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JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume 41 JANUARY, 1954 Number 1

A SHORT HISTORY OF SURVEYING

By Ernest A. Herzog

(Presented at a meeting of the Surveying and Mapping Section of the Boston Society of Civil Engineers, held on April 1, 1953.)

As far as can be found, the Egyptians were the first to use surveying principles. The Nile overflowed its banks and destroyed all boundary marks; the wise men of the courts were called upon to restore these bounds.

> "And thereof have we notable recordes in Histories, how much this science avayled the Egyptians when as by the inundations of the Nylus their whole country was so drowned that with the aime of the river all their boundes and markes were defaced. Yet certain wise men ayded with the knowledge in this science found and distributed to every man his own."[1]

The surveying done in Egypt was all planeangle work, involving and developing simple, basic geometric theorems. The land to be restored was flat and was easy to work with, yet the restoration of boundaries involved (as it does today) a great deal of trouble. Each landowner insisted that the boundary was not correct and a long controversy often resulted. It was at the very dawn of his profession that the surveyor became an arbitrator and a judge.[2]

As the Egyptians improved this science, they expanded it. It was applied to the construction of the tombs, the palace of the rulers and to the estates and camps of the royalty. Later they swung their attention toward the skies and tried to explain the great mysteries of the universe.

The Egyptian mathematicians derived many of the basic trigo-

[1]Leonard Digges, *Pantometra*, p. II (1571, London).

[2]Robert Gibson, early American engineer and schoolteacher, tells us that there is good reason to believe that Moses, while residing at the Egyptian Court, acquired the art of surveying and took part in land reclamation.

nometric concepts. They put math and the great mathematical sciences into a language; these they passed on to those who followed and were interested.

> "Achilles Tatius, in the beginning of his introduction to *Arotus' Phaenomena,* informs us that the Egyptians were the first to measure the heavens and the earth and their science in this matter was engraved on columns and by that means delivered to posterity."[3]

This knowledge was transferred to the Greek and the Roman Empires, where it remained quite the same kind of work; simple right angle geometry.

Very little is known of the Egyptian instruments except that they must have been crude and very similar in design and principle to those of the early Greek and Roman engineers.

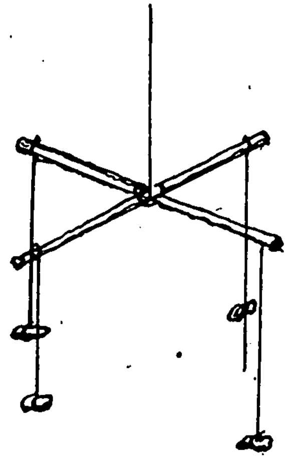

FIG. 1.—THE GROMA.

The Groma (fig. 1), the earliest Roman right angle instrument of which we have a record, consisted of two sticks of wood held perpendicular to each other by means of thongs and a joint. From the ends of these sticks hung plumb lines. Stones were employed as bobs. It was a simple enough matter to sight across the lines in both directions and obtain a right angle sight. The faults were many in this earliest version of the groma. There is reason to believe that this early groma came to Rome from Egypt by way of Greece. In the

[3] R. Gibson, *A Treatise of Practical Surveying* (Philadelphia, 1789), p. 1.

beginning of the Roman Empire Greek slaves were brought to Rome as teachers and skilled craftsmen. With some of these slaves came the first knowledge of the science and their tools. Thus the Romans probably obtained the early groma. Later this instrument was made of metal and stone and then put upon a steady stand and sights added. The plumb line was hung from bolts, made of iron, that looked very much like the modern day railroad spike. The bolt or rivet fit into a hole and could be moved for adjustment. The sighted right angle could then be transferred to the ground. Herman Schön,[4] a German archeologist, describes the two above phases in the groma's develop-

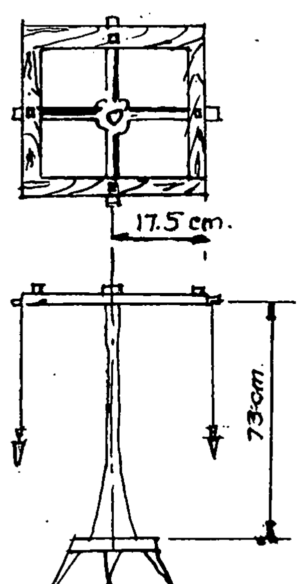

FIG. 2.

ment and one other. The third version (fig. 2) resembled a window frame put upon a post which in turn sat on a tripod base. The dimensions of the three forms remained constant during the evolution. From various examples found throughout Europe it seems that the post was about seventy centimeters long. Each of the perpendicular arms was seventeen and a half centimeters in length and perhaps two centimeters thick. The original of the modern cone plumb bob seems

[4]H. Schön, "Das Visirinstrument der Romanischen Feldmesser," *Jahrbuch des Deutschen Archäologischen Instituts,* XIII (1901), p. 127.

to have been used on this last type. The Romans applied their science to land surveying and to road, grade and level work. They built roads, small bridges, water systems, they divided the land, mapped and planned towns and forts. For grade and level work the Roman agrimensor[5] had another instrument, the chorobates (fig. 3), a very simple crude level, dating back to Egypt.

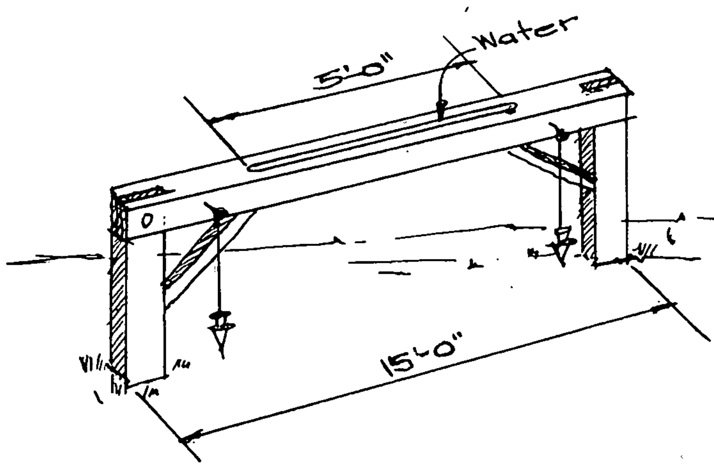

FIG. 3.—THE CHOROBATES

It was described by Vitruvious[6] about 16 B.C. It was a plumb level consisting of a wooden frame about 15′ 0″ long. This was supported at both ends by two legs and in the top a five foot water trough, to be used when the wind interfered with bobs. It was very unsatisfactory and may be the reason that Roman level work was irregular. There is, however, the fact that level work was done by skilled slaves and the poor work has been attributed to their lack of interest and training in leveling theory and the concepts of geometry.

The Greek surveyor of the same period developed a beautiful instrument, the dioptra (fig. 4).[7] This instrument was used for triangulation work, for plus and minus sights and for tunnel surveying.

It was set on a column, it could be used with the simple straight sight or a large circular table could be mounted with proper arrangements for angle work. It was turned and regulated with a gear system

[5]Agrimensor, measurer of the field.
[6]Finch, *Our Indebtedness to the Old Surveyor*, p. 2.
[7]This instrument was described by Hero in 50 A.D.

worthy of note. A crank and handle, attached to a horizontal gear could swing the sights through any angle, and in a plane parallel to the ground. Placed directly above this was a vertical, semi-circular, gear which controlled the vertical motion of the sights.[8] The dioptra stood about five feet from the ground, the sights were perhaps six feet apart. These were made of wood and metal and were of exceedingly good workmanship.

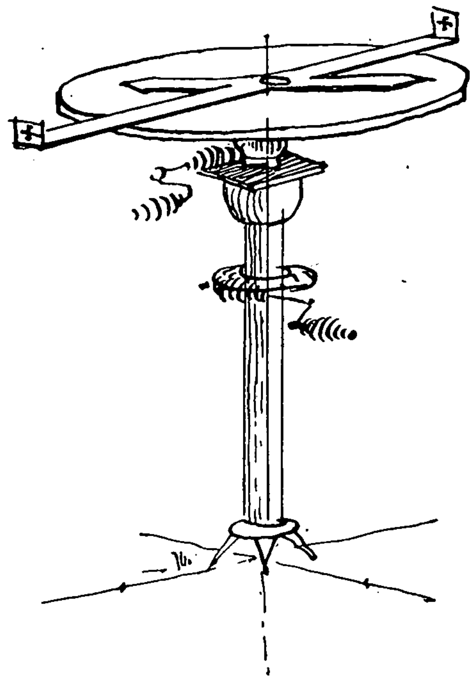

FIG. 4.—THE DIOPTRA.

Herman Schön tells of the professional arguments that arose between Greek and Roman engineers concerning the relative value of the Groma and "Die Dioptra des Herons." So convinced was each of his own instrument's superiority that grave stones of these engineers have been found containing arguments for and descriptions of their respective instruments.

These men were imbued with what amounts to a religious fervor when it came to carrying on their work.

[8]Finch, *Our Indebtedness to the Old Surveyor*, p. 1.

> "It was the sacred duty of the surveyor to seek after truth and to honestly divide the world onto its owners."

It was the great pride in their abilities in this art that kept the work at such a high standard over such a great period of time.

The surveyors[9] were an important and integral part of every army and of every human movement that occurred in history. There is little doubt that the exodus of the Jews across the Red Sea involved a surveyor's planning. These men made Hannibal a possibility. Their unsung and sung deeds in the great armies are remarkable.

> "But if there be so rude, ignorant and unlearned or so rudely blinded with self liking, that cannot be content to acknowledge anything in a perfect soldier that is wanting in themselves (for such there are that will most arrogantly maintain his fond opinion) let them but regarde and marke the renowned Captain Alexander the Great, who held this knowledge in such high estimation that he seldome, or never would, in his manifolde conquest, attempt anything whether it were forte, towne or countrey but first he would have the exacte Topographie thereof and hereupon invent, devise and after execute his warlike Polycies."[10]

We are told of the great deeds of the old armies accomplished in the crossing of great stretches of land and water. One of the best testimonies to the surveyor's powers comes from the pen of the historian, Herodotus telling of Cyrus' revenge upon the river Gyndes.

> "When Cyrus reached this stream which could only be crossed in boats, one of the sacred white horses accompanying his march, full of spirit and high mettle, walked into the water and tried to cross by himself; but the current seized him and swept him along with it and drowned him in its depths. Cyrus enraged at the insolence of the river, threatened to break its strength that in the future even women could cross it without wetting their knees. Accordingly he put off his attack on Babylon and dividing his army into two parts, he marked out by ropes one hundred and eighty trenches on either side of Gyndes, leading off from it in all directions, and setting his army to dig, some on one side, some on the other, he accomplished his threat."[11]

Later we again see the abilities of his engineers when:

> "He turned the Euphrates by a canal into a basin, which was then a marsh, on which the river sank to such an extent that the natural bed of the stream became fordable."[12]

[9]It is not known when this word first was used, it is suspected that these men were called supervisors in Egypt, Architects and wise men in Greece and Rome. Later, in southern Italy the term "engineer" made its appearance. This, from the fact that skillful men conceived practical notions from their brains—users of ingenuity. A. Fitzherbert tells us that the word "surveyor" is of French origin and means "Overseer of the land."

[10]Digges *Pantometra*, p. II

[11]Herodotus, *History*, I (London, 1927), 96

[12]Herodotus, *History*, I p. 97

Leonarde Digges insists that because Cyrus' men were not as well trained in the art of "topographie" as was necessary and because Cyrus himself did not apply it to his campaigns to the extent that Alexander did when entering upon the conquests of new and strange grounds, that he met defeat in his attack on Massagetae.

The Queen, Tomyris, advised him to stop building his bridges and towers and to cease all warlike activities; whereupon, according to Herodotus, Cyrus called together his generals, the Persian Wisemen, and his engineers. These advised him not to cross the river[13] but to allow the Queen to battle Cyrus on Persian ground.[14]

It would seem that Digges is not quite fair, and I would contest his assumption that Cyrus' topographical knowledge was wanting. Instead, I would offer the political interference of Croesus for the defeat of Cyrus.

These early army engineers used all the known forms of instruments. They measured distances with staffs or poles or strides. They used no constant units of length or area. They devised new methods as they were needed. They, in short, were men of great abilities and their importance cannot be ignored.

They sometimes traveled with the conquering armies; they often lived at one of the great cities where the captains could send their men with problems and for advice. This was perhaps the beginning of consulting engineering.

Of the early plummet and water level instruments, the latter quickly replaced the former in level work. The later instruments were slowly developed and were never more than modified Gromas or Dioptras. There was this slow methodical development through the dark ages that had no great change or impetus until the Renaissance. This development entered a violent stage with the bringing of gunpowder from the East.

The entrance of the projectile into mathematical science gave rise to our modern mathematics. It brought in the features of gravity, mass, wind resistance, earth curvature, vertical angles, inaccessible heights and modern trigonometry.

Books written at this time concerning the great developments in the sciences were many and varied. Astronomy and pure mathematics had long been the main interests of the educated men, and it was in the

[13]The River, Araxes
[14]Herodotus, *History*, I, p. 105

fifteenth, sixteenth, and early seventeenth centuries that this interest reached a climax.

Astronomy had the telescope or "perspective glasse" and the vertical angle measurement that first made its way into the art of surveying with the invention of the theodolite by the famous English surveyor, mathematician and Gentleman, Leonarde Digges.

It is true that the coming of gunpowder increased the mathematical activity, searching for devices and systems that would aid structure in more accurate artillery fire; but it is also true that above this field there arose a group of Gentlemen, calling themselves surveyors, who were interested in this science purely because of its potentialities to a great civilization. These men were not military men nor were they politically minded; they were surveyors, possessing the same feelings about their art that was found in the early Roman and Grecian engineers.

They spent huge sums of money on their own private geodetic surveys; in order that standards might be established they devoted their time to the development of new units and to the improvement and invention of new instruments. Their work was of great value to the governments and, in most cases, they were encouraged financially and morally by the reigning princes.

> "To the right, honorable, my singular good lord Sir Nicolas Bacon Knight, lord keeper of the great Seale of England."[15]

This interesting dedication was found at the beginning of longimetria, book one, of three by Leonarde Digges.

> "The other parte named Longimetra the ingeniouse practitioner will apply to topographic, fortifications and conducting of mines under the earth and the shooting of the great ordinance."[16]

It was in this first part that Digges reviewed geometry and the geometrical definitions—mainly as a form of reference for the problems and explanations given later in the writing. It is of interest to look at some of these same definitions and to remember that it was these men who developed our modern sciences.

> "A. Circle—a plane figure determined with one line (a crooked line), called the circumference in whose midsts there is a point named its center, from which all lines drawn to the circumference are equal."[17]

[15]Digges, *Pantometra*, p. I
[16]Ibid., p. I
[17]Digges, *Logimetra*, p. 6

Further on in the same book he describes the bisecting of a line.

