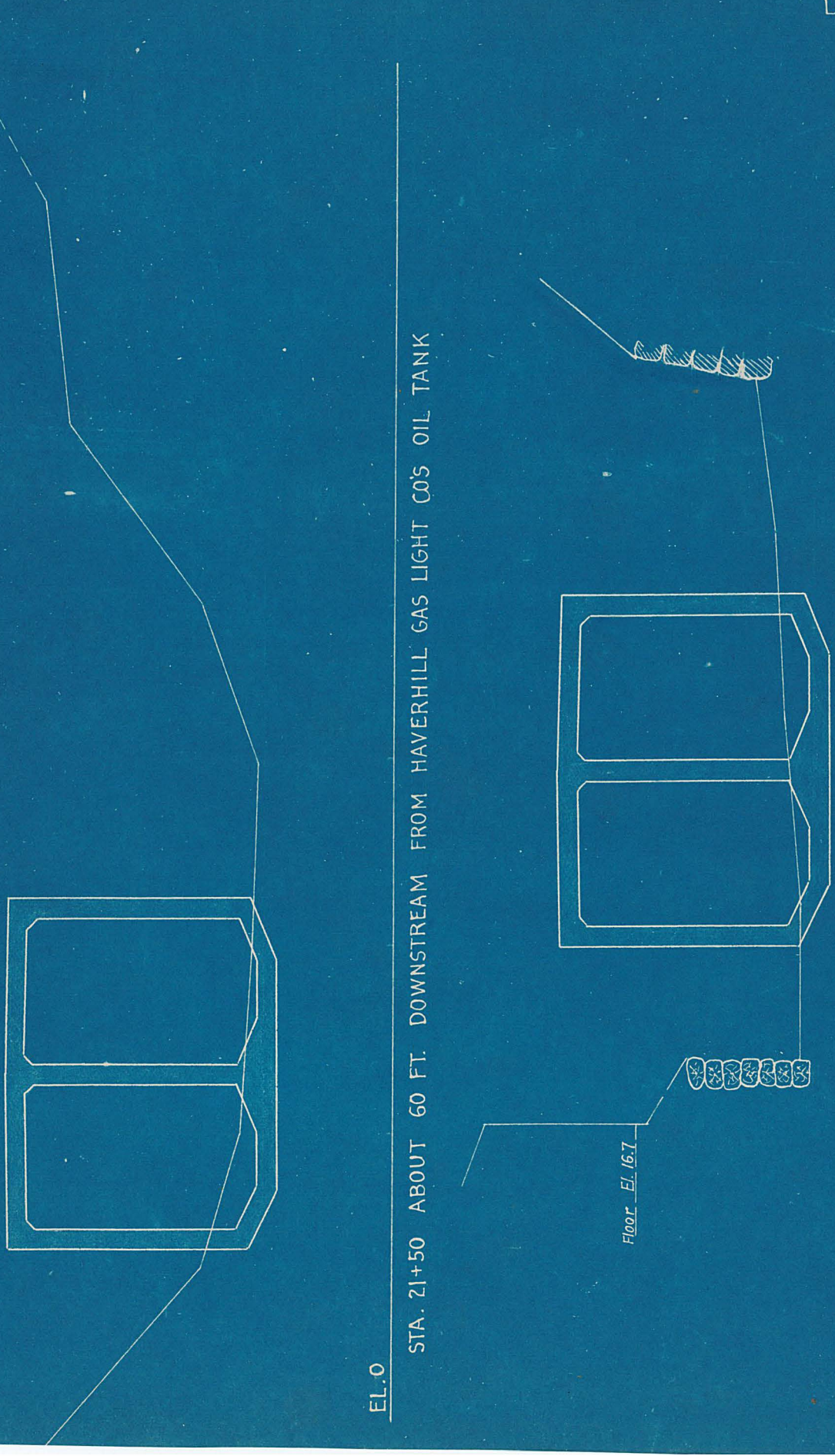


Fig 42

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Present and Proposed Cross Section

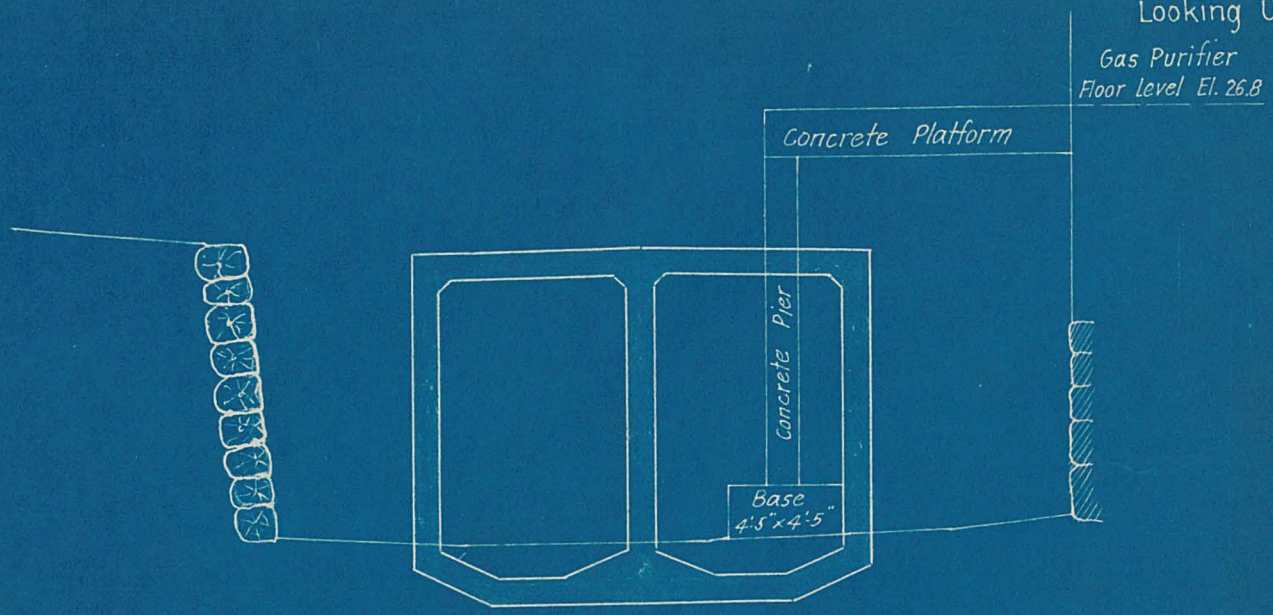
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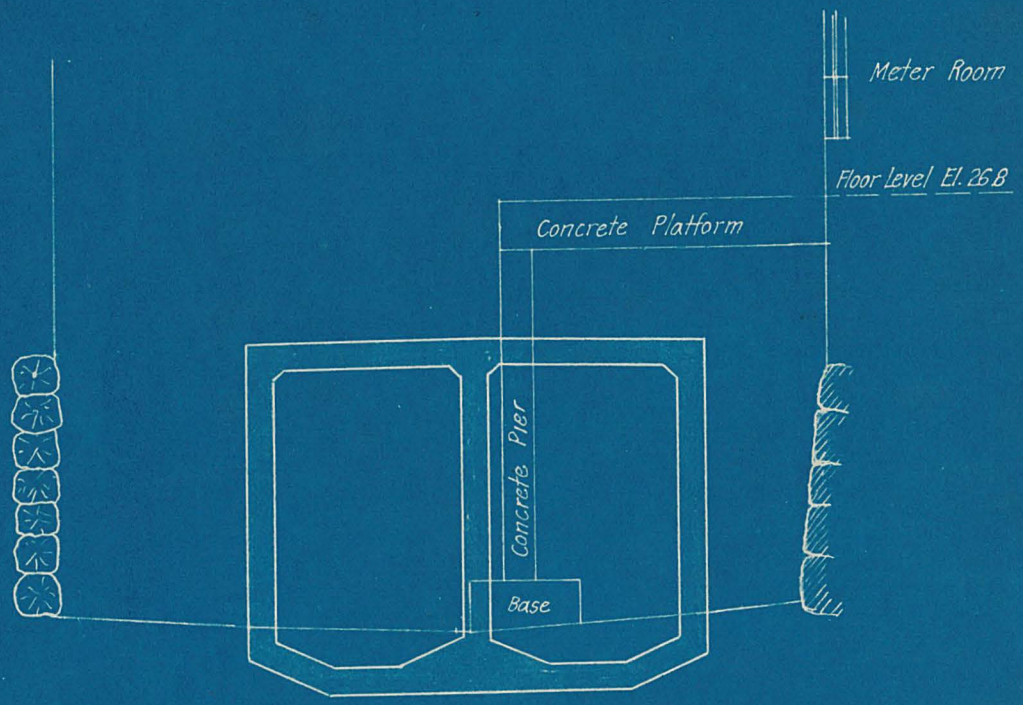
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Scale 1" = 8'
Looking Upstream



EL. 0

STA. 23+00 OPPOSITE PROPERTY OF HAVERHILL GAS LIGHT CO.



EL. 0

STA. 23+50 OPPOSITE PROPERTY OF HAVERHILL GAS LIGHT CO.

Fig. 43

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Present and Peoposed Cross Section

SHEET No.....