"Then take a Ruler and lay him upon both points, crossing the center and thus draw your squire line."

The squire line is a line perpendicular to the horizontal plane— or the plumb line.

Digges quickly covers the elements of geometry and then shows their application to surveying. He made very extensive use of proportional triangles and was perhaps the first surveyor to pay such a great deal of attention to the measuring of vertical distances. He describes a clever instrument, the "Quadrant Geometrical" which could be used in rapidly calculating the heights of trees, towers, walls, buildings and all types of vertical distances. He further tells all future surveyors the care with which they must work, describing the dire results that follow careless workmanship. He tells of problems and with amazing cheerfulness carefully relates the manner of solving each.

The quadrant was a simple device, a quarter circle with a radius of about two feet. It was divided into degrees and parts of degrees. From the center of curvature hung a plumb bob and line. Along one edge there were two metal sights[18] (see fig. 5).

This instrument was rather heavy and was not set upon a staff or stand, but was carried in the hands.

In using it the engineer sighted along the edge, through the sights and at some small point on the object whose height was to be determined. The plumb line would always hang vertically and would intercept the quadrant at a certain angle. The surveyor had to get close to the ground or add his height to the result.

There would then be two right triangles, the triangle formed by the object's vertical height and the line of sight, the other triangle formed by the plumb line and the line of sight. These were similar triangles, the sides were proportional and so by measuring the distance from the plumb line to the foot of the object a soluble proportion could be set up. These instruments were made of brass, wood and iron. They were made by order in the local instrument shops and differed in accuracy with the section. They were inaccurate in that they were held in the hands. They were heavy and unsteady. They were hand divided and tooled. It was this increasing interest in the vertical

[18]Digges, *Logimetra*, p. 11

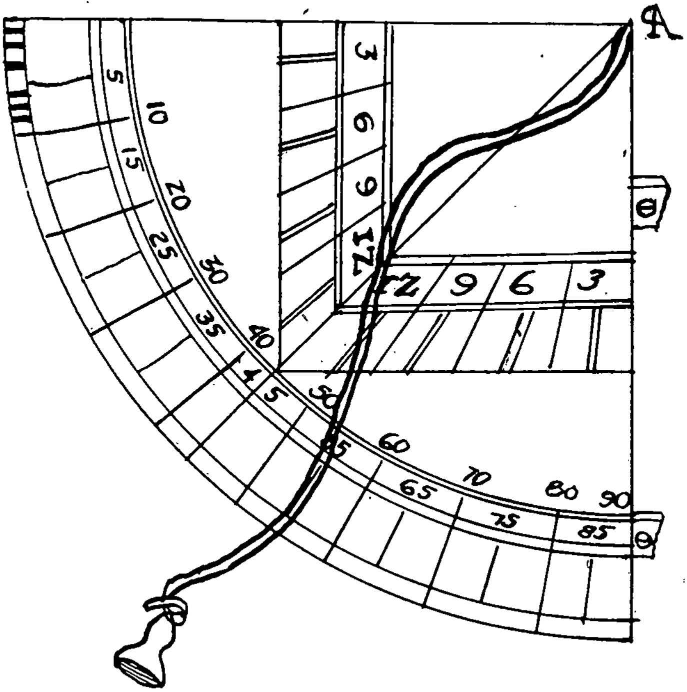

FIG. 5.—THE QUADRANT.

angle, however, that led to the improving of this instrument and combining it with other ideas that led to the theodolite and the modern transit. These men found the heights of buildings (see fig. 6),[19] the heights of mountains, walls—in short, they found the vertical distances.

"How by your Quadrant, with calculations speedily to know all heights accessible."[20]

Using the method of proportional triangles, Digges discusses the many rapid, rough simple methods of determining vertical distance.

If one found himself in a field and found it necessary to calculate the height of a tree, it would be a simple matter to tear a staff from this tree, place it upright in the ground and observe the shadows cast by both the tree and the staff. By pacing the length of two shadows and by measuring the length of the staff, the height of the tree can be obtained.

[19]Ibid., p. 20
[20]Ibid., p. 17

One of the cleverest methods that Digges describes is that of placing a piece of glass upon the ground.[21] Then by moving back and forth, always looking into the glass, until the top of the object's

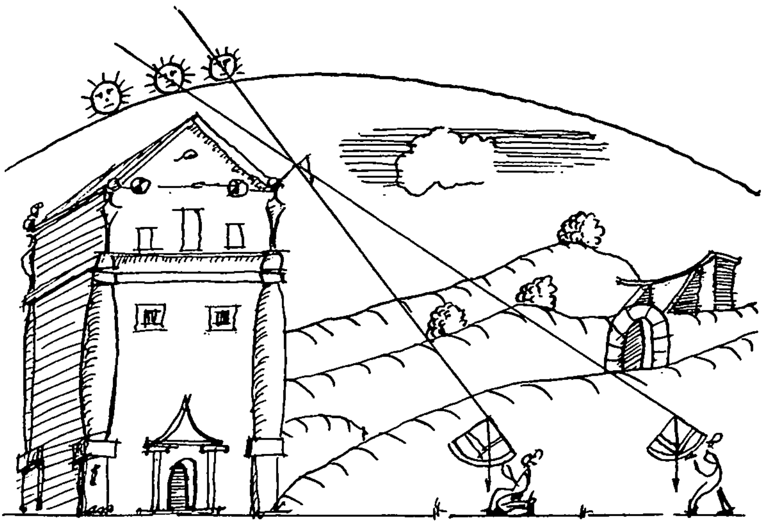

FIG. 6.

image comes into view, one creates two similar triangles. Since the angle of incidence is equal to the angle of reflection, the two angles are equal (see fig. 7). To determine the height of the object by proportional sides it is necessary first to obtain the vertical distance from the observer's eye to the ground. This is simply done by allowing a plumb line to touch the ground, holding the cord at eye level. When the measurements of the horizontal distances of the tree or other object and of the plumb cord to the mirror have been taken, the job is complete except for the simple proportion.

"By Glasse heights may be pleasantly practised and found in this wise."[22]

With a parting warning of the dangers and sources of error in the use of these instruments, the author goes on to his next book and topic. These early surveyors felt it their duty to spread their knowledge as far as possible. True teachers, some of them insisted that only the truths should be learned—they could see little reason for

[21]By "piece of polished glass" it is obvious from what follows that Digges was referring to a mirror.
[22]Ibid., p. 19

the existence of half or misguided conceptions or for their being passed on as knowledge.

"I would not have you ignorant that the nature of water is such as by pipes it may be veered above the mountain."[23]

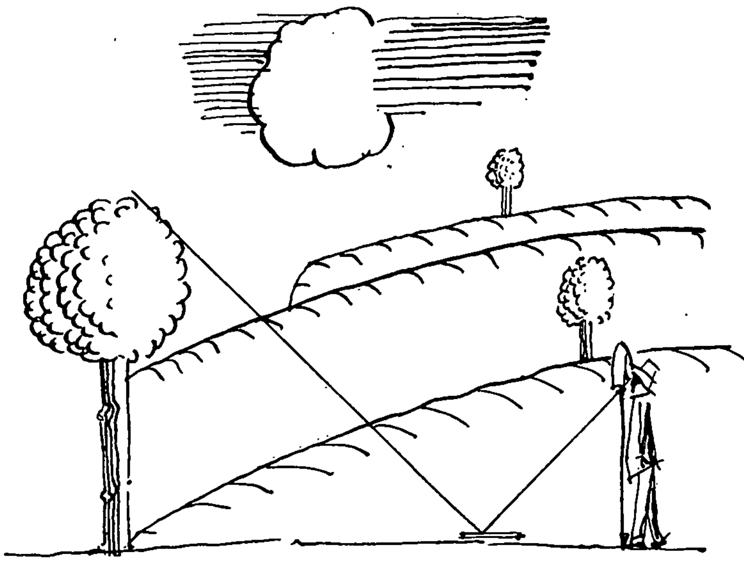

FIG. 7.

Far more violent is Arron Rathborne's feeling on the subject of incompetent workmen.

"In the Thirde Book I begin with the description of severall instruments fit and usuall for Survey; and thereof severall uses: wherein somewhat have I spoken (though too sparingly) concerning their abuse; being now growne shamefully generall by the multitude of ignorant persons (using or, rather, abusing) that good plaine instrument called the plaine table, who having but once observed a Surveyor, by looking over his shoulder, how and in what manner he directs his sights and draws his lines thereon; they apparently apprehend the businesses, provide them of some cast plaine table, and within small time after you shall hear them tell wonders, and what feats they can perform."[24]

It was with feelings of this nature that these surveyors described in detail their own surveying systems, their inventions, and their additions.

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[23] Ibid., p. 20
[24] A. Rathborne, *The Surveyor* (London, 1616), p. 33

In an attempt to abolish ignorance, a plea was made by both Rathborne and Digges to take care, a code of ethics was set forth, and there followed a civil upholding of this code.

It was in his third book, Stercometra, that Digges tells of the theodolite—the greatest single contribution made to the profession. This instrument was used for rapid vertical distance, vertical angle, and land work. The results were extremely accurate and it was through this instrument that the great geodetic surveys of the following centuries took place.

> "In the thirde named Stercometra is sette out and exacte mensuration of sundry solids, replenished with a number of rules and preceptes gathered out of Euclide, Archimedes and Appoloneus Pergeus, his "Conykes", wherein the Reader shall not a little delight himselfe with the finesse and subtlettie of their inventions, especially if he indevors himselfe to search out and reason, cause and demonstration of them. And to speake now somewhat of the commoditie of these conclusions as the skillful in architecture can applye the Stercomotra to persue his turne in preordinance and forecasting both of the charges, quantities and proportions of all parcells necessarily appertayning to any kind of building."[25]

It is in Stercometra that Digges describes thoroughly the art of land surveying, the division of land into the proper sections, the planning of town sites, the installations of water systems, roadways, mapwork, and fort construction. He gave the problems faced; he put down a standard method of note taking.

This he accomplished with the use of the "Theodolitus", an instrument consisting of a horizontal circle of "360 grades (degrees)" divided into 2 degree divisions and equipped with an "Allidada."[26]

> "Having already plainlie declared the making of the Quadrant Geometrical with his scale thereon contayned, whose use is chiefly for altitudes and profundities:[27] the composition also of the square and planisphere or circle named theodolitus, for measuring of lengths, breadthes and distances. Yt may seeme superfluous more to write of these matters, yet to finishe this treatise, I think it not amisse to shewe how you maye joyne these three in one wherebye you shall frame an instrument of such perfection that no matter, altitude, longitude, latitude or profunditie can offer itselfe, howsoever it be situated, which you may not both remedy readely and most exactly measure."[28]

The units used by Digges were especially interesting. It must be remembered the difficulties faced by these men because of the lack

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[25] Digges, *Pantometra*, p. 6

[26] This is merely a movable telescope. Today we use an instrument on the plane table called an alidade, which is derived from this word.

[27] Depths, technical.

[28] Digges, *Stercometra*, p. 81

of standards and it was not until the French Revolution that a national movement was undertaken to establish a standard.

Digges used the "Italian myel" defined by him as being one thousand paces, each pace being five feet. Distances were measured with knotted ropes, poles or foot paces.[29]

Rathborne used perches and rods, square perches, and square rods. For cubic measurement both men used an odd standard.

If the object whose volume was to be found was a perfect cube the volume was termed "content"[30] and was measured in "Cubical Unit." If, however, the object was of irregular proportions the volume was called "Crassitude"[31] and measured in square units.

Rathborne was a more well-rounded surveyor than Digges in that his knowledge and interests were wider spread. He paid a great deal of attention to accuracy and developed the "decimally divided tape," a great improvement over the earlier forms of measurement.

He advocated wide knowledge in the "many" instruments then in use, each to fit the proper job. He faced a great deal of ridicule for his accuracy:

> "But here methinkes I heare the Adversarie question, to what purpose serves this niceness of ynches in instrumental observation?"[32]

and his arguments were just and proper.

This violent man often bursts forth into indignant punishment of the "ignorant competitors", these destroyers of the art should in turn be destroyed.

> "And so I will leave the blind with tumbling the blind into the myre."[33]

It was at this time that the great estates of England were being divided and it was here the surveyor again increased his scope. He drew up the legal terms for the transfer of the land, he ascertained the value of land, houses, dogs, cattle, wives,[34] sheep, crops and lumber.

It was at the middle of the seventeenth century that the surveyor rose to his highest rank, and it is here that I end this paper.

> "These are to will and require you immediately to cause a Commission to be drawn up and directed to A. R. for the survey of his Majesties Honors, Lordships and Manors of A and B in the county of C, and of Castles, Houses.

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[29]The 5′ paces mentioned before were another type of measurement, since the foot pace at most is 3 feet.
[30]Ibid., p. 81
[31]Digges, *Stercometra*, p. 81
[32]Rathborne, *The Surveyor*, p. 116
[33]Ibid., p. 6
[34]Fitzherbert, *Surveying*, p. 32

Parkes, Lands, Tennants and Hereditments thereunto belonging or appertayning, whereunto is to be annexed the above mentioned Articles, Whereof fayle you not: and these shall be your warrant in behalfe from the Court & Co."[35]

The above was the parting order of the chief surveyor to his men.

"Men's works have faults, since Adam first offended, and those in these, are thus to be amended."[36]

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[35]Rathborne, *The Surveyor,* p. 204

[36]Ibid., p. 228.

CITY PLANNING AND THE CIVIL ENGINEER

BY ROLAND B. GREELEY*

(Presented at a meeting of the Boston Society of Civil Engineers, held on May 20, 1953.)

MY purpose is to point out some of the major objectives of planning and some of the major elements in a city planning program. By doing this I expect to show how directly the work of the civil engineer is inter-related with that of the city planner; and I hope also to indicate some ways in which the planner may be of direct assistance to the civil engineer.

First, I would like to emphasize that I see no clear line of demarcation between the functions of the city planner and the civil engineer. Both are concerned primarily with designing elements of our environment. Both deal particularly with physical components of the environment, but neither can hope to design with true success unless his plans lead to the improvement of man's social and economic condition. In other words, the physical environment is the medium with which both professions work, but the improvement of social welfare, in the broadest sense of that term, is the objective of all we do.

Perhaps it is appropriate to use the analogy of the rainbow. In the solar spectrum each color fades imperceptibly into the adjoining colors, with no hard-and-fast dividing lines between them. Technical definitions can be established to describe the lines which separate one "color" from another, but for most practical purposes these lines are indistinguishable: green fades into blue, blue into violet, etc. Similarly, we may liken the band of green to the field of the city planner, and the band of blue to the field of the civil engineer, without discovering any practically useful dividing line between them. However, in the case of any specific planning or design project, a closer analogy may be found in the spectrum of some specific element or relatively simple chemical: here the bands of color do not fade imperceptibly from one to another, but are present as rather clearly-defined bands, sometimes with one band or another standing out as clearly dominant. Similarly, the respective functions of the civil engineer and the city planner

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(and other professionals) may stand out clearly with respect to a specific planning or design project, even though the respective fields are not easily distinguishable as professional fields.

Further testimony to the lack of clear distinction between the two fields is offered by the large numbers of civil engineers who have become city planners. Accurate figures have not been compiled, but I suspect that one out of five members of the American Institute of Planners is, or has been, a qualified member of the civil engineering profession. I could name a few who have switched from planning to engineering, but most of the changes have certainly been from the larger, older profession of civil engineering to the much younger, more rapidly-growing profession of city planning. (The Boston Society of Civil Engineers was about to celebrate its 70th birthday when the first organization of professional city planners was founded in 1917.)

It would seem, then, that the difference between city planning and civil engineering is not one of basic function, or even of basic disciplines and tools. It is rather a difference in emphasis, in approach, in the application of method. There are undoubtedly many types of civil engineering work which a competent planner could handle satisfactorily, if he adopted the approach and methods of the engineer. Experience has demonstrated that scores of civil engineers have made notable contributions to city planning by adopting the emphases and approaches required in the planning process.

As a first attempt to explain this difference in approach between the civil engineer and the city planner, I would like to draw heavily from the remarks of a British civil engineer, Herbert J. Manzoni, City Engineer for Birmingham, who discussed "the Position of the Engineer in Relation to Town and Regional Planning" before the British Institution of Civil Engineers, in 1944. According to him the planning process involves the conducting of surveys and the making of deductions in a manner "common to the work of engineers." But, he goes on to say, "in the practice of planning the complexity of the process is outstanding . . . Only those who have attempted to envisage the complete necessities of a living community can form a reasonable idea of the task" which confronts the planner. In the process of community building, or town planning, it is essential that some member of the team "have sufficient knowledge of the complete requirements to ensure that each aspect of the work is performed by the most competent person." Obviously, the engineer will frequently be the most competent person to handle many aspects of the total job. Often the civil engineer will have most of the basic qualifications required of the coordinator, but according to Mr. Manzoni, "the specialist is very likely to pay undue attention to his own subject and thus achieve an unbalanced plan." Or, to express this viewpoint in a slightly different way, there must be a "generalist" on the team whose sole job is to look at the whole picture; and this generalist tends to disqualify himself if he also performs the functions of a specialist in connection with that job. It is not a question of his qualifications, but rather of his approach or attitude toward the job. His function is to see and cope with all the necessities of the living community, not to become involved with the details of providing any specific necessity. This is what the planner usually refers to when he talks about the "comprehensive" approach.

Another factor which contributes to the complexity of the planning job is the time factor. Most solutions to problems of the physical environment involve a fixing of patterns which may, and frequently will, far outlast the physical structures themselves. A building or engineering structure fixes a pattern which will normally last many years after the structure itself has become obsolete. And conversely, structures or engineering layouts frequently last for many years after the need which they were designed to satisfy ceases to exist. These are two very different facets of the same problem: the problem of designing the physical environment, with its relatively fixed and static structures, in such a way that it will continue to be consonant with the everchanging needs and values of the living community.

A few examples may help to illustrate this point. Elevated transit lines were built in New York City to serve significant transportation needs, and their construction in part caused significant changes in land use along the avenues where they were located. Although the elevated structures were dismantled many years ago the character and quality of buildings and uses along these avenues still show unmistakable effects of the elevated lines. The blight caused by the elevated structures will continue to last for many years and cost the City many millions of dollars not figured into the initial or operating "costs" of the transit system. Then again, most of the blighted areas in cities, and many of the facilities which contribute largely to the traffic and transportation problems which now beset us, were relatively well designed to meet the needs and standards of the period in which they were built, but have now become obsolete because of changed needs, changed standards, or changed patterns of activities in those areas. The housing in the outer South End of Boston was relatively good when it was built—as single-family row housing. These same structures have now become slums because of the changed pattern of urban residence and the resulting change in the type of residential use which can be maintained in that area. The typical gridiron street pattern of the Back Bay, South Boston, Mid-town New York, and countless other places withstood the test of generations as a good, workable system for handling circulation to and through urban areas. But it is difficult today to find any kind of land use that is really well-suited to a regular pattern of small rectangular blocks separated by continuous traffic lanes; and certainly there is no greater obstacle to urban traffic flow than the frequent intersections resulting from such a street pattern. The pattern was frozen by the design, but the uses, the facilities, and hence the currently "desirable" pattern have all changed since.

What is the implication of all this, so far as the planner and the engineer are concerned? It means that the implications of any planning design, and the implications of many engineering designs go far beyond foreseeable conditions. It means that, however well we may design with reference to today's needs and today's standards, the results of our designs may be woefully inadequate, may be liabilities rather than assets. Obviously, the simple answer to this is that the engineer or planner must endeavor to look into the future when he does his designing. He can't expect to be an expert at crystal-ball gazing, but if he is at all good at his job he will succeed in recognizing trends to such an extent that the structures he builds will not become obsolete, at least until they have "paid off."

That may be sufficient for the civil engineer; it may be all that can be reasonably expected in the design of a specific project to serve a specific function. But it is not enough to satisfy the criteria of good planning. Presumably the engineer can be satisfied if he makes skillful use of all relevant facts and determinable trends in arriving at the solution to his problem. But the planner must make significant use of another ingredient—an approximation of what should be. He must modify the preliminary solutions derived from analysis of facts and trends, by incorporating an estimate or judgment as to what will probably prove to be desired by or desirable for the people over the ensuing years. The social sciences have worked out some so-called scientific techniques for making these estimates, but much of this phase of the planner's work is much more an art than a science. Some of what appear to be the soundest plans are based much more on intuition, on subjective judgment, or on educated guesses conditioned by experience than they are on scientific or engineering procedures. The planner is thinking, at least in part, of the importance of this estimate of what should be when he emphasizes the importance of the "long-range" approach.

Because of the complexities of the comprehensive approach, and because of the uncertainties of the long-range approach, the task of the planner is one of solving problems for which there is no right solution. His plans may be relatively good, or relatively poor, but it is quite unlikely that they can be good, or correct, in an absolute sense. And as a consequence, it is quite unlikely that they can be complete. At any period in time they may actually be the best which could be expected; but at a later period, they may require significant changes because conditions and value judgments will have changed. The engineer or architect is accustomed to preparing blue-prints and specifications for a tangible structure which will, almost invariably, become a reality before any significant conditions or objectives change. The planner when working on long-range, comprehensive plans, is preparing plans for a living community with full realization that many significant conditions and objectives may change before his plans can possibly become reality.

This brings me to the major point which I wish to emphasize. The city planner is primarily concerned with planning, not with plans; he is interested in a process, not in the preparation of blue-prints; potentially his greatest contributions lie in guiding what is done, not in pre-determining what is to be done.

The city planner customarily places great emphasis on the master plan as a planning device. A well-prepared master plan may be of great use, for several years without modification. But if it is to be an effective instrument in the planning process, if it is to be a really useful guide in the growth of the community, it will be subject to continual review, and will be revised frequently in keeping with changing conditions. The master plan, without the planner and the planning process, is usually destined to serve a very short period of usefulness. When an engineer prepares a plan he can usually anticipate that a single decision will adopt it and insure its effectuation. If a planner prepares a master plan with the objective of securing its adoption by a single decision he should expect that it will be gathering dust in some pigeon-hole long before an appreciable number of his proposals have been realized. The competent city planner today does not think of the master plan as an objective, nor does he think of zoning or subdivision control, or urban redevelopment plans as objectives. They are merely instruments to assist in carrying on the planning process. Good master plans, zoning ordinances, and subdivision control regulations in no way insure that the growth and development of a community will be orderly, efficient, desirable. But if they are actually used as flexible tools to guide the public and private decisions which determine the future pattern of the community, or in other words, if they become an integral part of the planning process, then they are serving the purpose for which they were intended.

Now let us look at some of the ways in which the planning process may assist the engineer in performing his functions. I submit that there at least four contributions which good planning should make in this direction:

(1) The master plan, and similar planning tools, will establish a general, though flexible, framework for future development. It will show what changes in pattern or growth are "expectable"—that is, what can be expected in the future as a result of the conscious conditioning of trends to bring about that which will probably be considered desirable.

(2) The planning process will help to anticipate future environmental standards—to discover what effects changing technology and changing social customs and activities will have on the desirable environment in the living community. Standards of residential density, of circulation patterns, of community facilities and services, change significantly from generation to generation, and from place to place. Part of the planner's job is to coordinate the contributions of scientists, engineers, social scientists and other specialists into an integrated effort to anticipate what will emerge as desirable standards.

(3) Most projects which are undertaken for development or growth of the living community are affected by, and affect, both directly and indirectly, other aspects of the community. The competent designer of an architectural or engineering project inevitably adjusts and adapts his design so as to make allowance for the more obvious implications of each project. The express highway designer allows for the factor of "induced traffic;" the sanitary engineer allows for future residential

growth in designing water and sewer lines; the architect considers potential community and adult education needs in designing a school building. But there may be secondary implications which are not apparent either to the designer or to the representative of the client: the location of an expressway may have serious long-range effects on local circulation or neighborhood land use patterns, far more serious than just the immediate "land damages;" controls over land density or changes in domestic water supply uses may significantly affect the demand for water and sewer facilities in an undeveloped area; potential changes in the social pattern of the community, or in the demarcation of school districts may alter the future need for special facilities in a proposed school. Or, on the other hand, the secondary implications may be in such fields as economics and municipal finance, population growth and composition, or political and social structure. If twenty million dollars is available for highway improvements in a given area, it is relatively simple to determine what improvements will bring the greatest benefit for the expenditure; if the same amount is to be spent for either highway or transit improvements the decision as to how best to spend the money becomes more difficult; if the same amount is available for whatever will benefit the people most, then the task of deciding where it will do the most good becomes exceedingly complex, chiefly because of the multiplicity of secondary effects and benefits which may accrue. Normally the planner should be in a favorable position to submit sound advice on such problems. But even if he is not, he should accept, as part of his job, the responsibility for clarifying and pointing out the implications of one choice or another. The very process of planning includes a careful study of the inter-relationships among the various phases of community development, and the analysis of the effects which one project will, or may, have upon all others.

(4) Another major contribution of the planner should be the evaluation of tools and devices to facilitate the achievement of desirable objectives in community development. Some of these tools, such as zoning, subdivision control, and the official map procedure, which have been evolved in the past few decades, are primarily for the use of the planner. Others, such as urban redevelopment, excess condemnation, and highway access control, are usually wielded by other agencies of government, but are instrumental in effectuating planning goals. Many similar tools, and perhaps many not now even dreamed of, will doubtless be developed in the years to come, and the planner's position is one where he should contribute significantly to such development.

I do not mean to imply that any of the contributions described above are solely the responsibility of the planner, nor that he has any special "inside track" which enables him to excel in making these contributions. Almost by definition, he can not successfully work alone, and he should expect the politician, the lawyer, the specialists of many different types, and even the laymen to make significant contributions along these lines. However, these are part of the work for which he should be trained, and for which he presumably is being paid, and hence it is reasonable for others to look to him for leadership in these directions.

In conclusion I want to make one further point: the planner may in fact be a very realistic individual and may make very practical contributions to society, even though the nature of his work appears to be quite intangible. He is frequently called a dreamer, because he must look so far into the future; an idealist, because he must recognize objectives which seem remote in contrast to the exigencies of the moment; a dispensable cog in the government machine, because he doesn't build things and he doesn't accept responsibility for ultimate decisions. But I submit that his purely advisory role constitutes an essential, practical, and economic function of government, and perhaps of industry. I insist that he is performing his role adequately if he makes the right suggestions to the right people at the right time—in the interests of a better environment for the living community.

TRANSPORTATION PROBLEMS OF CEYLON'S PORTS

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(Presented at a joint meeting of the Boston Society of Civil Engineers and the Transportation Section, B.S.C.E., held on September 23, 1953).

Synopsis

This paper describes briefly the historical development of Ceylon's ports and discusses some of the technical and economic transportation problems connected therewith. Mention also is made of various projects, proposals and recommendations which are expected to solve some of these problems. They should also provide for more efficient port operation as well as a better distribution of commercial port facilities to serve the island.

The ports of Colombo, Galle and Trincomalee are discussed in more detail. For some time past Colombo has suffered from extreme congestion of shipping. On the other hand, at Galle the amount of shipping operations has been very limited due to navigational hazards and to lack of adequate port facilities; while Trincomalee has been developed primarily as a naval base.

At Colombo, major development works are already in progress or proposed. The case for the fuller development of Galle and Trincomalee for commercial purposes is discussed and Master Plans for the layout of the respective port facilities as suggested by the author are described.

Background

Since the development of transportation media is so closely associated with the collateral economic and political development of any country, it has been deemed advisable to give the following introductory background to facilitate the better understanding of the various transportation problems involved.