DATE, August 1916

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Scale, 1" = 8'
Looking Upstream

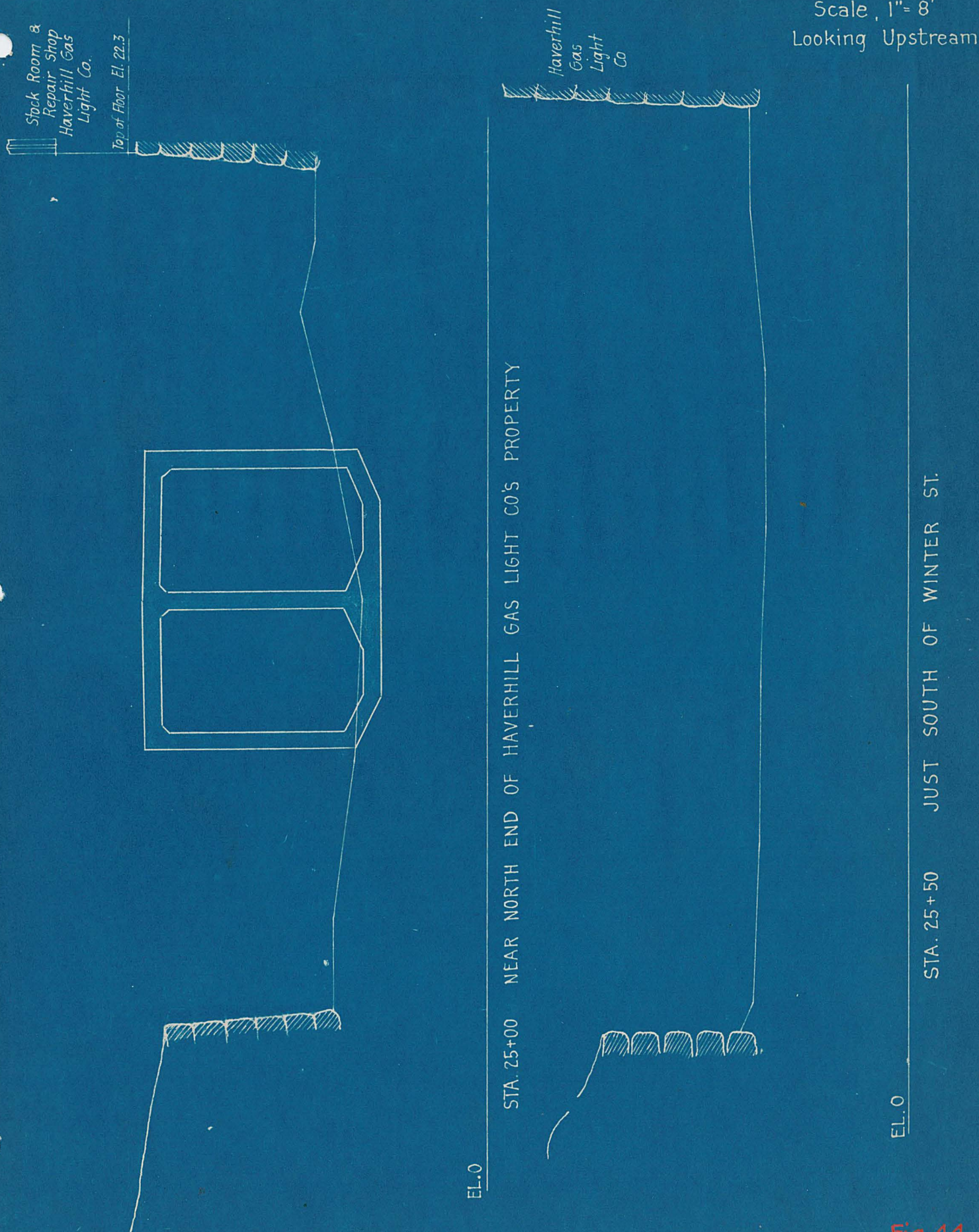


Fig. 44

the river bed at the up-stream end of the conduit and properly bond it into the concrete floor of the conduit to act as a cut-off for the water, which might tend to undermine the upper end of it. It will also be advisable to pave part or all of the area of the small bay between the upper end of the conduit and the Winter St. arch. Two wing walls should be constructed which will guide the flow of water from the openings of the Winter St. arches to the conduit.

Opportunity for a Street from Washington Sq. to Locke St.

It is not the understanding of your engineer that he is to proceed farther than to report upon the proper means for abating the Little River nuisance. He has, however, interpreted his instructions to be general enough so that he should at least call attention to other possible municipal improvements which would be closely allied to this project.

A one-way street can be constructed from Washington Sq. to Locke St. on top of the proposed conduit. To do this the city will have to acquire the following properties.

The small buildings on the north side of Washington Square owned by David, Priest and Bircket and by Chase & Laubham and now occupied by Walter McCutcheon's restaurant and by Carbone Bros.' fruit store. (Fig.45.)

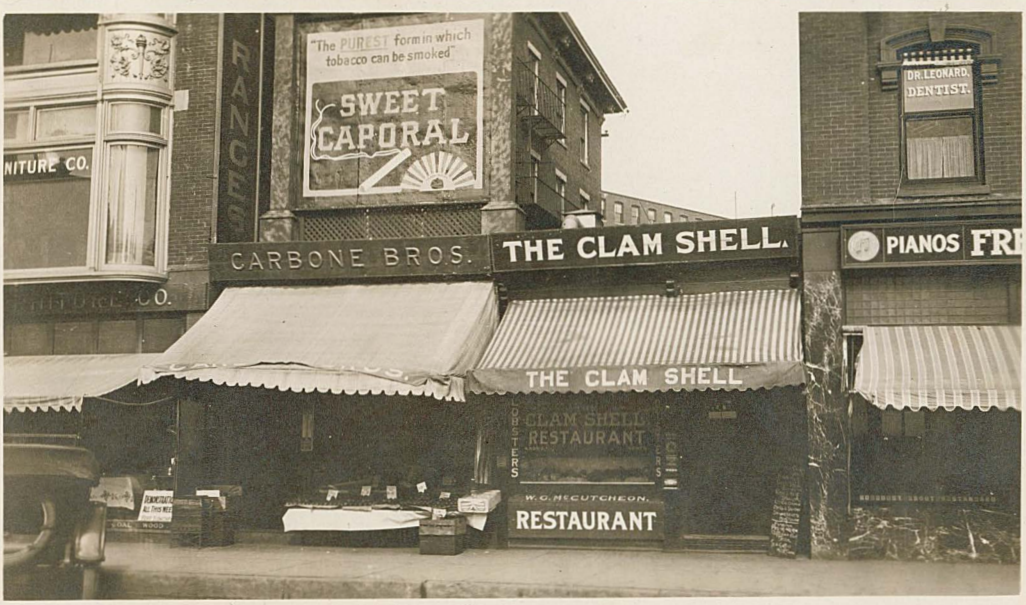


Fig. 45.

Part of the building on the south side of Locust St. owned by The Granville Rugg Heirs and now occupied by The United Shoe Repairing Co. and by Thomas F. Collins's tobacco store and pool room and bowling alley. (Fig. 46.)



Fig. 46.

The two buildings on the north side of Locust St. owned by Louis J. Soinette and by Basil M. Comeau and now occupied by a Chinese Laundry and by Morris Shykin's dry goods store, respectively. (Fig. 47.)



Fig. 47.

The assessed value of these takings is about $14,000.

Such a street can be constructed with a width of about 30 ft. without encroaching on any of the buildings on the abutting properties. It will be of considerable value to the owners of property abutting on the river, will provide another teaming and pedestrian way into the midst of the factory district between Essex St. and Walnut St., and will afford a valuable way for approach of fire apparatus in the event of fire in this district. At present the approaches for such apparatus to parts of this district are very circuitous, narrow and awkward. Such a street also relieves Essex St., which is only 50 ft. wide, and in which is located an electric car track.

On account of the location of the Essex Associates' brick building over the river at Locke St. it is not practicable to extend this new street up to the railroad bridge; but since the conduit is designed strong enough to support such a roadway throughout its entire length it is thoroughly practicable to construct a road over any portion of it where it will be of service to the public or to abutting properties.

The taking lines for the proposed new street are shown in red dash lines on Fig.2.

The grade line of the proposed new street is shown by red dash lines on the profile, Fig.3. Two different profile lines are shown for it, the upper one being the one recommended. The lower grade line w ll, however, not interfere with the windows of existing buildings as much

as the upper one will, but in the event of such extreme high water in the Merrimac as to flood Washington Square the hollow portion of this lower proposed grade would be filled with water and flood out the adjacent factories. Such a flood has occurred but twice in the past 30 years. Another disadvantage of the lower grade line is that the yards of the abutting properties will not fit well to this grade; but will connect in a thoroughly practical manner with the upper grade line. Fig.3 shows every building on both sides of the river, their floor levels, windows, drains and retaining walls, and from a study of this profile the relative elevation of the proposed street with respect to the several buildings along the river can readily be seen.

It will be observed from an examination of the profiles that the recommended grade for the suggested street will in all instances be below the windows of the present properties except as follows.