Physical and Climatological. Ceylon is a tropical island about 300 miles long by 150 miles at its maximum width. It is situated between 5° and 10° north of the equator off the southern tip of the Indian subcontinent at the confluence of the Indian Ocean, the Ara-

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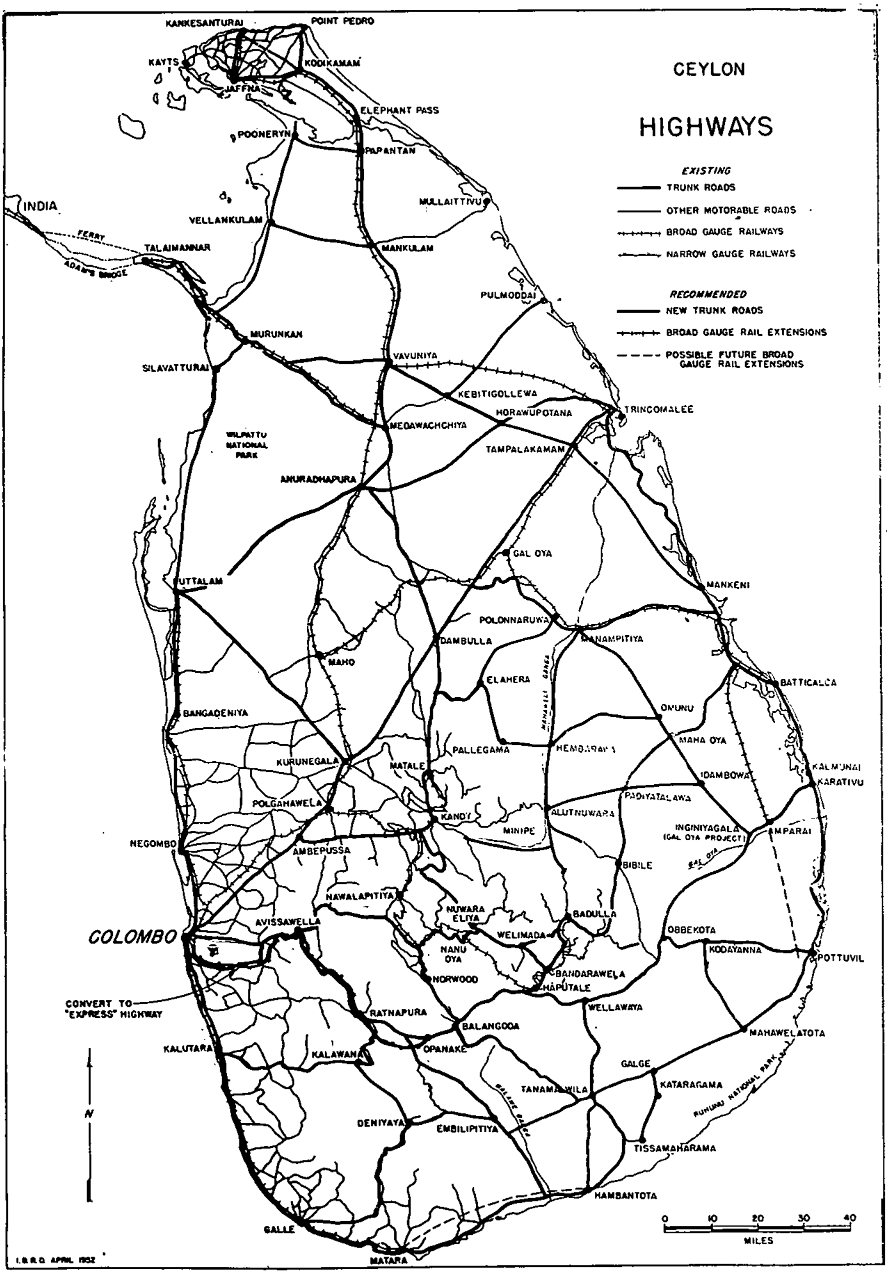


MAP OF CEYLON SHOWING TRANSPORTATION SYSTEM.

bian Sea and the Bay of Bengal. It comprises an area of some 25,000 square miles (about the area of New York State) and currently has a population of roughly 8,000,000.

Topographically, the island may be likened to a hat, the crown being formed by the mountain massif in the south-central region where peaks rise to 7,000 feet. The brim is represented by low lying coastal plains which extend outwards on all sides to the sea. Consequently, rivers generally flow in a radial pattern from the mountains to the sea. Both geographical location and topography have played an important part in the life and development of the country. Moisture laden winds from the Indian Ocean strike the central highlands and result in the "Southwest Monsoon" with heavy rainfall averaging 113 inches yearly falling over the southwest quarter of the island. It is in this region of abundant rainfall and steady tropical temperatures that Ceylon's agricultural development has mainly been centered and where the density of population is greatest.

Over the remainder of the island, usually called the "Dry Zone" within which most of the malarial territory is situated, the rainfall averages 64 inches per year, falling mostly during the "Northwest Monsoon" of comparatively short duration. This results in long periods of dryness when the flow of water in the rivers drops or ceases entirely and soils dry out under heavy evaporation.

Thus, from a topographical viewpoint, inland lines of communication, in the form of railroads and highways, encounter some formidable obstacles, either as mountainous terrain or as low lying plains subject to heavy flooding.

Historical and Political. Civilization in Ceylon can be traced back some 2000 years when, strangely enough, it was the "Dry Zone" which was settled. Ruins still testify to the highly advanced skills in the arts, religion, technology and civil organization of those and later times.

Ingenious and complex systems of irrigation canals and "tanks" or reservoirs can still be seen, having been constructed at various times down through the centuries. These irrigation works supported rice production and are so well laid out with regard to grade over long distances that they could hardly be improved upon even with the use of modern survey instruments.

Conquests by invading Indian tribes and internal civil wars and strife made their impact on this ancient civilization and, after the last great revival at the end of the twelfth century, decay set in with the result that most of the country returned to jungle infested by the malarial mosquito.

With the rounding of the Cape of Good Hope by Vasco Da Gama towards the end of the 15th century and the discovery of a sea route to India and the east, Ceylon became of considerable importance to the western world, situated as it is about half way between the east coast of Africa and the East Indies Archipelago. Thus, it was partly occupied by the Portuguese in the 16th century, by the Dutch in the 17th century, and wholly by the British towards the end of the 18th century.

During the past hundred years the agricultural resources of Ceylon have been developed for export on an extensive scale due primarily to British capital investment and enterprise. Coconuts and coconut products, tea and rubber, became the principal export commodities of the island and these largely paid for imports of rice and other foodstuffs, manufactured goods, raw materials, fuels (oil and coal) and other necessities.

Meanwhile, the political status of Ceylon steadily advanced. An able civil service administration was developed upon which was placed increasing responsibility with a view to eventual complete self-government. Constitutional reforms were enacted from time to time and for a number of years internal affairs were almost wholly under the control of Ceylonese Ministers. In 1947 full political independence was granted to Ceylon who elected to remain within the British Commonwealth as a dominion in a similar status as that of Canada.

Thus, a long period of stable government, coupled with a steadily increasing economic development, has given Ceylon the highest standard of living of any country in Asia. The new regime inherited a soundly based, honest administrative machine, together with large overseas financial balances and a healthy surplus in the state treasury.

The People. The present population of Ceylon comprises a mixture of racial and religious groups who have retained a cultural distinctiveness though living together with considerable communal tolerance. About 70% of the people are Sinhalese, being descendants of early Aryan migrators from northern India. Their language is Sinhalese and religion largely Buddhism. About 20% comprise Tamils of the Hindu religion, the majority of whom inhabit the northern part of the island, known as the Jaffna peninsula, and are derived from the early invasions from South India. A large block of this minority group comprises Tamil laborers brought in over the years to develop the large tea and rubber plantations. A smaller group of about 6 per cent are known as "Moors," who are mostly Moslems derived from the Arabs who were actively trading with Ceylon before the arrival of the Portuguese in the early 16th century. The remainder of the population comprises Eurasians, Malays, Europeans, and the fast disappearing aboriginal stock, the Veddahs. About 10% of the people are Christian, mostly Roman Catholic, who mainly inhabit the west coast of the island.

Due to climatic conditions, the majority of Ceylon's population, or about 70%, is concentrated in the southwest quarter of the island, a region which includes Colombo, the capital, and an important port of call. Density reaches over 700 persons per square mile in this region where also about two-thirds of the total cultivated area is located. Pressure on the land is thus severe.

Elsewhere, the main areas of population concentration are on the Jaffna peninsula at the northern end of the island and on the east coast in the vicinity of Batticaloa. Thus, about 80% of the population occupies only about one-third of the island area while the remainder is thinly settled over the "Dry Zone" in small settlements and isolated villages. As may well be imagined, this pattern of population distribution provides major inland transportation economic problems, there being congestion in some areas and scarcity of population in others.

Due to the success of anti-malarial campaigns (spraying of DDT) since World War II, the rate of increase of the population has risen from 1.7% to 2.8%, so that the total population is expected to reach 10,000,000 by 1962 and 12,700,000 by 1972. This tremendous growth has caused a severe shortage of food necessitating larger imports of rice from southeast Asia and even from China. Reported malarial cases have been reduced to an annual average of about 700,000 compared with about 2,660,000 in the preceding years. With the opening up of the former malarial country, located chiefly in the "Dry Zone," for colonization purposes, a better distribution of the population will be possible. This redistribution will call for improved and increased road and rail transportation but should ultimately result in a better transport usage factor.

General Economy. Peasant and estate agriculture constitute the core of Ceylon's economy. According to the 1946 Census, the gainfully employed population was distributed as shown in Table I.

TABLE I

Occupational Grouping of Gainful Workers, 1946 Census

	Number	*Percent*
Agriculture	1,339,100	51.3
Forestry and fishing	42,300	1.6
Industry and mining	286,500	11.0
Trade, transport & banking	552,500	21.1
Professions, public & domestic services	390,900	15.0
Total	2,611,300	100.0

Of the total population only about 15% may be considered as urban, the remainder are predominantly rural, inhabiting the villages, small holdings and large estates.

In 1950-51, the gross national product of the island was estimated at approximately Rs. 4,450,000,000 (1 Ceylon Rupee is equivalent to $0.21 U.S.). Of this total, about Rs. 2,400,000 or 55% is attributed to the production and handling of agricultural commodities grown in Ceylon. Table II shows percentagewise the breakdown of the gross national product.

TABLE II

Gross National Product by Sources, 1950-51

Source	*Percent*
Production, Processing and Distribution of Domestic Agricultural Products:	
For export	42.1
For domestic consumption	12.9
Other Domestic Goods and Services:	
Factory and cottage industry, fisheries construction, etc. (including government investment)	17.2
Trade and transport (other than domestic agricultural products)	11.3
Professions, finance, personal service	7.9
Government services	5.3
Rents	2.5
Income from Abroad	0.8
Total	100.0

From this table it will be apparent how vital is the part which transport plays in the general economy. About 80% to 85% of the gross national product is dependent upon transportation, either for domestic distribution or for overseas commerce.

A breakdown of the total developed agricultural area of some 3.5 million acres, 560,000 acres are under tea cultivation, 660,000 acres are under rubber, and about 1,000,000 acres are under coconut production.

Cultivation of these export crops is located principally in the "Wet Zone" and spreads from the coast up into the central highlands. Coconuts occupy the coastal belt, rubber the intermediate levels and tea at the higher elevations. Rice is grown in thousands of small plots scattered about the country, though mainly concentrated in the "Wet Zone." These add up to a total of over 600,000 acres. However, rice production has almost never sufficed to feed the population and recently up to 50% of the rice consumption has had to be imported.

Industrial development outside the processing of agricultural products has been very limited. This is chiefly due to the absence of any appreciable quantity of industrial raw materials and, to a lesser extent, the lack of cheap power and local technological "know-how." An important contributory factor is the lack of business enterprise by the population. This is exemplified by the general desire to confine financial investments to trading or land holding, and employment to the pensioned security of a government department. There are no deposits of coal or petroleum, while iron ore deposits are scattered. Graphite, precious and semi-precious stones are the most important minerals presently exported. The development of hydroelectric power for public distribution was commenced after World War I and is in the process of further development.

Consequently, the economy of Ceylon is based largely upon the three major export crops and any world price fluctuations of tea, rubber and coconuts vitally affect the balance of payments and the national income. From the point of view of foreign exchange, tourism now ranks as the fourth industry of Ceylon.

Despite price fluctuations, a rising volume of exports has been sufficient to meet the minimum requirements of the growing population and to maintain a foreign trade surplus. Total exports have exceeded imports in all but two of the past twenty-five years. Internal finances have been kept in balance and ordinary expenditures have been consistently covered by revenues so that a surplus was left to meet some part of capital expenditures for development.

TRANSPORTATION

Development of transportation media in Ceylon has proceeded steadily over the past century in the form of seaports, railroads, highways, canals and waterways and, more recently, airways. But, like many other countries of the world, natural growth and improvements were retarded during the depression of the Thirties and the later war period. This retardation has become even more apparent due to the increased tempo of economic development experienced during the war and post-war periods which has superimposed a greater demand for all types of transportation.

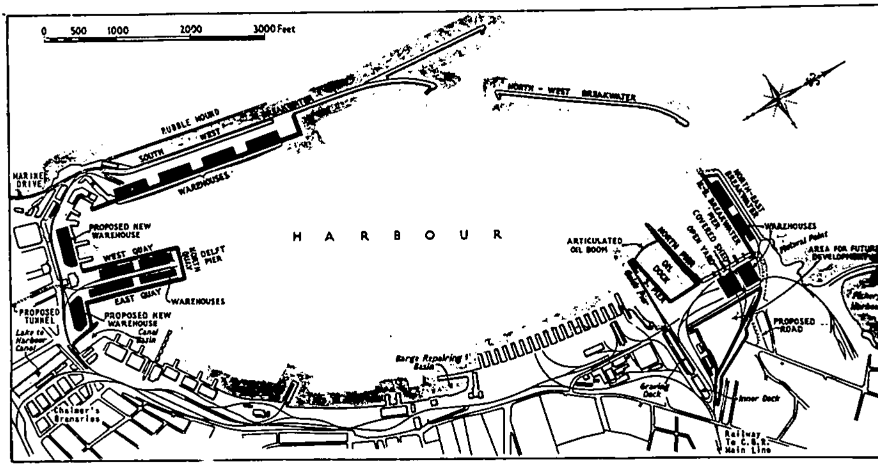
Most of Ceylon's population, production, commerce, and industry are concentrated in the southwestern or "Wet Zone," which is served by the only major port of Colombo. With a population of nearly 1.5 million, Colombo is also the only major city of the island and is the seat of government and finance, most of the existing commerce and industry, and nearly all the export-import trade. This state of affairs arises chiefly from geographical conditions and from the comparative ease of developing the country's natural resources in this area. Due also to the mountain ranges in the south-central region which form a natural barrier to easy surface transportation, most of the existing road and rail transportation facilities and main lines of communication lie in the western half of the island, with comparatively sparse facilities in the eastern half.

PORTS

Apart from the major port of Colombo, there are some half-dozen minor commercial ports of the open roadstead type strung around the coast of Ceylon. The most important are Galle on the south coast: Batticaloa on the east; and Kankesanturai, Kayts, and Jaffna in the extreme north. In addition, there is an important naval base at Trincomalee Harbor on the northeast coast under control of the British Admiralty by inter-governmental agreement. Hitherto, Trincomalee has not been put to commercial use.

PORT OF COLOMBO

History. Assisted by the opening of the Suez Canal in 1869, development of this artificial harbor occurred mainly between 1874 and 1912 with the construction of concrete block breakwaters to form about half the perimeter of a water area of some 640 acres.



PORT OF COLOMBO
DEVELOPMENT PROJECT

The southwest breakwater was completed in 1885, the northeast and later the northwest (island) breakwater by 1906, and the extension to the southwest breakwater in 1912. However, up to 1951 no deep water alongside berths, except oil tanker piers, had been constructed. Ships of deep draft are moored in midstream and all freight and passenger traffic between ship and shore are handled by harbor craft. Plans for deep water berths were drawn up in 1902, 1908, 1917 and 1926, but not until 1946 was real progress made. Between 1871 and 1952 net tonnage of shipping calling at Colombo increased from 170,000 tons to over 13,338,000 tons as Colombo became one of the chief ports of call in South Asia. Maximum draft is 35 feet, while berths in midstream numbered 38 (now reduced to 29) during the Southwest Monsoon (April to October), and 47 (now reduced to 37) during the Northeast Monsoon (October to April).

Currently, shore facilities at Colombo include two graving-docks, the larger one being capable of taking a vessel of 22,000 tons. The larger dock, 695 feet long, was constructed in 1909 and the smaller one, 350 feet long, in 1939 as an extension of the former. Other facilities include bulk coconut oil tanks; extensive bulk oil tank farms located 1½ miles from the harbor and owned and operated by different oil companies; coal storage yards; barge repairing basin; mechanical workshops; patent slipway of 1,000 tons capacity; boat repair yard; a small naval yard recently turned over to the Ceylon Government by the British Admiralty; shallow water piers and wharves for passenger and cargo craft; and a number of outmoded warehouses and transit sheds scattered over the port area. Prior to the current development construction, total shed accommodation was under 700,000 square feet. Nearly 400 cargo lighters of 35 to 100 tons capacity are owned and operated by five licensed landing companies.

The harbor basin is also connected by means of a narrow canal with a system of lakes known as Beira Lake, east and west, located within the city and these in turn are connected with the main canal system of the west coast. This canal system of inland waterways is partly man-made (mainly by the Dutch during their occupation) and partly natural waterways, such as rivers, lakes, and lagoons. The system extends for over 96 miles between Puttalam in the north and Kalutara in the south.

A belt railroad serving the port is operated by the Port Commission and connects with the main lines of the Ceylon Government Railways which serve the island. Track gage is 5′-0″ which is the local standard gage.

Housing for port personnel is the subject of a nine-year plan, to cost about Rs. 10,000,000. Up to the middle of 1951 the following housing had been constructed out of a total of 1050 houses projected:

Staff Officers' and Clerks' Bungalows	26
Overseers' Quarters	35
Senior Artisans' Quarters	12
Junior Artisans' Quarters	59
Laborers' Quarters	385
Total	517

Administration. Administration of the port is vested in the Colombo Port Commission set up by parliamentary act in 1950 which revised in some particulars the previous form of administration. The Port Commission consists of an Advisory Board presided over

Aerial View of Colombo Harbor

by a Port Commissioner who is responsible for the day to day administration and operation of the port under the general direction and control of the Minister of Transport and Works. The Board consists of ten unofficial members representing commerce and industry plus six official members, namely, the Principal Collector of Customs, the Mayor of Colombo, the General Manager of the Ceylon Government Railways, the Director of Health Services, the Master Attendant, and the Harbor Engineer. The staff are classified as public servants coming under the Civil Service Code, while total personnel of all types employed by the Commission now amounts to nearly 10,000. Of this total only some half-dozen key staff members are European.

Apart from the naval base of Trincomalee, the Commission is also responsible for navigation lights and marks for the whole of Ceylon and the supply of technical services, such as pilotage. Otherwise, with the exception of Galle, the minor ports are administered through the Principal Collector of Customs.

Of considerable importance to the day to day administration of Colombo port is the Port Working Committee. This Committee, composed of the Master Attendant, the Traffic Manager, representatives of ocean shipping lines and lighterage companies, as well as the Customs and Food Departments, meets three times a week under the Chairmanship of the Port Commission and does excellent work in obtaining, as far as possible, maximum coordination and efficiency in the working of the port.

Traffic. Table III shows some recent figures for port utilization in southern Asia.

TABLE III

Port Utilization Comparison

Tonnage of Vessels Entering Ports, 1947-50

(To nearest 1,000 Tons)

Port	1947-48	1948-49	1949-50
Colombo	8,732,000	11,748,000	12,344,000
Bombay	7,909,000	14,947,000	7,175,000
Calcutta	3,698,000	4,386,000	4,728,000
Madras	3,063,000	3,488,000	3,763,000
Cochin	1,823,000	2,170,000	2,221,000
Rangoon	3,225,000	2,679,000	2,649,000
Singapore	5,559,000	6,980,000	8,205,000

For Colombo, the figures for 1950-51 and 1951-52 were 12,400,000 and 13,338,000 tons respectively.

Despite the fact that many of the vessels carrying intransit passengers call at Colombo for only short periods of a few hours to a day, they occupy valuable berthing space as well as utilizing other facilities. With over 100 steamship lines using Colombo as a regular port of call, the number and tonnage of ships handled at Colombo have greatly increased during the post-war period. Figures for these years are shown in Table IV.

TABLE IV

Colombo Shipping

(Merchant Ships, Hired Transports, Hospital Ships)

Year	Number	Registered Tons
1946	1,352	5,168,465
1947	1,561	6,127,904
1948	2,054	8,732,381
1949	2,584	11,747,518
1950	2,700	12,344,074
1951	2,778	12,399,923
1952	3,041	13,338,442

In 1952 the port's pilots, numbering only eleven, carried out 7,259 ship-movements, which included arrivals, departures and movements within the harbor from one berth to another. This meant that an average of about 20 ship-movements took place every 24 hours, which is a remarkable achievement considering the ship congestion within the relatively small water area.

Import and export figures for cargo through Colombo during the post-war period are given in Tables V and VI.

TABLE V
Colombo Imports
(Long Tons)

Year	General Cargo	Coal	Bulk Fuel Oil	Total
1946	1,119,580	342,966	508,694	1,971,240
1947	1,244,430	319,668	336,532	1,900,630
1948	1,302,074	347,622	444,858	2,094,554
1949	1,509,427	378,737	668,850	2,557,014
1950	1,550,100	339,112	711,586	2,600,798
1951	1,770,766	290,373	714,384	2,775,523
1952	1,720,542	275,146	648,945	2,644,633

TABLE VI
Colombo Exports
(Long Tons)

Year	General Cargo	Coal Bunkers	Fuel Oil Bunkers	Bulk Coconut Oil	Total
1946	484,282	137,944	286,205		908,431
1947	540,186	97,160	293,428		930,774
1948	701,305	115,233	370,922	66,507	1,253,967
1949	683,863	111,064	563,992	55,024	1,413,943
1950	711,664	87,019	558,434	47,144	1,404,261
1951	705,606	73,178	570,766	71,585	1,421,135
1952	791,993	32,943	530,057	79,561	1,434,554

Finance. Table VII shows the annual revenue and expenditure of Colombo port during the post-war period. With the increase in traffic, both working revenue and expenditure increased but with the latter advancing at a higher rate due to increased cost of living and mounting cost-of-living allowances. Consequently, in March 1949, a 60 per cent surcharge on port charges was introduced enabling revenue to exceed expenditure substantially since that date. Charges for services rendered to or by other government departments are not included in this statement.

A decrease in working revenue of about one million rupees occurred in 1951-52 compared to the previous year. This was due almost entirely to a decline in warehouse rent on account of more expeditious clearances under new Customs arrangements.

TABLE VII

Colombo Port—Annual Revenue and Expenditure

(Rupees)

Year	Working Revenue	Working Expenditure	Excess of Revenue Expenditure (—)	Lone Fund Expenditure
1946-47	8,838,835	8,215,719	623,116	192,215
1947-48	9,992,961	11,792,666	(—)1,799,705	396,433
1948-49	13,685,312	11,721,531	1,963,781	1,641,554
1949-50	17,483,910	12,173,383	5,310,527	1.264,099
1950-51	21,052,560	13,279,317	7,773,243	6,551,663*
1951-52	20,034,192	16,219,622	3,814,570	12,309,961*
1952-53 (Est.)	19,476,000	16,809,600	2,666,400	—

*Includes expenditures on Port Development Scheme of Rs. 5,229,914 for 1950-51, and Rs. 9,830,992 for 1951-52.

The excess of working revenue or expenditure is absorbed in the general fund of the government while capital expenditure is made from governmental loan funds. At least up to very recently, no statement of over-all capital expenditure on the port has been maintained, nor has any method of amortization been employed.

A point of interest is that if the port accounts were to be maintained on a commercial basis they would probably show an annual loss. However, whether the annual loss were great or small, the value of the port is vital to the general economic well-being of the country with direct and indirect benefits far outweighing the funds spent on its development.

A further point of interest lies in the fact that, unlike the United States where salaries and wages have been directly increased more or less in step with the increased cost of living, in Ceylon and elsewhere special cost-of-living allowances are added to the basic wage which is still shown, in the hope that one day such allowances may be eliminated entirely. In 1951-52 personal emoluments coming under the Colombo Port Commission were Rs. 2,199,269, whereas cost-of-living allowances on wages and salaries amounted to Rs. 4,886,682, or 222% of base pay.

Loan fund expenditure on capital account varies from year to year, depending upon the projects in hand. For example, in 1943-44 the amount was under Rs. 85,000, whereas in 1951-52 it was over Rs. 12,000,000. Table VIII shows a consolidated statement of

TABLE VIII
Colombo Port—Loan Fund Expenditure
(Rupees)

		Amount Chargeable	Est. Exp. to Sept. 30, 1951	Est. Exp. 1951-52
Coal Handling Equipment		1,434,000	1,184,000	250,000
Housing C.P.C. Employees		8,250,000		1,000,000
Extra High Tension Supply		3,555,000	600,000	800,000
Diesel Locomotives		1,800,000		900,000
				1,000*
14" Oil Pipe Line to K.O.D.		900,000		900,000
Salvage of SS "Soli"		850,000		850,000
Dock Pumps, etc.		620,000		100*
Twenty-Ton Travelling Crane		200,000		100*
Port Development Scheme		79,270,000	10,250,000	23,200,000
Original Estimate	77,920,000			
Marine Drive	750,000			
York St. Tunnel	2,600,000			
	81,270,000			
Loss charged to Loan Scheme 1937	2,000,000			
Balance	79,270,000			
Deepening Lake and Locks		450,000		175,000
Purchase of Lighters, etc.		1,700,000		1,600,000
Diesel Repair Shops		1,348,000		356,000
Suction Dredger		900,000	700,000	200,000
Totals		101,277,000	12,734,000	30,232,200
Estimated Expenditure 1950-52		42,966,200		12,734,000
Balance Estimated Expenditure 1953-?		58,310,800		42,966,200

*To place indents.

proposed loan fund expenditure derived from Government Estimates, 1951-52, Vote No. 11.

Since 1951 the Port Commission has commenced to carry out a continuous internal audit of its accounts while valuation of assets was also commenced. With this as a basis, the World Bank (IBRD) Mission, which visited Ceylon during the latter part of 1951, has recommended that the port's accounts be commercialized so as to reflect the true financial operations of the port.

Traffic Problems. The chief problem at the port of Colombo, particularly in the post-war period, is the congestion of ships and cargoes due to the fact that traffic has increased far beyond the levels for which the port was designed. This in turn resulted in much slower ship turnaround which brought about a special freight surcharge of 25 per cent in April 1951 by shipping lines calling at Colombo and an all-around increase in the cost of landing and shipping cargo. Only recently, in January 1953, was the special freight surcharge entirely eliminated.

In the absence of alongside deep water berths for general cargo handling, Colombo could not be considered an efficient port by modern standards. Prior to the World War of 1939-45, stevedoring labor and general operational costs were comparatively low. Consequently, the more employment which could be given the better, and the tendency was to carry on with existing facilities. However, the war brought about a big increase in the cost of living with a consequent substantial rise in labor and operational costs. Other factors also entered into the picture and these, as well as the foregoing, may be summarized as follows:

(a) Inadequate and outmoded port facilities, principally the lack of alongside deep water berths and transit sheds, lack of sufficient warehouse space, the inadequate and diverse nature of land transportation methods (which included the bullock cart) for the clearance of import cargo and generally poor accessibility to the port area and existing sheds. Consequently, the mechanization of cargo handling could not be carried out to any appreciable extent.

(b) Uneven arrivals of shipments of bulk food on government account.

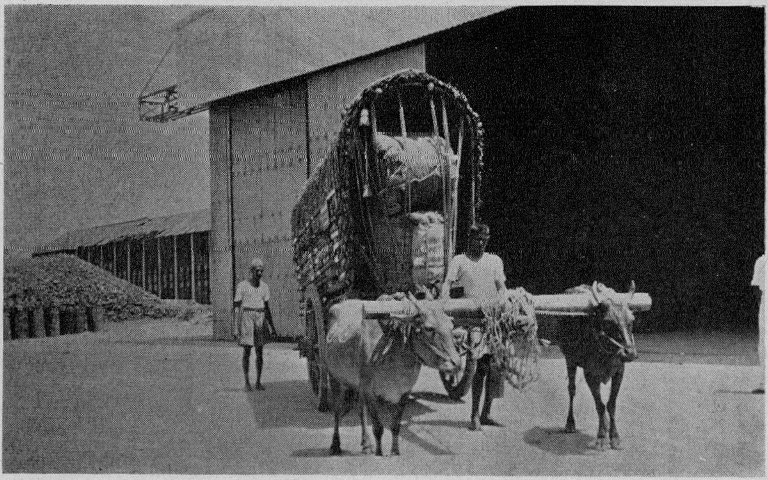
(c) Less skilled labor and lower output as a result of the national policy of Ceylonization.

(d) Large increase in the number of importers and delays in clearing cargoes.

(e) Shortage of qualified technical staff employed by the Port Commission.

(f) Labor employment conditions and lack of incentive to greater output.

(g) Excessive number of stevedoring contractors and poor supervisory control.

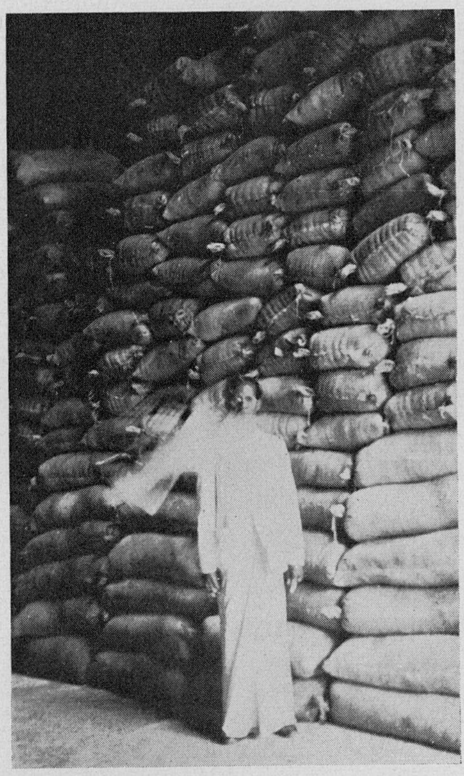


BULLOCK CART HANDLING EXPORT CARGO

Depending upon local conditions and cargo characteristics, there are advantages for both alongside berths and berths in midstream. With more room to maneuver in midstream a ship can be moored and be ready to load or discharge cargo in less time than one berthing alongside a pier or congested marginal wharf. In the case of loading cargo, previously loaded lighters or barges are quickly brought alongside on both port and starboard sides adjacent to the hatches being worked. When cargo is being discharged, empty lighters or barges are handled similarly. Where barge loads are intended for a single importer, the craft may then be taken either via the Customs Office located on the waterfront or direct to the waterfront warehouse of the importer where a Customs official checks the consignment. This method reduces the space requirements of port constructed transit sheds and warehouses as well as the number of expensive alongside deep water berths.

In the case of full ships carrying bagged cargo, such as rice or flour, the rate of discharge at Colombo has reached as high as 24.3 tons per gang-hour with a maximum of nearly 2,400 tons per day working two shifts. However, discharge of general cargo from ships seldom exceeds 750 tons per day.