Chase & Laubham (12 windows)

Morris & Jacob Bloomfield (5 windows)

Basil M. Comeau (7 windows)

Marly L. Dinsmore (1 window and 1 door)

Michael H. McCarthy (3 windows and 2 doors)

Granville Rugg Hrs. (6 windows)

C. S. Coombs (8 windows)

J. H. Winchell & Co. (39 windows)

In many of these cases enumerated the lower half only of the windows would be covered by the new street grade.

The sections (Figs. 30 to 36 inclusive) show this new street in cross-section, and from them it will be seen the driveways and yards between the present buildings will join in a practical manner with the suggested street.

Reliefs of Present Essex St. Sewer.

During short, hard storms the Essex St. sewer, which is a combined sewer, occasionally becomes overcharged. To partially relieve this condition a 24" relief drain was built from a relief chamber in Essex St. to Little River at Locke St. This relief has not proved to be sufficient in exceptionally severe storms, which is evidenced by the occasional flooding of Lafayette Square. This flooding is due to the fact that the storm water flows so rapidly off from the steep grades of the Hilldale Ave. and Broadway districts that the Essex St. sewer cannot under unusual conditions discharge this storm water fast enough. It is therefore proposed to correct this difficulty by constructing an additional 24" relief drain from the Essex St. sewer to Little River at Winter St.

Neither of these reliefs will act until the Essex St. sewer is seriously overcharged with storm water, and the character of the discharge through these reliefs will then be almost entirely storm water which could properly be discharged into the conduit.

The proposed relief at Lafayette Square will be a temporary relief; it probably will not be required when the storm water drains which have been designed for the Hilldale Ave. district have been constructed, since those drains will empty directly into Little River.

Land Takings and Legal Features.

Land Takings.

It is recommended that the city take in fee the land lying between the two existing walls of the river, and that where no walls exist the taking line be 5 ft. outside of the walls of the proposed conduit, which 5-ft. strip would be within the present river bed because the proposed conduit is much narrower than the present river bed. If this is done the city will then at all times have access to the conduit for repairs or other purposes. If an easement only over the required land is taken the city will from time to time have to face the problem of determining what kinds of structures may or may not be permitted to be constructed over the conduit. If structures are built over the conduit they are liable to cause embarrassment to the city when repairs to the conduit may be needed in the somewhat distant future. In a few isolated instances, where existing buildings lie over the site of the proposed conduit, the city can take easements instead of a fee title to the land.

The writer has not attempted to estimate the value of the land comprising the bed of Little River, because it appears at present to have no commercial value; the city assessors do not consider this land in appraising any of the abutting property. The stream is not navigable in any practical sense and the water discharged through it is so filthy that it is of no use for manufacturing purposes. In fact if the water were not filthy it would be of practically no commercial value to abutters along the river because its flow is not dependable; for several weeks in the year it has practically no flow at all.

In connection with the suggested street from Washington Square to Locke St., besides the taking of the land lying between the present river walls, the city should take portions of the narrow strips of land lying between the tops of the present walls and the existing buildings, - this for the purpose of building the street 30 ft. wide or as near 30 ft. as is consistent with taking no land now occupied by buildings. From Washington Sq. to Locke St. these strips average about 2 ft. wide and have a total area of only about 1900 s.f. Considering the benefits to abutters that such a street would present, it does not appear that the total cost to the city of this 1900 s.f. of land should reach any relatively large figure. The average assessed value of this land is about 60¢ per sq.ft.

Legal Features.

It appears that by Act of the Legislature in 1826 Ezekiel Hale was authorized to deepen and alter the channel of Little River within four years sufficiently deep and wide so that at ordinary high tides rafts and boats could be floated on the river. No specific place for a public landing was mentioned in this act, but it appears that a so-called "Public Landing" now exists on the west bank of the river just below Winter St. (See Fig.16)

If it is found that the general law is not sufficient to carry out this project, then special legislation can be enacted during the coming winter so that the work may start next spring if deemed advisable.

Estimated Cost.

Under the prevailing high and rapidly changing prices for materials and labor any estimate of cost made at the present time must be relatively uncertain. The following estimate has been based on present prices, which are much in excess of those which prevailed two years ago.

The estimated cost of the proposed conduit extending from Winter St. to Washington Square, including 3 ft. of filling on top of the conduit and including engineering, is $195,327.

The estimated cost of constructing, in addition to the conduit, a new street with concrete pavement, granite curbs and 6 ft. granolithic sidewalk on top of this conduit

from Locke St. to Washington Square is $9,004, exclusive of the cost of three properties and narrow strips to be acquired, the assessed value of which totals about $16,000.

If the conduit is to be constructed a portion at a time, the following scheme can be carried out. Each portion, from street to street, can be treated as a separate section and can be constructed without affecting the rest of the project. For example, the work from Washington Square to Locust St. can be built in one season, from Locust St. to Locke St. the next season, and so on.

The following tabulation of the estimated cost of the project by sections will assist in determining the expense of carrying out any part of the project; these are exclusive of the street construction but include a fill of 3 ft. of earth on top of the conduit.

	Construction and Engineering
Washington Square to Locust St.	$ 58,445
Locust St. to Locke St.	16,666
Locke St. to Railroad Bridge	67,458
Railroad Bridge to Winter St.	52,758
Washington Square to Winter St.	$195,327

Estimates for the entire conduit are given more in detail in the Appendix.

Results to be Attained by Constructing the Proposed Conduit.

The general effect of the construction of this project will be that properties along the river will benefit from better sanitary conditions, and if the new street is constructed, from increased fire protection and increased transportation facilities. After the conduit has been built the property owners on each side of the river can look forward to conditions which are more permanent and to relief from all liability of flooding.

The Pentucket Mills will be assured of a clear channel, unobstructed by debris, for discharging the water which passes through the wheel or over the dam, with the result that with high water conditions in the Merrimac flooding out of the mills will probably be less serious in the future than in the past.

The city as a whole will benefit by an improved sanitary condition and the removal of whatever menace to health this may be to the entire community.

Acknowledgment.

The writer acknowledges the hearty cooperation and advice of the City Engineer, and also the efficient work of his assistants in making the surveys and preparing the necessary plans for this report.

Acknowledgment is also due to Mr. Richard A. Hale, Engineer of the Pentucket Mills, and to Mr. J. A. Currier, Superintendent of the Pentucket Mills, who have willingly rendered all assistance requested and have given your engineer access to the daily records of flow of the river which have been kept by the Pentucket Mills during the past two years.

Supplementing this report, in the Appendix are technical data used as a basis for the conclusions.

Respectfully submitted,
(Signed) Charles B. Breed,

Consulting Engineer for Board of Health.

A P P E N D I X

Elevations of Extreme High Water of Merrimac River at Haverhill in various years from 1887 to date.

These are referred to Haverhill City Datum, which is as follows:-

Mean Low Water = 2.25
Mean High Water = 6.87

1887	Extreme H.W. freshet	22.0
April	16, 1895	19.7
March	3, 1896	21.6
April	9, 1901	19.4
March	2, 1902	18.0
March	13, 1903	14.0
April	30, 1904	14.9
March	30, 1905	13.8
May	3, 1906	13.5
Nov.	8, 1907	11.5
Feb.	17, 1908	12.8
April	16, 1909	13.0
March	3, 1910	10.4
April	5, 1912	10.8
April	2, 1913	13.6
March	4, 1914	13.3
Feb.	27, 1915	13.8
May	20, 1916	13.0

Table I.

Haverhill Little River Improvement.

Discharge Capacity of One Side of Double Conduit as per Design of Sept. 2, 1916.

Sept. 5,1916.
Computed by C.B.B.
Checked by M.S.W.

Depth of Water	Area sq. ft.	Wet Per. ft.	A÷WP = T ft.	Ave. Value of n	Q and mean V for different Slopes. n = .020 on bottom and .012 on sides.													
					s = .0004		s = .0006		s = .0008		s = .001		s = .002		s = .003		s = .004	
					Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V
0.1	0.325	3.54	0.092	.020	0.06	0.20	0.08	0.25	0.10	0.31	0.11	0.33	0.15	0.46	0.20	0.62	0.25	0.78
0.2	0.70	4.09	0.171	.020	0.24	0.35	0.30	0.43	0.35	0.50	0.39	0.56	0.57	0.80	0.70	1.00	0.81	1.15
0.5	2.125	5.69	0.374	.020	1.38	0.65	1.72	0.81	2.02	0.95	2.25	1.06	3.23	1.52	3.90	1.87	4.53	2.13
0.7	3.325	6.77	0.491	.020	2.76	0.83	3.36	1.01	3.89	1.17	4.35	1.31	6.22	1.87	7.65	2.30	8.82	2.65
1.0	5.50	8.38	0.657	.020	5.67	1.03	6.98	1.27	8.08	1.47	9.14	1.66	12.93	2.35	15.90	2.89	18.30	3.33
2.0	13.50	10.38	1.30	.018	25.65	1.90	32.4	2.40	38.0	2.81	42.6	3.16	60.3	4.46	74.0	5.47	85.5	6.32
3.0	21.50	12.38	1.74	.017	55.0	2.55	68.2	3.17	78.6	3.65	88.3	4.10	124.8	5.80	153.0	7.11	176.7	8.21
4.0	29.50	14.38	2.05	.017	83.5	2.83	108	3.57	122	4.13	135	4.57	190	6.47	234	7.95	290	9.16
6.0	45.50	18.38	2.47	.016	157	3.45	193	4.24	222	4.89	249	5.47	351	7.72	432	9.47	496	10.9
8.0	61.50	22.38	2.75	.015	240	3.90	294	4.78	338	5.51	380	6.18	537	8.74	658	10.7	757	12.3
10.0	77.50	26.38	2.94	.0145	329	4.25	411	5.30	467	6.02	521	6.73	738	9.52	907	11.7	1060	13.7
12.0	92.50	30.44	3.07	.014	424	4.54	520	5.56	600	6.43	671	7.18	955	10.2	1168	12.5	1363	14.6
12.42	96.36	*31.62	3.04	.014	435	4.52	532	5.52	615	6.39	685	7.12	974	10.1	1193	12.4	1396	14.5

V in above table taken directly from Table 1 of U.S.Geological Survey Hydraulic and Excavation Tables.