In special circumstances, such as in wartime where volume and not cost is paramount, it may be found that offshore anchoring of ships enables a greater tonnage to be landed by means of barges and small craft than if a ship were berthed alongside. A 500-foot ship with its mooring lines occupies about 600 feet of wharf frontage to work five hatches. With the use of barges and mobile cranes spotted about



Bagged Rice Stacked in Wharf Shed by Head Loading

50 feet apart, twelve cranes can operate in the same area. By this method it has been shown (specifically at the port of Naha in Okinawa) that at least three times as much cargo can be handled enabling three ships at anchor to be serviced by a pier or wharf frontage which would normally be occupied by one vessel. In wartime an additional advantage of this method lies in the fact that the sinking of large ships by bombing or by typhoons would not obstruct the wharf frontage. At Colombo during the war, an oil tanker, the SS "Soli," after being torpedoed at sea, sank in her berth. Up until 1952, when she was

raised by an Italian salvage company and towed to Karachi for scrap, the vessel caused considerable obstruction to navigation and port usage.

Projects and Proposals. Considering the traffic problems at the port of Colombo enumerated above, the most important is the inadequacy of port facilities for the handling of the increased traffic. The fact that congestion was not greater reflected very favorably on the work and ingenuity of the officers and staff of the Port Commission.

In 1946, the government authorized the Commission to instruct its consulting engineers, Messrs. Coode & Partners of London, to prepare construction plans and specifications for the further development of Colombo harbor. This engineering work was in progress for nearly four years, during which period a round-world tour of major ports was made by the Chairman of the Port Commission, Lt. Col. P. A. J. Hernu, M. Inst. T. (London). This tour took in many of the ports of the United States, including Boston, Massachusetts.

In 1950, tenders were submitted by four French contractors,

View of Blockyard. Completed Northeast Breakwater Quay in Distance.

two Danish, and one Dutch, although both American and British concerns had been invited to tender. The lowest tender of Rs. 56,342,270 by the French concern of Schneider & Billiard was accepted and work commenced before the year's end.

Briefly, the development project comprised the following works:

Stage I

(a) *Northeast Breakwater Quay.* Conversion of the existing breakwater into a solid quay 1,232 feet long and 188 feet wide by means of a bulkhead wall of some 5,000 precast 14-ton concrete blocks. The two berths provided include two transit sheds, 400 feet by 80 feet, served by three railroad tracks on the apron and one in the rear. Dredged depth will be 32 feet.

(b) *Oil Dock.* North pier, of 15-20 ton concrete block construction and 1,078 feet in length, to form a 425-foot wide oil dock with the Guide Pier and dredged to 35 feet in depth. Dock to be equipped with a floating boom at the entrance to prevent spreading of oil over the harbor in case of fire. Dock will accommodate two oil tankers and be equipped with oil pipe lines leading to main tank farms ashore.

(c) *Guide Pier.* Lengthened to 1,000 feet to permit berthing of two vessels. Equipment will include pipe lines to permit loading ships with bulk coconut oil and bulk rubber latex.

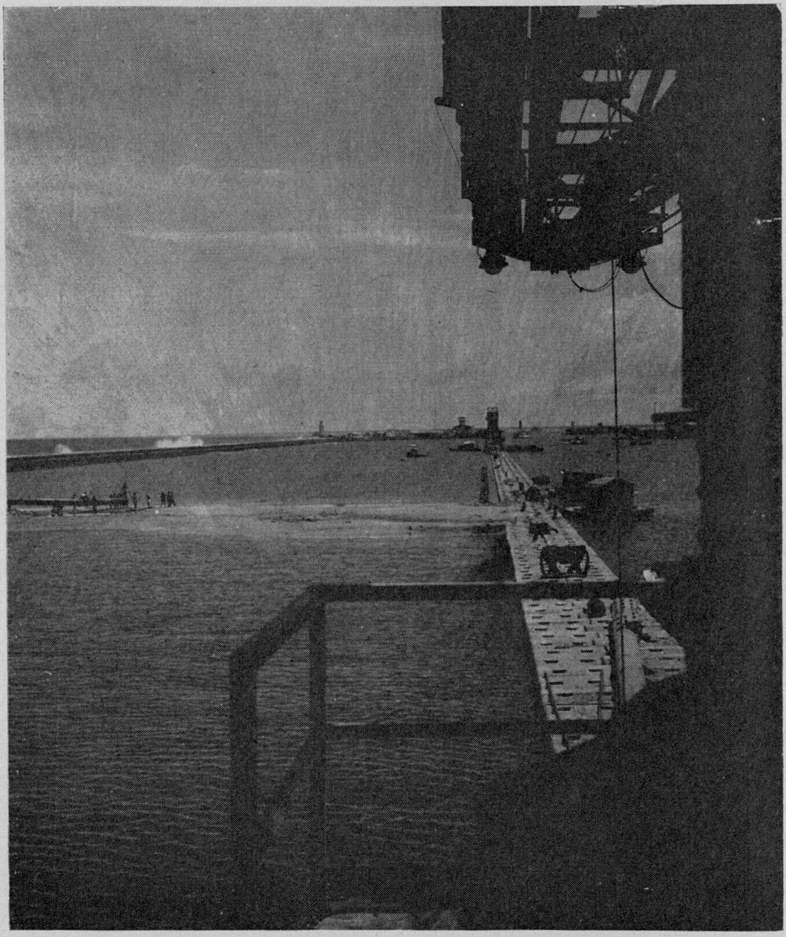
(d) *Delft Pier.* Located near the entrance of the Lake to Harbor Canal, 425 feet wide by 1,384 and 1,352 feet long on its east and west sides, respectively. Four transit sheds (two of 450 feet by 110 feet, one of 500 feet by 110 feet, and one of 600 feet by 110 feet) will also be provided. The pier, of precast concrete block wall construction, will be served by road and rail, the latter taking off from the port belt railroad.

Stage II

(a) *Southwest Breakwater Quay.* Of concrete block construction, some 3,000 feet long by 400 feet wide and located inside and abutting the southwest breakwater. Four 500 feet by 120 feet transit sheds and a large office and passenger terminal building will be provided for this six-berth quay. Apron width will be 50 feet and water depth 36 feet at M.L.W.

(b) *Rubble Mound Breakwater.* Located on the seaward side of the southwest breakwater to provide additional protection to the new quay inside the breakwater.

The foregoing works, (Stages I and II) comprising about 7,000 lineal feet of deep water quays, and some two million square feet of reclamation, are now under construction at the rate of about 10 feet of blockwork wall per day and should be completed sometime in 1954. Some 17 alongside berths will then be available to supplement the midstream berths of the port and should serve to overcome port congestion for at least the next ten years.



SOUTHWEST BREAKWATER QUAY WALL PARTLY COMPLETED.

Other port development proposals include the extension of the Southwest breakwater quay (Stage III) and the construction of additional breakwaters (Stage IV) to form an outer harbor. The IBRD Mission has recommended that these projects be postponed for a number of years and that, in the case of Stage IV, the relative merits of further developing either Colombo or Galle be carefully analyzed and weighed from the overall economic point of view.

Construction and maintenance work carried out by the Port Commission on force account during 1952 amounted to Rs. 10,200,000. Of special interest is a pier for the Royal Ceylon Navy, with a concrete deck supported on 6-foot diameter caisson cylinders, both items being of prestressed design.

Proposals to improve road and rail access to the port which is hemmed in by the city include what is called the Marine Drive to connect the Galle Face with the southwest breakwater area, and the York Street railway tunnel to connect the main line system with the port belt railroad at the root of the new Delft Pier.

Other means for improving the flow of traffic through the port have been recommended by the IBRD Mission or by various independent committees. These include:

(a) Preparation of coordinated plans to improve port accessibility by the Port Commission, Colombo Municipality, Government Railways, and the Public Works Department.
(b) Better regulation of vessel arrivals bringing full cargoes, such as rice, into the port.
(c) Advance arrangements for clearance of food cargoes direct from lighter via road and rail transport to destinations outside the port area.
(d) Unloading of lighters on a 24-hour basis.
(e) Reduction in number of stevedoring companies by amalgamation or reorganization.
(f) Improvement of labor output by various means, including piece work or incentive bonuses, and instruction in port operation for all grades of staff and labor.
(g) Maintaining at all times a complete staff of qualified and experienced technical and administrative officers to insure that all departments function at maximum efficiency.

Obviously, it is usually more difficult to solve a problem than it is to recognize one. Take the case of labor output. Over the past years the port administration has made considerable progress in improving working conditions in the way of emoluments, security, and frequency of work, recruitment, registration, and general welfare, including free meals. In spite of this, there is the almost universal tendency for labor to reduce output in inverse ratio to the improvement in working conditions. Since the granting of dominion status to Ceylon, the general policy of the government has, quite understandably, been to Ceylonize both public and private undertakings to the maximum extent. In the case of port operations, the displacement of the more efficient Indian labor by Ceylonese has proved uneconomic to the extent that it has resulted in lower output and higher costs to exporters and importers alike. These higher costs are eventually passed on to the consumer with a snowballing effect thereby increasing the general cost of living while reducing profits on exports. This is most serious when it is remembered that exports are the economic life blood of the island. The degrees of Ceylonization of the employees of the Port Commission is indicated in Table IX. The total force employed in the port, including both commercial and government employees, is over 20,000.

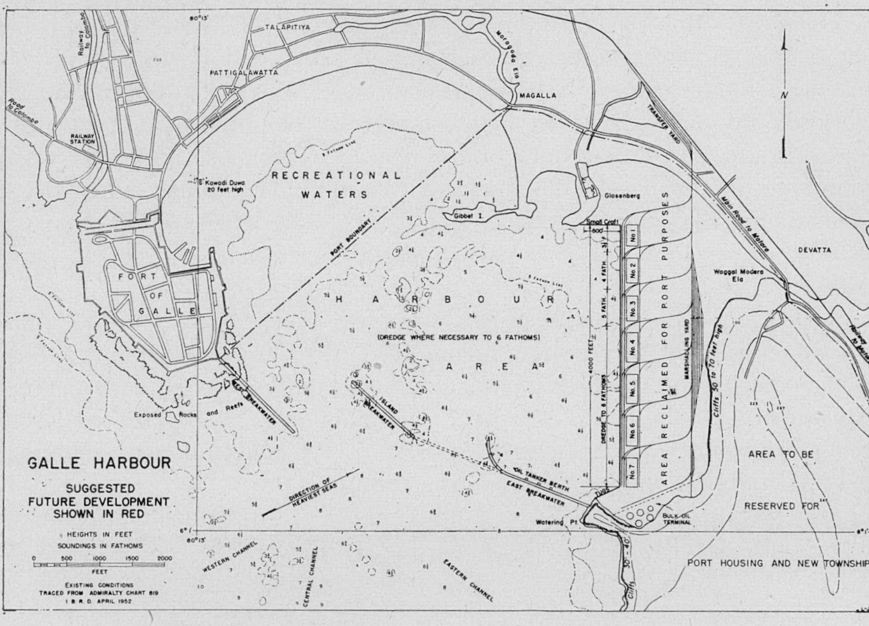
TABLE IX
Colombo Port Commission—Employees

Year	Ceylonese	Non-Ceylonese	Total
1948	1,979	4,498	6.477
1949	3,831	3,747	7.578
1950	5,050	3,354	8.404
1951	5,620	3,283	8.903
1952	6.433	3,233	9.666

PORT OF GALLE

History. The natural harbor at Galle (pop. 47,000) has been used by shipping since the earliest days and predates Colombo. It is situated near the southern tip of Ceylon and about 75 miles southeast of Colombo. The harbor is a comparatively small bay formed by the headland known as "Watering Point" on the east and on the west by the headland on which the old Fort of Galle was built by the early Dutch. These headlands are rocky, the one on the east rising steeply to nearly 300 feet above the sea and are about 6,000 feet apart. The landward depth of the bay to Gibbet Island is about 3,300 feet and since it faces south it is exposed to the full force of the southwest monsoons. Much of the entrance and area within the bay is covered with reefs and rock shoals. Historically, the name "Watering Point" was derived from the days of sailing ships when these would enter the bay and send their longboats to the base of the high cliff on the east to fill their water kegs at a still flowing fresh water spring.

Ever since 1858 proposals for improvement of the port have been made but were dropped on account of excessive cost. These proposals all comprised some form of breakwater system, the cost of which was estimated in 1935 at Rs. 17,000,000, excluding dredging and removal of underwater rock out-crops.



Ships calling at Galle Harbor await favorable wind and tide conditions before being brought in through narrow passages between underwater reefs. They are moored and anchored in the bay with bows headed seaward for quick escape in the event of bad weather. Accidents to ships striking the bottom have occurred on several occasions and hazards have become greater with the increasing size and draft of modern ships. Cargo is transported between ships and shore by means of small lighters which are now usually beached and the loads head-carried to warehouse.

Officially the port has the following accommodation:

Depth at entrance, 13 FMS. Three narrow lighterage piers, 250 to 350 feet long with light cranes. Four ships' berths ranging from 20 feet to 26 feet, (330-450 feet during southwest monsoon; 350-500 feet during northeast monsoon). One berth 500 feet with 30-feet draft open during northeast monsoon.

Administration. The Port of Galle is administered by the

Colombo Port Commission by means of a staff of about 50 persons headed by an Assistant Master Attendant who also acts as the pilot.

Traffic. Although the number of ships calling at Galle had risen from 96 in 1924 to 123 in 1935, since 1946 the average has fallen to 35 per year. In 1952 the number was only 22. This decline is primarily due to the fact that all rice imports for Ceylon were diverted through Colombo where a fumigation process was instituted. With a declining shipping service at Galle, much of the potential export and import traffic of the southern and southeast region of the island was bypassing the port to the detriment of the local community. Normally, the main imports comprise rice, sugar, and salted fish, while exports include tea, coconut oil, coir yarn and rope, citronella oil, copra, and rubber.

Finance. The annual port revenue at Galle is very small and was under Rs. 100,000 yearly during 1949-52. On the other hand, for 1951-52 recurrent expenditure was estimated at Rs. 70,000 and special expenditure at about Rs. 150,000, including Rs. 45,000 for cost-of-living allowances and about Rs. 105,000 for maintenance, repairs, inshore dredging, and small pier construction.

Transportation Problems. The main transportation problem at the port of Galle may be summarized as follows:

(a) Navigational hazards and an exposed anchorage.
(b) Uneven depth of water in the bay resulting in the number of ships of

LANDING RICE CARGO BY HEAD LOADING.

average size being limited to two at any one time and then only under favorable weather conditions.

(c) Lack of proper facilities for discharging and loading lighters.

(d) The complete absence of any deep water alongside berths.

(e) The diversion of bulk import rice cargoes to Colombo on account of the necessity for fumigation, the facilities for which had been provided only at Colombo.