* exclusive of roof of conduit.

Table II.

Haverhill Little River Improvement.

Discharge Capacity of Single Conduit as per Design of Sept. 2, 1916.

Sept. 9,1916.
Computed by C.B.B.
Checked by M.S.W.

Depth of Water	Area sq. ft.	Wet Per. ft.	A÷WP = T ft.	Ave. Value of n	Q and mean V for different Slopes. n = .020 on bottom and .012 on sides.													
					s =.0004		s =.0006		s =.0008		s = .001		s = .002		s = .003		s = .004	
					Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V
0.1	0.72	7.48	.096	.020	0.14	0.19	0.17	0.24	0.19	0.27	0.22	0.31	0.32	0.44	0.39	0.54	0.52	0.72
0.2	1.49	7.96	.19	.020	0.55	0.37	0.70	0.47	0.81	0.54	0.91	0.61	1.30	0.87	1.58	1.06	1.83	1.23
0.5	4.05	9.42	.43	.020	2.96	0.73	3.69	0.91	4.29	1.06	4.82	1.19	6.85	1.69	8.43	2.08	9.72	2.40
0.7	5.98	10.38	.58	.020	5.56	0.93	6.82	1.14	7.95	1.33	8.97	1.50	12.75	2.13	15.67	2.62	18.12	3.03
1.0	9.20	11.82	.78	.020	10.78	1.17	13.25	1.44	15.48	1.68	17.31	1.88	24.58	2.67	30.10	3.29	34.90	3.79
2.0	22.1	15.08	1.47	.018	47.5	2.15	58.6	2.65	68.2	3.08	7.56	3.42	107	4.85	131	5.95	152	6.88
3.0	36.0	17.12	2.10	.018	99	2.75	122	3.38	141	3.91	158	4.38	223	6.20	273	7.58	316	8.77
4.0	50.0	19.12	2.62	.017	169	3.39	207	4.14	241	4.81	269	5.39	380	7.60	463	9.27	540	10.8
6.0	78.0	23.12	3.38	.016	331	4.23	404	5.18	467	5.99	522	6.69	740	9.48	905	11.6	1045	13.4
8.0	106.0	27.12	3.91	.0155	505	4.77	620	5.84	715	6.75	800	7.54	1123	10.6	1388	13.1	1600	15.1
10.0	134.0	31.12	4.31	.015	696	5.20	853	6.36	984	7.34	1100	8.21	1555	11.6	1900	14.2	2180	16.3
12.0	161.8	35.62	4.53	.0145	905	5.59	1105	6.83	1275	7.88	1425	8.81	2030	12.5	2480	15.3	2850	17.6
12.42	166.9	*37.80	4.41	.0145	914	5.48	1120	6.72	1295	7.76	1440	8.65	2060	12.3	2505	15.0	2890	17.3

V in above table taken directly from Table 1 of U.S.Geological Survey Hydraulic and Excavation Tables.

* Exclusive of roof of conduit.

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT AREA AND HYDRAULIC RADIUS OF SINGLE RECTANGULAR CONDUIT 14 FT. WIDE × 12 FT. HIGH

SHEET NO. 2

DATE, Aug. 30 1916

COMPUTED BY C.B.B. & E.C.S.

CHECKED BY

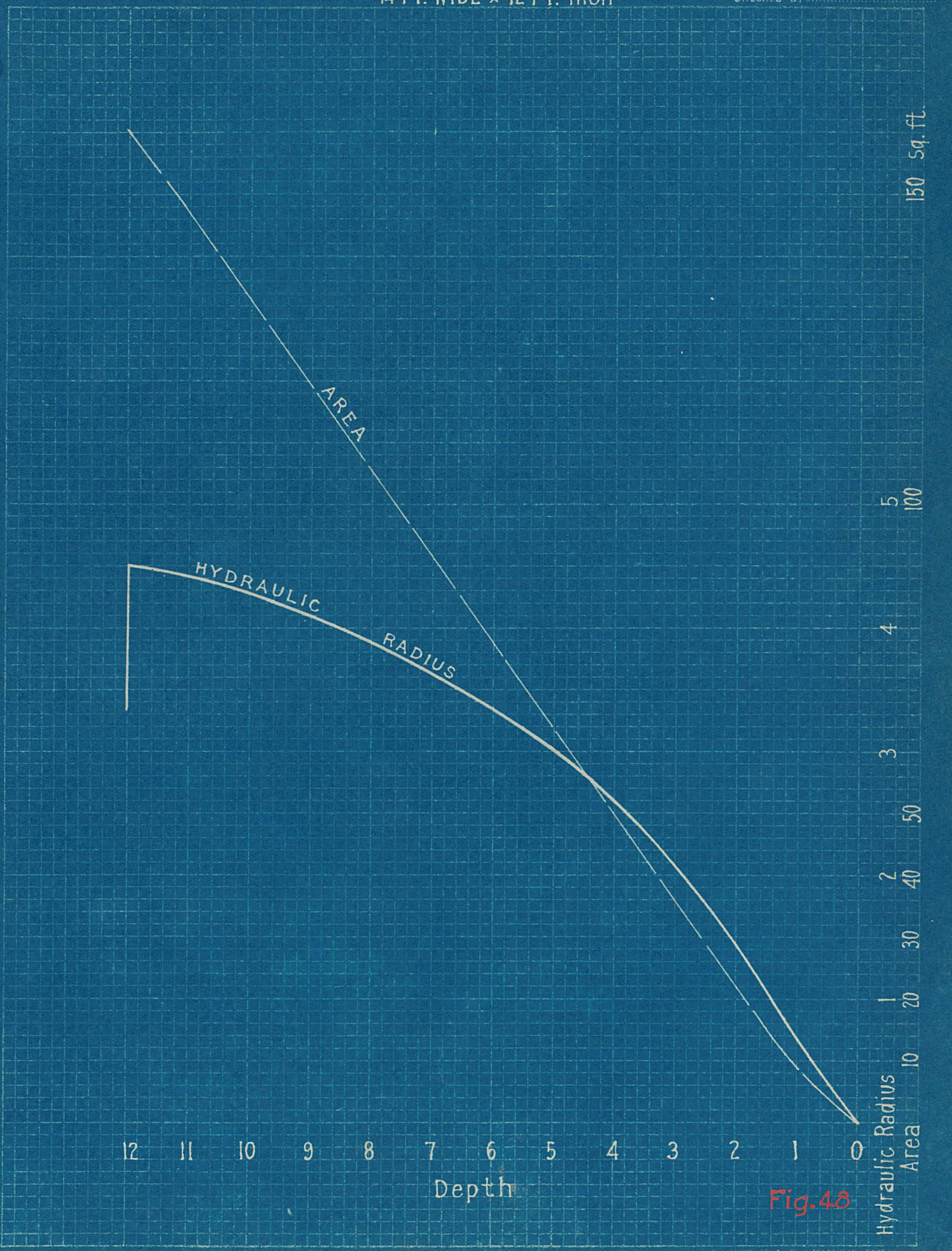


Fig. 48

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

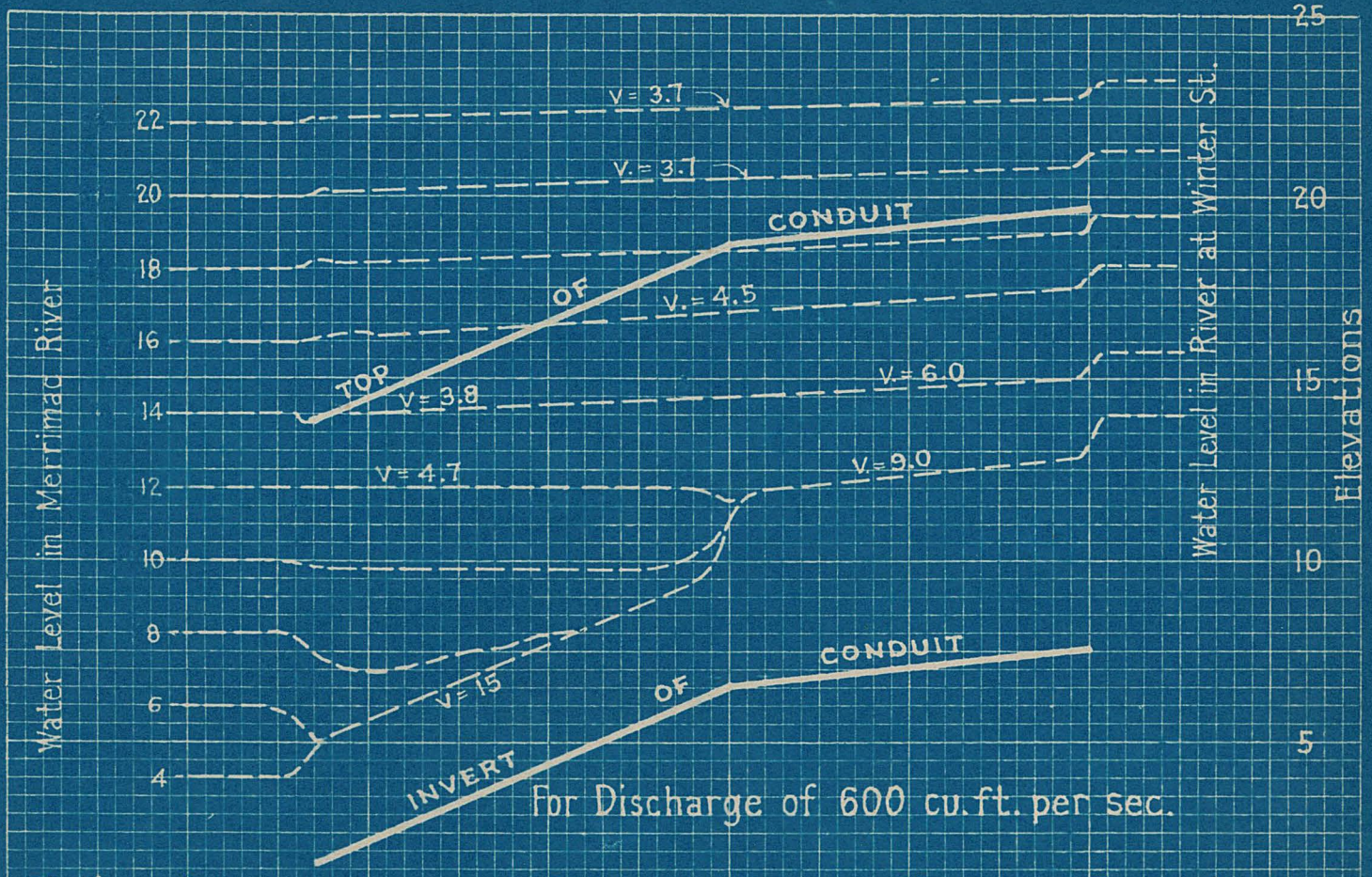
SUBJECT BACKWATER CURVES FOR SINGLE RECTANGULAR CONDUIT 14 FT. WIDE × 12 FT. HIGH FOR DISCHARGE OF 600 AND 1200 SEC. FEET

SHEET NO. 1

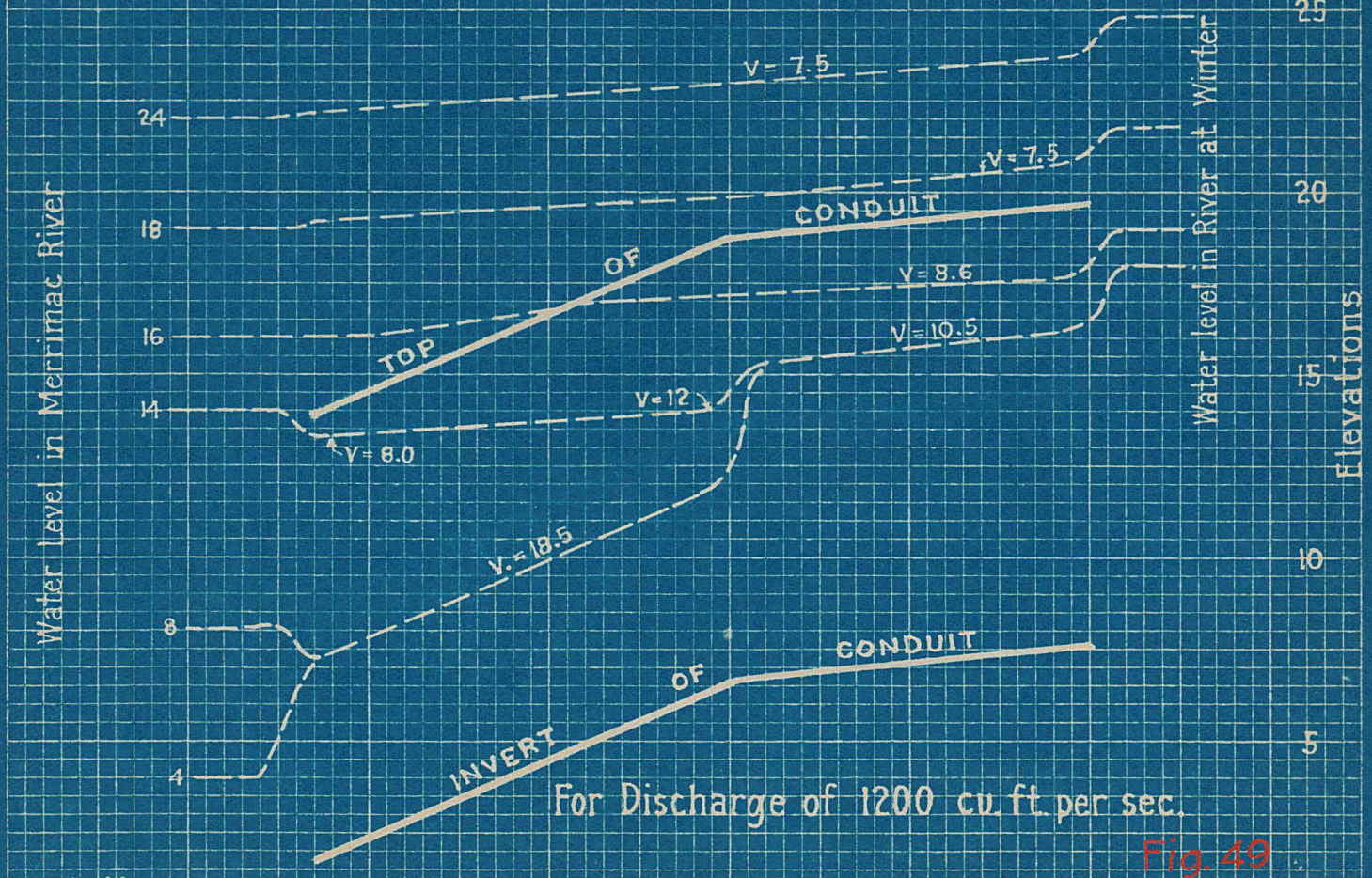
DATE Aug. 30, 1916

COMPUTED BY C.B.B. & E.C.S.

CHECKED BY



For Discharge of 600 cu. ft. per sec.



For Discharge of 1200 cu. ft. per sec.

Fig. 49

Haverhill Little River Improvement.

Loadings, Unit Stresses, and Conditions Considered in Design of Conduit.

LOADS

Loads on Roof

6 1/4 feet of fill @ 90 lbs.	562#
Paving	150#
Live Load	100#
Total	812# say 800# per sq.ft.

HYDRAULIC PRESSURE

8' head under side of roof 500# per sq.ft.

Side Pressure on Walls Due to Earth Fill

Uniform pressure (Surcharge) 200# per sq.ft.

Varying pressure 33# " " " per foot of depth, measured downward from top of conduit.

DESIGN OF SINGLE CONDUIT

Moments and Shears

1st -- Moments and sheare computed for weight of structure.

2nd -- Moments and sheare computed for weight of structure plus 800# per sq.ft. superimposed load.

3rd -- Moments and sheare computed for external side pressure due to earth fill. Uniform pressure 200# per sq.ft. Varying pressure 330 per sq.ft.

per foot of depth, measured downward from top of conduit.

4th -- Moments and sheears computed for weight of liquid.

5th -- Moments and sheears computed due to hydraulic pressure of 500# per sq.ft.

Conditions of Loading

1-- Conduit empty. (Weight of structure only).

2-- Conduit full of water. (Weight of structure plus weight of liquid).

3-- Conduit under 8' head of water. (Weight of structure plus weight of liquid plus hydraulic pressure of 500# per sq.ft.).

4-- Conduit empty. Fill and paving in place and subjected to live load of 100# per sq.ft. on roadway. (Weight of structure, superimposed load of 800# per sq.ft. and side pressure due to earth fill.)

5-- Conduit full of water. Fill and paving in place and subjected to live load of 100# per sq.ft. on roadway. (Weight of structure, superimposed load of 800# per sq.ft. and side pressure due to earth fill, plus weight of liquid).

6-- Conduit under 8' head of water. (Same as No. 5 plus hydraulic pressure of 500# per sq.ft.)

UNIT STRESSES

The structure was designed for the maximum moments and sheears obtained from conditions No. 1, 2,

4 and 5. The sections were computed for a maximum tension of 16,000# per sq.inch on the steel, and compression of 650# per sq.inch on the concrete. These cases combined with the improbable condition of water pressure (Conditions 3 and 6) were considered and the stresses obtained thereby did not exceed 20000# per sq. inch tension in the steel and 750# per sq. inch compression in the concrete.

The maximum bearing pressure on the soil under the conduit did not exceed one ton per sq.ft.