(f) Generally increased transportation costs for exports and imports of the Southern Province due to most of the commerce being routed via Colombo.

Proposals. When studying the future role of Galle Harbor, it appeared to the author that there were three possible policies which invited consideration. These were:

(a) Allow present conditions to continue indefinitely with the probable result of diminishing overseas trade (since ships are tending to increase in size and draft) and the slow decline of Galle as a port of call.

(b) Carry out partial improvements from time to time of relatively limited scope and cost, but as part of a master plan which would be used as the basis for the full future development of the port.

(c) Embark upon a full-scale port development project over the next few years.

The second policy was selected as offering the best answer to the problem. Galle could become a useful satellite port to Colombo and would assist in the development of local trade and industry without calling too heavily on the country's financial resources.

A master plan was prepared to show the development potential of the port. Briefly, it provides for a system of three breakwaters strung across the entrance to the bay, each one located so as to take advantage of existing reefs and shoals. A west breakwater would extend for a distance of about 1,700 feet from the ramparts of Fort Galle in a southeasterly direction to near the five-fathom line. An island breakwater, some 1,350 feet in length, would connect two rock shoals near the center of the entrance to the bay and also run roughly parallel to the west breakwater but leaving a sufficiently wide opening between the two walls to provide an entrance to the harbor. An east breakwater would extend for a distance of some 2,100 feet from Watering Point in a northwesterly direction and either curve at its outer end to connect with a rock shoal or continue an additional 1,000 feet to connect up with the island breakwater. Since the direction of the heaviest seas follows a northeasterly line, this breakwater system would provide a well protected harbor.

Within the harbor area the master plan provides for a 4,000-foot marginal quay providing seven berths and located on the eastern side of the bay. Bulkhead construction would be of precast mass concrete blocks set by divers upon a concrete footing laid upon the hard bottom of the bay. Behind the block wall the area would be reclaimed with fill obtained locally and would be widened to its full width in stages. Along the quay face a comparatively small amount of hard dredging would provide minimum water depths of 21, 24, and 30 feet at the first three berths, and 36 feet at the remaining four berths. At the north end, and at right angles to the main quay, provision is made for a 500-foot shallow draft wharf for small craft. At the south end of the quay the wall is extended southwesterly to meet Watering Point and provides berthing space for tow boats and tugs.

On the north side of the east breakwater, and in sheltered water, provision is made for an oil tanker berth. Pipe lines along the breakwater wall would connect up with a tank farm located close to the cliff side which rises 30 to 70 feet shear out of the sea, thus affording excellent protection frmo the south and east.

Provision is made for transit sheds at each of the seven berths and ample space is provided for warehouses and other port buildings and facilities. The whole area is served by rail and road which would connect up to the adjacent Colombo-Galle-Matara main railroad line and highway.

Since both the Fort of Galle and the bazaar area at Pattigalawatta are extremely overcrowded, provision has also been made in the master plan for a new township and port housing area located on the open and fairly level ground above the cliffs on the east side of the bay.

Some rock and sand dredging in the central area of the harbor would be necessary to provide a minimum depth of 36 feet in the working area. On the northeast, provision is made for the town's recreational water by locating the port boundary on a line between the root of the west breakwater and the mouth of the Moragoda Ela at Magalla.

Currently, there is no justification to proceed very far in implementing the major proposals contained in this master plan, nor will there be, until the south and southwestern regions of the island have undergone considerable agricultural and industrial development. This, in itself, is a long-term proposition. But in the meanwhile it has been recommended that partial improvements to Galle Harbor be carried out to the extent of dredging and removing hazardous rocks in the vicinity of the berthing areas and the provision of heavier equipment for the mooring and anchorage of vessels using the port.

The provision of rice fumigation facilities or fumigatorium at Galle has also been recommended. This will relieve congestion at Colombo and reduce transportation costs of rice distributed in the south and southwest regions of the country.

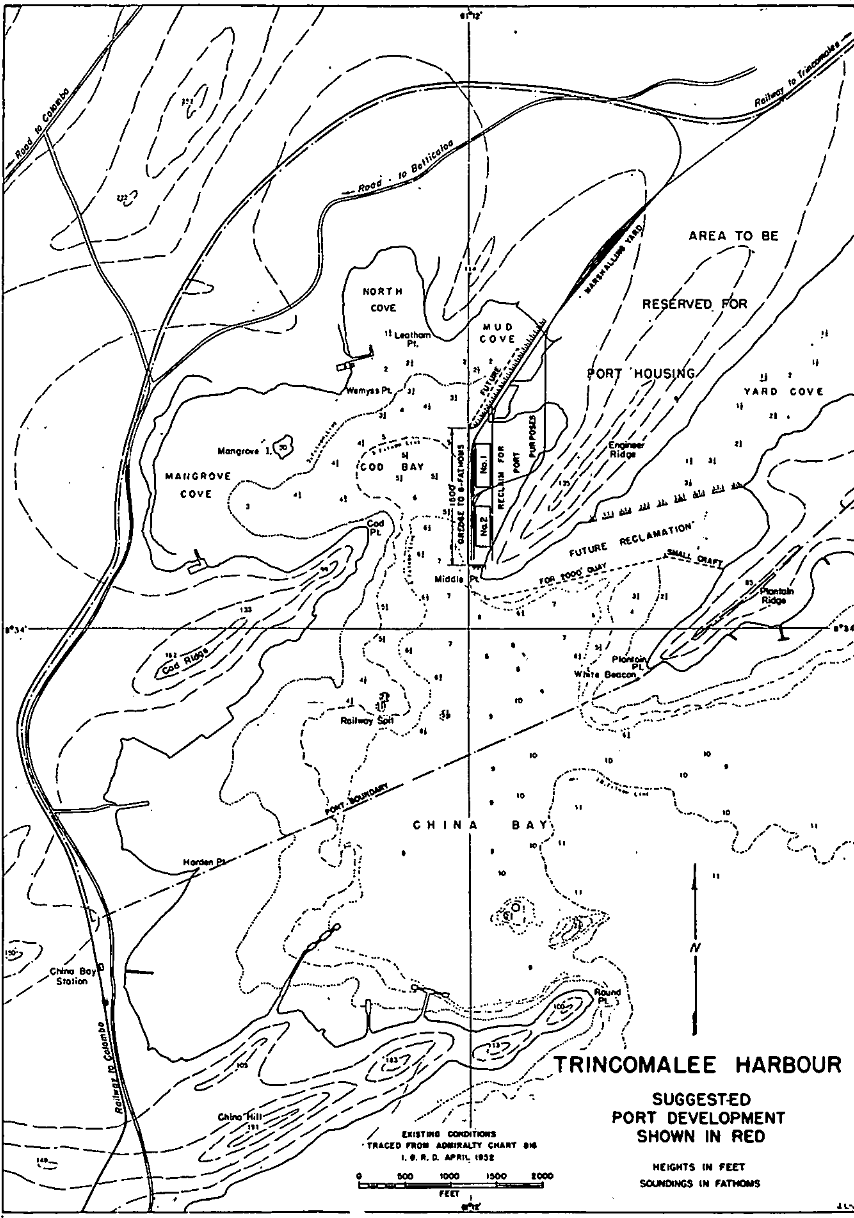
For both strategic and economic reasons, the author believes that the long-term development of Galle Harbor into a modern port providing safe anchorage in all weathers ought to be continuously borne in mind by the Ceylon government. It is evident that Colombo City will become increasingly congested and Galle offers a good location for the development of a second major city and port for the island. It is felt that when the time arrives for seriously considering the expansion of Colombo Harbor under Stage IV (outer breakwater), it might well be found that a better return would be obtained in developing Galle Harbor in accordance with the master plan described above.

Port of Trincomalee

History. The large natural harbor at Trincomalee, (pop. 27,000) is situated on the northeast coast of Ceylon and about 175 road miles from Colombo. The inner harbor, known as China Bay, consists of a wide expanse of deep water and is land-locked except for a narrow entrance from outer Koddiyar Bay. China Bay is sheltered from the effects of both the southwest and northeast monsoons and in every way may be considered an ideal natural harbor. It is open to shipping all the year round and is large enough to accommodate an entire naval fleet. Since 1795 Trincomalee has functioned principally as a naval base, operated by the British Admiralty and is at present the headquarters of the British East Indies Naval Station.

In World War II, with the fall of Singapore to the Japanese, Trincomalee became of great strategic importance. On the south shores of China Bay a large R.A.F. air base was hastily constructed and these sea and air bases played a prominent part in defending southern Asia and the western areas of the Indian Ocean.

Land communications between Trincomalee and the rest of Ceylon comprise the railroad link from Maho Junction on the main Colombo-Jaffna line, the main paved highway from Colombo via Dambulla, a minor road from Anuradhapura, a coastal road from Batticaloa to


TRINCOMALEE HARBOUR
SUGGESTED PORT DEVELOPMENT SHOWN IN RED
HEIGHTS IN FEET
SOUNDINGS IN FATHOMS
EXISTING CONDITIONS TRACED FROM ADMIRALTY CHART 816
I. G. R. D. APRIL 1932
0 500 1000 1500 2000
FEET
AREA TO BE RESERVED FOR PORT HOUSING
NORTH COVE
MUD COVE
YARD COVE
MANGROVE COVE
COD BAY
CHINA BAY
Mangrove I.
Leatham Pt.
Wemyss Pt.
Cod Pt.
Middle Pt.
Cod Ridge
Railway Spit
Harden Pt.
China Bay Station
China Hill
Round Pt.
Plantain Pt.
White Beacon
Plantain Ridge
Engineer Ridge
MARSHALLING YARD
FUTURE
RECLAIM FOR PORT PURPOSES
No. 1
No. 2
DREDGE TO 6-FATHOMS
FUTURE RECLAMATION
FOR 2000' QUAY
SMALL CRAFT
PORT BOUNDARY
Road to Colombo
Road to Batticaloa
Railway to Trincomalee
Railway to Colombo
N

the south (often impassable due to monsoon floods) and a minor dirt road of some 35 miles connecting with the village of Pulmoddai on the north coast. Pulmoddai is the site of extensive deposits of ilmenite sand—a source of monazite, a strategic atomic material.

Administration. Trincomalee Naval Base is controlled at present by the British Admiralty under agreement with the Government of Ceylon. The small amount of commercial shipping using the port is under the control of a single government officer with the title of Assistant Government Agent, Deputy Master Attendant, Assistant Collector of Customs, and Shipping Officer.

Traffic and Finance. Such traffic as there exists comprises mainly the import of general merchandise and the export of paddy, timber, dried fish, and tobacco. Annual revenue from commercial shipping using the port was only Rs. 12,606 in 1949-50 and about Rs. 15,000 in 1951-52.

Port Facilities. Except for oil tankers, merchant ships are anchored in the bay and ship-to-shore transport is effected by lighters and small harbor craft. The official description of harbor facilities states: "Accommodation—The merchant anchorage is in 4 to 8 fms about 4 cables from wharf. China Bay quay, 2 fms loading and unloading by lighters. Harb. can accommodate largest ships and large numbers. D at en. of harb. min. 21 fms.; 1-½ fms. at quays. One-ton crane at landing jetty. W. of E. 1700 yards. One 3-ton crane, China Bay wharf."

On the south shore of China Bay are located large bulk oil tank farms which supply the naval and air bases, while in Cod Bay on the north there has been constructed in small L-shaped dock for naval harbor craft.

Future Prospects. Hitherto, the need for extensive land and sea transportation facilities in the eastern half of the island have not been great due to the comparatively undeveloped state of the area. However, this situation is changing since the control of malaria and the opening up of the region to colonization. Agricultural, colonization, and, to a lesser extent, industrial schemes are already in operation or are being planned. At Inginiyagala, some 35 miles south of Batticaloa on the east coast and about 25 miles inland, a large multi-purpose dam has recently been completed. This project, first proposed in 1935 by Mr. J. S. Kennedy, at that time Director of Irrigation in Ceylon, is known as the "Gal Oya Project." It will include the clearing and irrigation of about 100,000 acres of jungle-covered land, the resettlement of some 250,000 people, and the installation of a 25,000 kw hydroelectric power station.

The project is administered by the Gal Oya Development Board, an agency financed and established by the government in 1949 and possessing considerable autonomous powers.

Some 35 miles inland from Inginiyagala lies the valley of the Mahaweli Ganga, the longest river in Ceylon. It rises in the south-central mountains and after running north through the ancient capital of Kandy it turns east and in a series of rapids it reaches the level eastern plain. It then strikes north and reaches the sea at Koddiyar Bay. In the author's opinion the valley of the Mahaweli Ganga offers the greatest potential for agricultural development. Thus, it was felt that the general development of the eastern and northern regions of the country would be largely assisted and accelerated by the establishment of a commercial seaport at Trincomalee, which is nearer and more accessible than Colombo.

Proposals. Formulation of a master plan for the commercial development of Trincomalee required a study of the harbor and its environs. Through the good offices of the Chairman of the Colombo Port Commission, the author was received as a guest of Vice-Admiral, Sir Geoffrey Oliver, K.C.B., D.S.O., at "Admiralty House," the residence of the Commander-in-Chief, East Indies Station, and was given the greatest cooperation by the naval authorities.

Main requirements for the establishment of commercial facilities at Trincomalee are that they should be well removed from naval establishments, that the area and depth of water be sufficient, that the necessary supporting land area be available, that construction costs be reasonable, that road and rail communications be easy to provide, that electric power and water supplies be available, and that there be ample space for future development.

It was determined that these requirements could best be served at the inlet known as Cod Bay. It is believed that here a 1,500-foot marginal quay can be constructed northward from "Middle Point" with 36 feet depth of water alongside as an initial development, with a future 1,000-foot extension into "Mud Cove" on the north for lighter draft vessels. Fill for reclamation purposes behind the quay wall can readily be obtained from the west side of "Engineer Ridge," thereby creating additional land area for warehouses, railroad tracks, and other facilities. The land area surrounding Cod Bay is as yet undeveloped and can be reserved for port use. The main rail and road routes are located in close proximity to Cod Bay and can readily be linked with the wharf area.

Furthermore, it was learned that a working arrangement could be made with the Admiralty for general development of the port, and that surplus Admiralty electric power and water supplies could be made available.

The master plan, prepared for the commercial development of Trincomalee, shows the above mentioned works. In addition, provision is made for the future reclamation of an area at the mouth of "Yard Cove" where a 2,000-foot deep water marginal quay and an extension to accomodate small craft may be readily constructed and supporting facilities provided. This master plan ensures an integrated port located within a proposed commercial port boundary sufficiently extensive to permit of considerable future expansion.