DESIGN OF DOUBLE CONDUIT

Moments and Shears

1st -- Moments and shears computed for weight of structure.

2nd -- Moments and shears computed for weight of liquid. (A- Both tubes full. B - One tube full).

3rd -- Moments and shears computed for hydraulic pressure. (A - Both tubes full. B - One tube full).

4th -- Moments and shears computed for external side pressure due to earth fill. (A - Uniform 200# per sq.ft. B - Varying pressure 33# per sq.ft. per foot of depth, measured downward from top of conduit).

5th -- Moments and shears computed for weight of structure plus superimposed load of 300# per sq.ft.

Conditions of Loading

1 -- Weight of structure. Conduit empty.

2 -- Weight of structure plus weight of liquid. (Maximum of one or two tubes full).

3 -- Weight of structure plus weight of liquid in one or both tubes plus hydraulic pressure in one or both tubes.

4 -- Same as No. 1 with fill and paving in place and live load of 100# per sq.ft. on roadway .

5 -- Same as No.2 plus fill, paving and live load of 100# per sq.ft. on roadway.

6 -- Same as No. 3 plus fill, paving and live load of 100# per sq.ft. on roadway.

Unit Stresses

The structure was designed for the maximum moments and shears obtained from conditions No. 1, 2, 4 and 5. The sections were computed for a maximum tension of 16000# per sq. inch on the steel, and compression of 650# per sq. inch on the concrete. These cases combined with the improbable conditions of water pressure (Conditions 3 and 6) were considered and the stresses obtained thereby did not exceed 20000# per sq. inch tension in the steel and 750# per sq. inch compression in the concrete. The maximum bearing pressure on the soil under the conduit did not exceed one ton per sq. ft.

It is assumed that in case the double conduit is under maximum hydraulic pressure, relief openings have been left in the central wall at the inner side of the roof slab, so that the central wall will not be subjected to hydraulic pressure.

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Location of Borings

SHEET NO.

DATE, September 1916

COMPUTED BY

CHECKED BY

Scale, 1" = 300'



Fig 50

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PROJECT Haverhill Little River Improvement

SHEET NO. 2

DATE, August 1916

SUBJECT Borings

COMPUTED BY

CHECKED BY

(Bottom of Proposed Conduit comes where red arrows are shown)

Scale, 1" = 5'

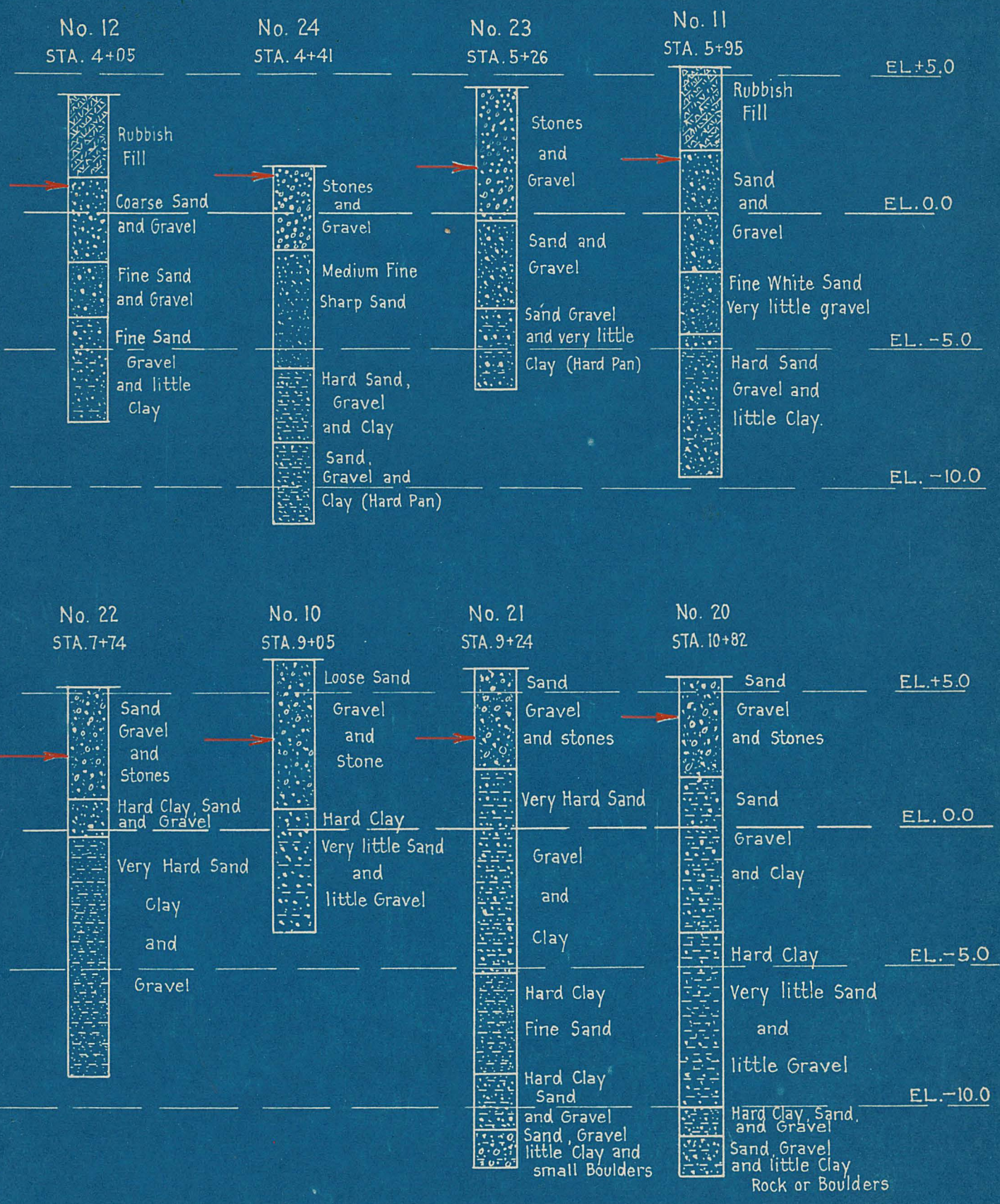


Fig. 51

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Borings

(Bottom of Proposed Conduit comes where red arrows are shown)

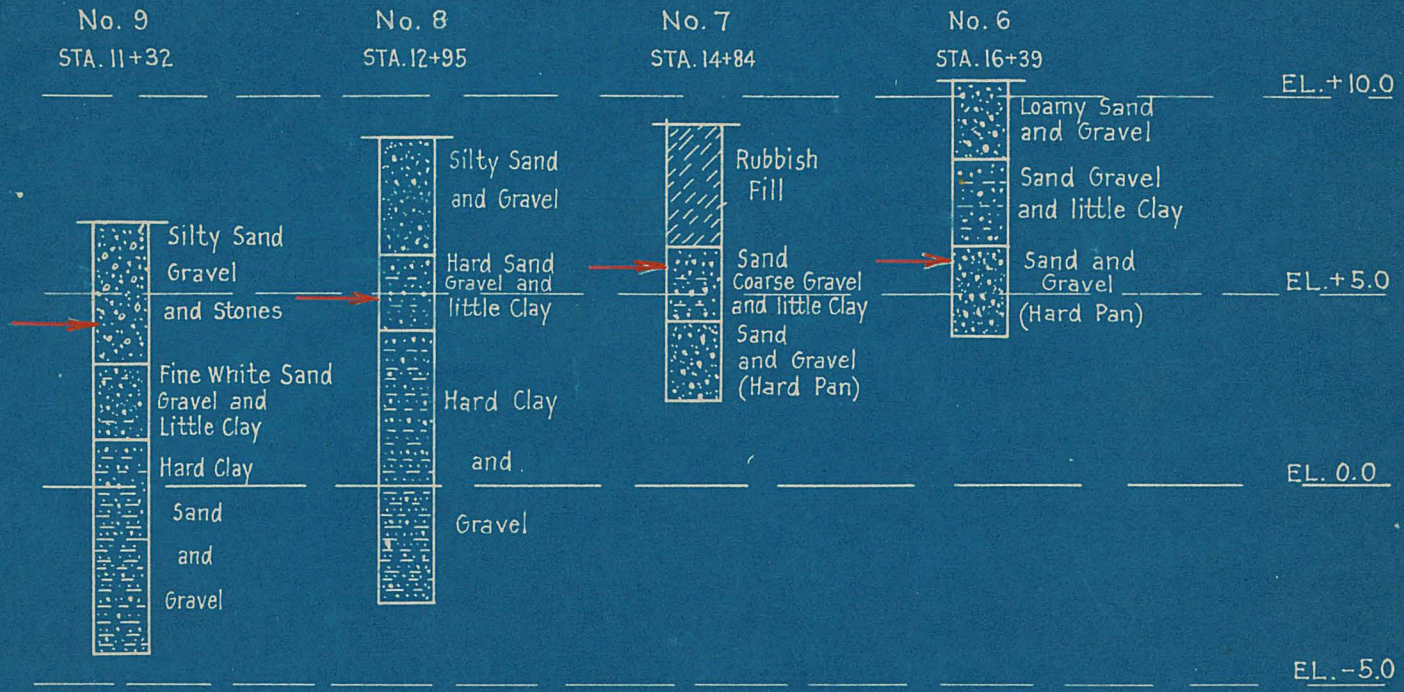
SHEET No. 3

DATE, August 1916

COMPUTED BY

CHECKED BY

Scale, 1" = 5'



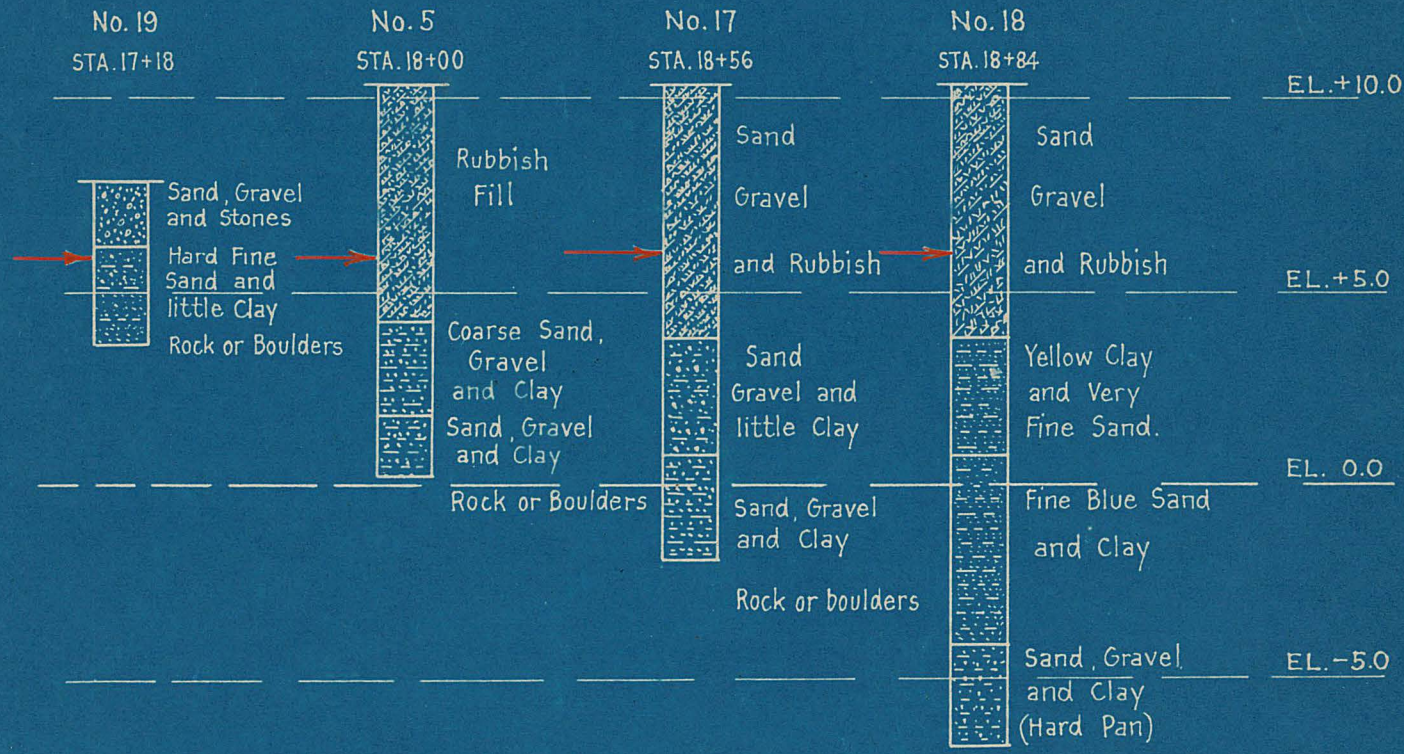


Fig. 52

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Borings

(Bottom of Proposed Conduit comes where red arrows are shown)

SHEET No. 4

DATE, August 1916

COMPUTED BY

CHECKED BY

Scale, 1"=5'

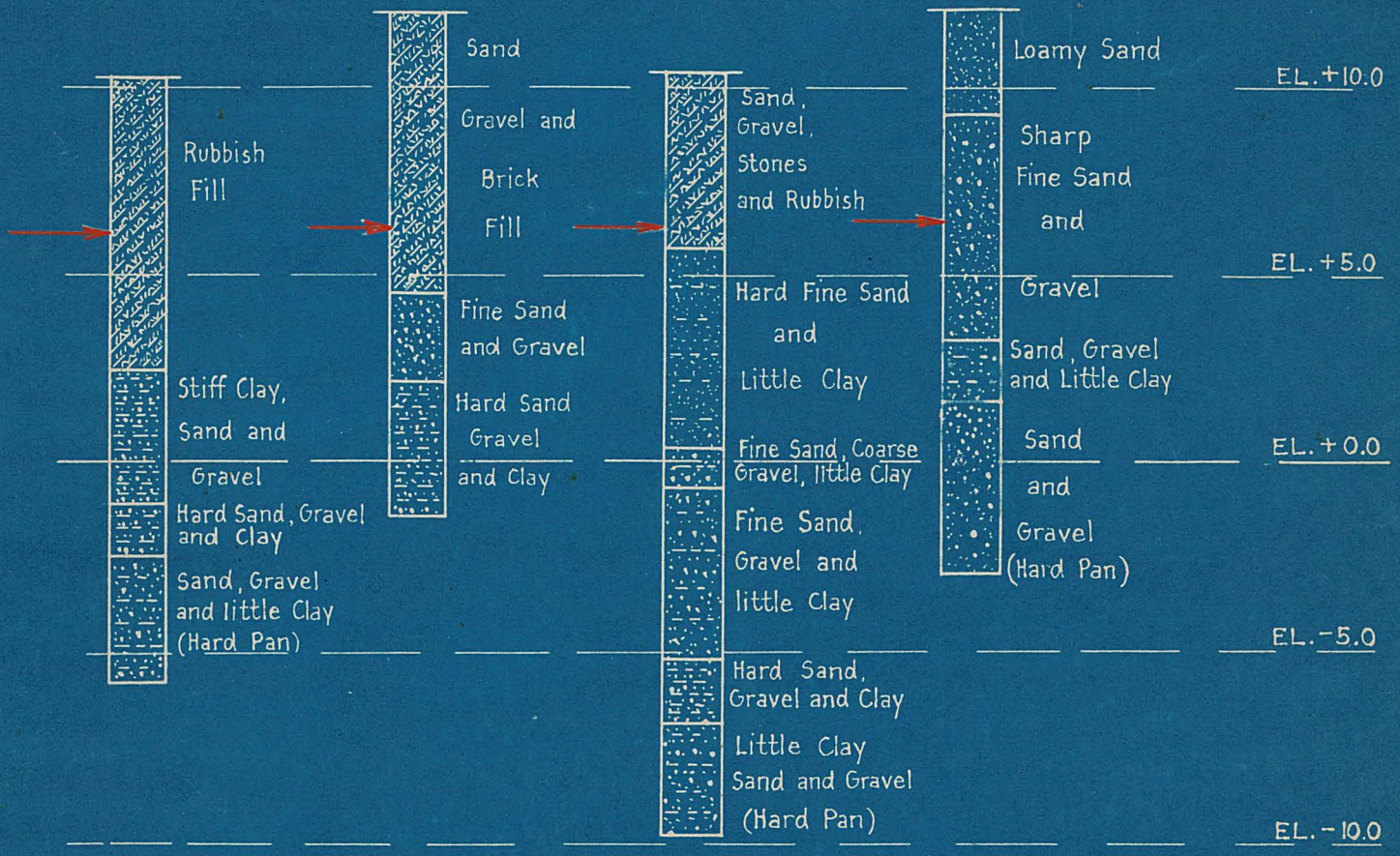


Fig 53

CHARLES B. BREED
6 BEACON ST., BOSTON

PROJECT Haverhill Little River Improvement

SUBJECT Borings

(Bottom of Proposed Conduit comes where red arrows are shown)

SHEET NO. 5

DATE, August 1916

COMPUTED BY

CHECKED BY

Scale, 1" = 5'

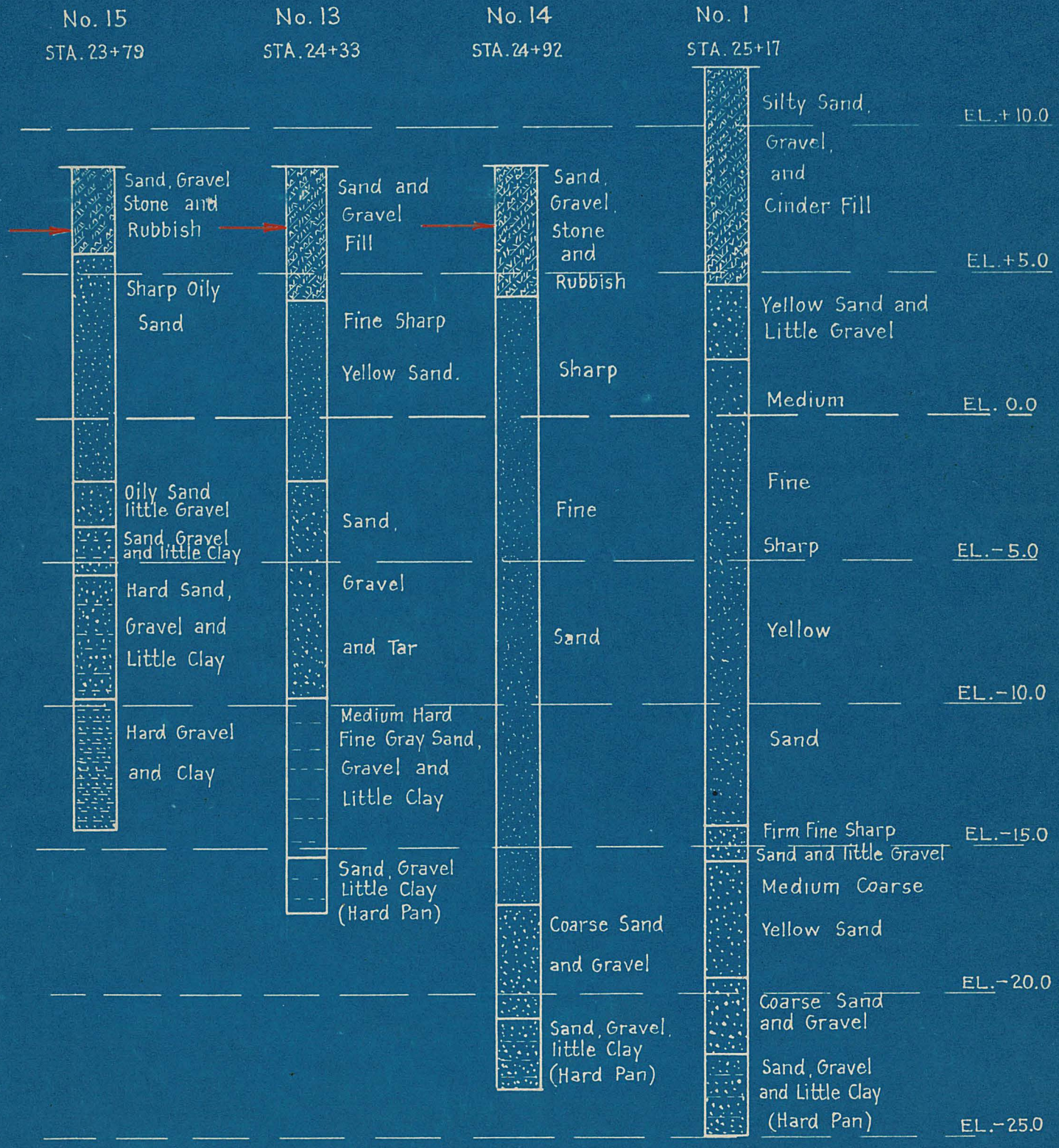


Fig. 54

Estimate of Cost of

Construction and Engineering for Proposed Conduit

including 3-ft. Cover of Earth.

From Washington Square to Winter Street.

3500 c.y. Excavation in river bottom @ 60¢ . . . . . $ 2100.

Conduit (Twin Section)

2.8 cu.yds.	concrete	@ $8.00 c.y.	=	22.40	
900 lbs.	steel	@ 4¢	=	36.00	
87 sq.ft.	forms	@ 10¢	=	8.70	
17 sq.ft.	granolithic invert	@ 5¢	=	.85	
				$67.95	per l.ft.

2147 l.ft. Conduit @ $67.95 . . . . . 145899.

22670 c.y. Gravel backfill on sides of conduit and for 3 ft. deep on top of conduit @ 80¢ c.y. . . . . 18136.

10 M. H.P. sheet piling in place for cut-off at upper end of conduit @ $60 . . . . . 600.

250 s.y. Paving basin at upper end of conduit @ $2.50 s.y. . . 625.

580 c.y. Retaining wing walls at Winter St. @ $9.00 c.y. . . 5220.

Stop planks, manholes and connections of existing drains to conduit . . . . . 3000.

Locke St. sewer siphon . . . . . 2000.

Essex St. sewer relief drain at Winter St. (Charge to Sewer Department) . . . . . ———

Total for Construction . . . . . 177570.

Add 10% for Engineering and Contingencies . . . . . 17757.

Total for Construction and Engineering . . . . . $195327.

Estimate of Cost

From Washington Square Arch to North Side of Locust Street.

920 c.y. Excavation in river bottom @ 60¢ . . . . $ 552.

Conduit (Twin Section)

2.8 cu.yds.	concrete	@ $8.00 c.y.	=	$22.40
900 lbs.	steel	@ 4¢	=	36.00
87 sq.ft.	forms	@ 10¢	=	8.70
17 sq. ft.	granolithic invert	@ 5¢	=	.85
				$67.95 per l.ft.

712 l.ft. Conduit @ $67.95 . . . . . 48,380.

4125 c.y. Gravel backfill on sides of conduit and for 3 ft. deep on top of conduit @ 80¢ c.y. . . . . 3,300.

Manholes and connections of existing drains to conduit . . . . . 900.

Total for Construction . . . . . 53,132.

Add 10% for Engineering and Contingencies . . . . . 5,313.

Total for Construction and Engineering. . . . . $58,445.

Estimate of Cost

From North Side Locust St. to North Side Locke St.

222 c.y. Excavation in river bottom @ 60¢ . . . . $ 133.

Conduit (Twin Section)

2.8 cu. yds.	concrete	@ $8.00 c.y.	=	$22.40
900 lbs.	steel	@ 4¢	=	36.00
87 sq.ft.	forms	@ 10¢	=	8.70
17 sq.ft.	granolithic invert	@ 5¢	=	.85
				$67.95 per l.ft.

171 l.ft. Conduit @ $67.95 . . . . . 11,620.

1372 c.y. Gravel backfill on sides of conduit and for 3ft. deep on top of conduit @ 80¢ c.y. . . . . 1,098.

Manholes and connections of existing drains to conduit . . . . . 300.

Locke St. sewer siphon . . . . . 2,000.

Total for Construction, ... 15,151.

Add 10% for Engineering and Contingencies. . . . . 1,515.

Total for Construction and Engineering . . . . . $16,666.

Estimate of Cost

From North Side Locke St. to North Side Railroad Bridge.

1470 c.y. Excavation in river bottom @ 60¢ . . . $ 882.

Conduit (Twin Section)

2.8 cu.yds.	concrete	@ $8.00 c.y.	=	$22.40
900 lbs.	steel	@ 4¢	=	36.00
87 sq. ft.	forms	@ 10¢	=	8.70
17 sq. ft.	granolithic invert	@ 5¢	=	.85
				$67.95 per l.ft.

773 l.ft. Conduit @ $67.95 . . . . . 52,525.

8773 c.y. Gravel backfill on sides of conduit and for 3 ft. deep on top of conduit @ 80¢ c.y. . . . 7,018.

Manholes and connections of existing drains to conduit . . . . . 900.

Total for Construction. . . . . 61,325.

Add 10% for Engineering and Contingencies . . . . . 6,133.

Total for Construction and Engineering . . . . . $67,458.

Estimate of Cost

From North Side Railroad Bridge to Winter St.

888 c.y. Excavation in river bottom @ 60¢ . . . . $ 533.

Conduit (Twin Section)

2.8 cu.yds.	concrete	@ $8.00 c.y.	=	$22.40
900 lbs.	steel	@ 4¢	=	36.00
87 sq.ft.	forms	@ 10¢	=	8.70
17 sq.ft.	granolithic invert	@ 5¢	=	.85
				$67.95 per l.ft.

491 l.ft. Conduit @ $67.95 . . . . . 33,364.

8400 c.y. Gravel backfill on sides of conduit and for 3 ft. deep on top of conduit @ 80¢ c.y. . . . . 6,720.

10 M. H.P. Sheet piling in place for cut-off at upper end of conduit @ $60 . . . . . 600.

250 s.y. Paving basin at upper end of conduit @ $2.50 s.y. . . . 625.

580 c.y. Retaining wing walls at Winter St. @ $9.00 c.y. . . . 5,220.

Stop planks, manholes and connections of existing drains to conduit . . . . . 900.

Essex St. sewer relief drain at Winter St. (Charge to Sewer Department) . . .

Total for Construction . . . . . 47,962.

Add 10% for Engineering and Contingencies . . . . . 4,796.

Total for Construction and Engineering . . . . . $52,758.

Haverhill Little River Improvement.

Estimate of Cost of Construction of New Street from Washington Square to Locke St, on Basis of the Higher Grade Line shown on Fig. 3.

Washington Square to Locust St.

2983 cu.yds.	Fill	@ $0.80 =	$2386.40	
1725 sq.yds.	Concrete road	@ 1.50 =	2587.50	
396 sq.yds.	Granolithic sidewalk	@ 1.80 =	712.80	
647 lin.ft.	Curb	@ 1.25 =	808.75	
		Total		$6495.45

Locust St. to Locke St.

880 cu.yds.	Fill	@ $0.80 =	$ 704.00	
414 sq.yds.	Concrete road	@ 1.50 =	621.00	
95 sq.yds.	Granolithic sidewalk	@ 1.80 =	171.00	
155 lin.ft.	Curb	@ 1.25 =	193.75	
		Total		$1689.75

Total Construction	$8185.20
Add 10% for Engineering and Contingencies	818.52
Total for Construction and Engineering	9003.72