Capital Requirements

The estimated capital requirements for port and harbor development as recommended by the IBRD Mission during the six-year period 1953-59 are shown in Table X. It was assumed that Stages I

Table X

Estimated Capital Requirements, Ports and Harbors

(Million Rupees)

	Particulars	Estimated Cost 1953-59
Colombo	Port Development Scheme (Stages I and II) Ancillary Port Works	65
	Port Access Improvements	13
	Engineering Survey for Stage IV	0.1
Galle	Hydrographic Survey and Partial Dredging	4
	Improvements to Anchorage Equipment	0.3
	Provision of Facilities for Rice Imports	0.5
Trincomalee	Provision of Commercial Port Facilities	25
Kankesanturai	Engineering Survey	0.1
	Total	108.0

and II of the Colombo Port Development project would be completed by 1953-54, the ancillary works by 1954-55, and the port access improvements by 1956-57. At Trincomalee it was assumed that if the proposal for limited commercial development was carried out by the Ceylon Government, construction would commence about 1956-57 and be completed about 1958-59. In addition to the estimated capital requirements of Rs. 108,000,000, about Rs. 10,000,000 was believed necessary for additional port equipment of all kinds.

Ceylon Ports Authority

In reviewing the functioning of the Colombo Port Commission, it was felt that there were some inherent administrative and operational defects. These would increase with the continued growth of Colombo Port and even multiply in the event of major development of the ports of Galle and Trincomalee. Consequently, it was recommended in the IBRD Mission report that the Commission be reconstituted as the "Ceylon Ports Authority," having semi-autonomous powers and with responsibility for the administration and operation of all commercial ports. Broad governmental control would continue to be retained through the Minister of Transport and Works, and the government-appointed Chairman of the Authority.

Acknowledgments

Contents of this paper are based upon an on-the-spot study by the author, supplemented by statistical and factual data derived from various memoranda and publications, including annual reports by the Colombo Port Commission and other governmental departments, the "Port of Colombo Quarterly Review," "Ferguson's Ceylon Directory," and the report of the IBRD Mission to Ceylon entitled "The Economic Development of Ceylon," (Johns Hopkins Press, Baltimore, Md.) to which the author contributed the section on Transportation.

ALEWIFE BROOK CONDUIT AND PUMPING STATION

By Chester J. Ginder,* *Member*

(Presented at a meeting of the Sanitary Section of the Boston Society of Civil Engineers, held on October 7, 1953.)

The Alewife Brook Conduit and Pumping Station, a sewerage works facility in the valley of the Mystic River, has been under construction for several years and is now nearly completed. The system went into full-time operation in the spring of 1953 and except for adjustments to pumping controls is ready for final acceptance. The conduit, itself, about 18,000 feet in length, was constructed by the Construction Division of the Metropolitan District Commission during the years 1949 and 1950, under two separate contracts, Numbers 154 and 169, and the Pumping Station was built during 1951 and 1952, under a third contract, Number 155.

The need for the conduit and pumping station is to provide relief for the existing Alewife Brook Sewer System which has served portions of Belmont, Cambridge, Arlington and Somerville for a matter of almost 60 years, and which has become entirely inadequate to serve the area properly.

Like the existing sewer, the new conduit follows along the line of the Alewife Brook from its upper reaches in Belmont and Cambridge to its intersection with the Mystic River from which point it more or less parallels the river easterly to a connection with the North Metropolitan Relief Sewer in Medford.

The Existing Alewife Brook Sewer

The existing Alewife Brook Sewer, which the new construction will relieve, was built in 1893; and the old Alewife Pumping Station in 1894 and 1895. The years from 1889 to 1896 were those of great activity in the design and construction of sewerage facilities in and adjacent to Boston proper and saw the first real advance in the development of such facilities under the direction of the State in the Metropolitan Boston area.

The whole question of sewerage disposal and pollution of streams

*Designing Engineer, Metr. District Commission, Construction Division in Massachusetts has been studied by various commissions and departments of the State since before 1871, and only after long intervals of study has construction followed in an effort to improve conditions. In 1871 a special report on the pollution of Mystic Pond water was made and printed in the second annual report of the State Board of Health. At that time the upper part of the Mystic River drainage area was the source of domestic water supplied from Mystic Pond to Somerville, Charlestown, Chelsea and Everett by the Mystic Water Board, and Horn Pond, also within that same area, furnished water to Woburn. To protect these supplies, a sewer line serving several tanneries in Woburn had been constructed along the Aberjona River to a point below the upper Mystic Lake where it discharged into the Mystic River. This sewer line was the only one in the Mystic Valley in 1880. The Metropolitan Drainage Commission in 1881 reported on the problem of pollution in the Mystic River Valley and its recommendations included the proposal of a main sewer running the entire length of the valley, passing through Chelsea, across to Winthrop, under Shirley Gut, and thence to a deep water outlet off the end of Deer Island.

The polluted condition of the Mystic River and Alewife Brook was recognized as a vexing problem requiring a solution and one which the individual towns by themselves could not correct.

A rather complete study of pollution in the Mystic, Blackstone and Charles River valleys was made by the Massachusetts Drainage Commission in 1886, which accepted the fact that conditions needed to be remedied and devoted its study to ways and means of accomplishing the needed improvements.

In reporting on the matter some of the feelings of the Commission as expressed are interesting. Regarding the plans investigated the Commission had this to say:

> "We may as well preface what we have to say by admitting frankly the great importance which we have invariably attached to the relative expense of different plans. We felt that the necessity of strict economy should not be lost sight of for a moment. Sewerage at its cheapest is very dear, and it must always be remembered that the communities which will be called upon to pay for this improved sewerage are already heavily taxed and often deeply in debt, and it may well be that a project for their relief might be so admirable that it would be ruinous".

This report goes on to say:

> "People can hardly be blamed if they prefer enduring a good deal of

discomfort and considerable jeopardy of health rather than face possible bankruptcy and certain impoverishment".

In those years considerable thought and attention was given to the possible use of domestic sewage for agricultural purposes in the form of fertilizer either on private farms or by use of municipal farms established to use the sewage for irrigation. The complications involved in such a solution for the Mystic Valley were considered insurmountable. The Commission in 1886 felt the disposal of sewage in the outer harbor would be the best solution, but rejected it in their recommendations as being entirely too expensive. Mr. Eliot C. Clarke was engaged to head up the engineering studies. Their interest in the filtration of sewage on land was so strong that Mr. Clarke was directed to go to England to make a thorough study of methods of filtration used there for the larger cities and towns. Mr. Clarke went to England in 1885 and brought back data which apparently influenced the Commission to reach the conclusion that filtration offered a satisfactory solution for the disposal of sewage even on a large scale.

Having rejected the disposal of sewage in the Harbor as too expensive, and as fertilizer for agricultural purposes as impractical, the only remaining solution seemed to be by filtration on land. The following Engineer's report gave in detail the means of accomplishing this filtration and it involved a project of considerable size.

"*Practicability of purification on land.* This is the only remaining method of treatment, and the only one by which purification can be effective. To adopt it in this case, it would be necessary to use an area of land which eventually might amount to nearly 1,000 acres. It should be flat or gently sloping, should not be expensive to buy, should be somewhat remote from thickly populated districts, should be easily accessible from the lower part of the Mystic Valley. There is one, and but one, tract of land which fulfills these several conditions. It is the tract of meadow land lying to the westward of the Lynn Turnpike in Saugus and Revere, in the vicinity of Pines River. With any probable increase of population and amount of sewage hereafter, a sufficient area could be obtained to effect purification by means of intermittent filtration. As purification at this point is believed to be at once the cheapest and most effectual method of disposal in the case under consideration, it is recommended that it be adopted for the sewage of the Mystic Valley district."

Therefore the recommendation of the Massachusetts Drainage Commission in 1886 included, as far as the Mystic River Valley was concerned, the acquisition of a large area of land in Saugus and Revere which would be used for the filtration of sewage originating in that area and also sewage originating in Malden, Everett, Chelsea and Revere.

The Commission felt as a result of the studies made in England that ample experience existed to demonstrate that it would be entirely feasible, upon the ground designated in Engineers' studies, to treat the whole sewage of the district tributary to the main sewer in the Mystic Valley . . . "for the next fifty years without causing any serious annoyance". The Commission felt very sure of their position and went on to say: "If any person finds it difficult to accept this statement, it is only necessary to look into the material which we have collected to be convinced of its reliability".

Sanitary requirements in 1885 were much different from what we think of as being acceptable at the present time. For instance, a perfect sanitary contrivance for disposing of excrement is described and pictured in the report as consisting of: a wooden seat; a coal hod to receive the earth and excrement; a box of dry earth and a scoop to distribute it with. The system was considered perfectly simple in its operation, requiring only reasonable care on the part of the user. It was recognized, however, that if and when the introduction and use of public water supplies became general, the problem of sewage disposal would greatly increase and more or less in proportion to the increase in the use of domestic water. Apparently the report of 1886 was not fully convincing, at least with regard to the use of filtration, as that method of disposal was never adopted.

Following the report of 1886, further studies were made and that of the State Board of Health in 1889 was finally agreed upon as recommending the solution best suited to correct the problem of sanitation confronting the metropolitan area at that time. With respect to the area north and west of Boston, the proposed plan of construction included the provisions recommended back in 1881, namely a main sewer for the full length of the Mystic River Valley through Winthrop to Deer Island with an outfall to deep water. Filtration as a solution recommended in 1886 by the Massachusetts Drainage Commission was rejected.

The State Legislature, by Chapter 439 of the Acts of 1889, established a Board of Metropolitan Sewerage Commissioners and directed them to construct sewerage works for the cities of Boston, Cambridge, Somerville, Malden, Chelsea and Woburn and the towns of Stoneham, Melrose, Winchester, Arlington, Belmont, Medford, Everett and Winthrop. It was under this commission's direction that the existing Alewife Brook Sewer was built. A five million dollar bond issue was set up to cover the cost of construction and the first major step was begun towards the solution of sanitation problems on a community-wide basis for the Boston metropolitan area.

The existing Alewife Brook Sewer was designed to take the prospective sewage from parts of Cambridge, Somerville, Arlington and Belmont and to serve a population estimated in 1890 at about 13,200. The sewer was built with a capacity of 11 m.g.d. with the expectation that for the ensuing 50 years it would be adequate. However, the increase in population and the use of public water supplies exceeded expectations. Arlington's population, for instance, increased from 5600 to over 44,000 and that of Belmont from 2100 to 27,000 in sixty years, a population 9 or 10 times as great as that when the sewer was built. The increase is undoubtedly the cause of some of the surcharging of the old sewer. The upper portions from Belmont and Cambridge are 15″ and 18″ in size, respectively, then increasing in size from 23″x33″ at the Belmont connection on a slope of 1:1500 to a 35″x42″ on the same slope at the old pumping station where the sewage was lifted about 13½ feet to a force main section of sewer 36″x43″ extending to the main Mystic Valley sewer. The force main portion has a capacity of about 12 m.g.d. Most of the existing sewer is of brick construction. Fourteen overflows into the Alewife Brook were provided and since the sewer has been overtaxed for years, the Alewife Brook became increasingly polluted and offensive. It was to relieve this situation that the present construction with greatly increased capacity has been necessary. The original pumping plant installation consisted of two upright 48-inch tubular boilers, rated at 25 horsepower each, two marine-type engines and two 9-inch Andrews centrifugal pumps. The James Russell Boiler Works Company made the boilers at a contract price of $1135. The engines were furnished by the Fore River Engine Co. for $1500 and the pumps by Joseph Edwards Co., New York, for $1100.

Conduit and Pumping Station

The construction of the Alewife Brook Conduit and Pumping Station follows the authorization for extensive improvements of sanitary facilities in the Boston Metropolitan area by the passage of Chapter 705 of the Acts of 1945. The elimination of Alewife Brook pollution was one of several projects authorized as part of a very large program, namely:

Project 1. Sewage treatment plant at Nut Island.

Project 2. Extension of North Metropolitan Relief Sewer from East Boston to Deer Island.

Project 3. Alewife Brook Conduit and Pumping Station.

Project 4. South Charles Storm Overflow Conduit.

Project 5. North Charles Storm Overflow Conduit.

for which work $15,000,000 was authorized with certain restrictions. The full use of the Alewife Brook facilities depends upon the completion of Project 2 and additional work contemplated at Deer Island.

It is apparent that local sanitary problems have been the subject of study almost continuously over the last sixty years and although the construction during 1890 and 1895 made a great contribution towards the elimination of pollution at that time, the situation was improved only temporarily and soon the matter was under further study by the Legislature and special commissions. Surveys made in 1900, 1917, 1929, 1930, 1935, 1936, 1937 and 1939 indicate the continued concern with the problem.

House Document 1600 of 1937 presented a very thorough study of the whole matter with particular emphasis on the condition of Boston Harbor. The Commission presenting that report was repeatedly told at hearings that . . . "the conditions in Boston Harbor are revolting to the esthetic sensibilities and violate all public health requirements". Fifty years earlier after careful study a conclusion had been reached to the effect that "Boston found that it would not do to use her harbor, spacious as it is, for a cesspool".

House Document 2465 in 1939 brought the solution into clearer focus calling for elimination of pollution of the inland waters and for treatment works to be constructed for the protection of the harbor waters. This report recommended conduits in the Mystic, Malden and Charles River basins and treatment works at Nut Island, Moon Island and Deer Island at an estimated cost of about

$25,000,000. In recommending this program, the report expresses this attitude with respect to meeting the cost:

> "Members have realized that any huge program which might be suggested must of necessity be based on a financing program which extends payments for the capital expenditure for as long a period in the future as sound financing will permit. In so doing, the Public enjoying the use of the works throughout the life of the works will be paying for the benefits received without impairing the credit of the city and town governments which contribute to the operation of these sewerage districts".

The problems were much the same as those confronting the Legislature in 1880, but were greatly increased in magnitude by reason of the growth in population on the one hand, and on the other the higher standards with respect to matters of public health which are considered essential today.

The new Alewife Brook Conduit (Fig. 1), including a branch from Belmont, runs from Concord Avenue in Cambridge, along the Alewife Brook to a new pumping station near the Mystic River and discharges into the North Metropolitan Relief Sewer in Medford. It is intended as a relief for the old sewer which will be continued in use throughout its full length . The conduit consists principally of reinforced-concrete pipe, 48-inch at the upper end, 36-inch for the Belmont Branch and 66-inch for the main line below the Belmont connection.

The total quantity to be provided for was computed as being 90.4 m.g.d. of which the old sewer could carry 12, leaving a balance of 78.4 m.g.d. to be carried by the section below the pumping station.

These figures were arrived at by taking the areas of Belmont, Cambridge, Arlington, Somerville and Medford found to be tributary to the conduit, and estimating their expected population densities in 1975. To the estimated population in 1975 a certain gallon per capita per day was set as the amount of sewage which would have to be provided for in the case of each area. The conduit is provided with overflows into the Alewife Brook to take care of emergency conditions and because of the necessity of this provision a certain dilution factor was applied which it was felt would allow the overflows to be made without again causing excessive pollution of the brook.

Some of the areas being zoned for industrial purposes dictated the necessity of making a further allowance to take care of contribu-

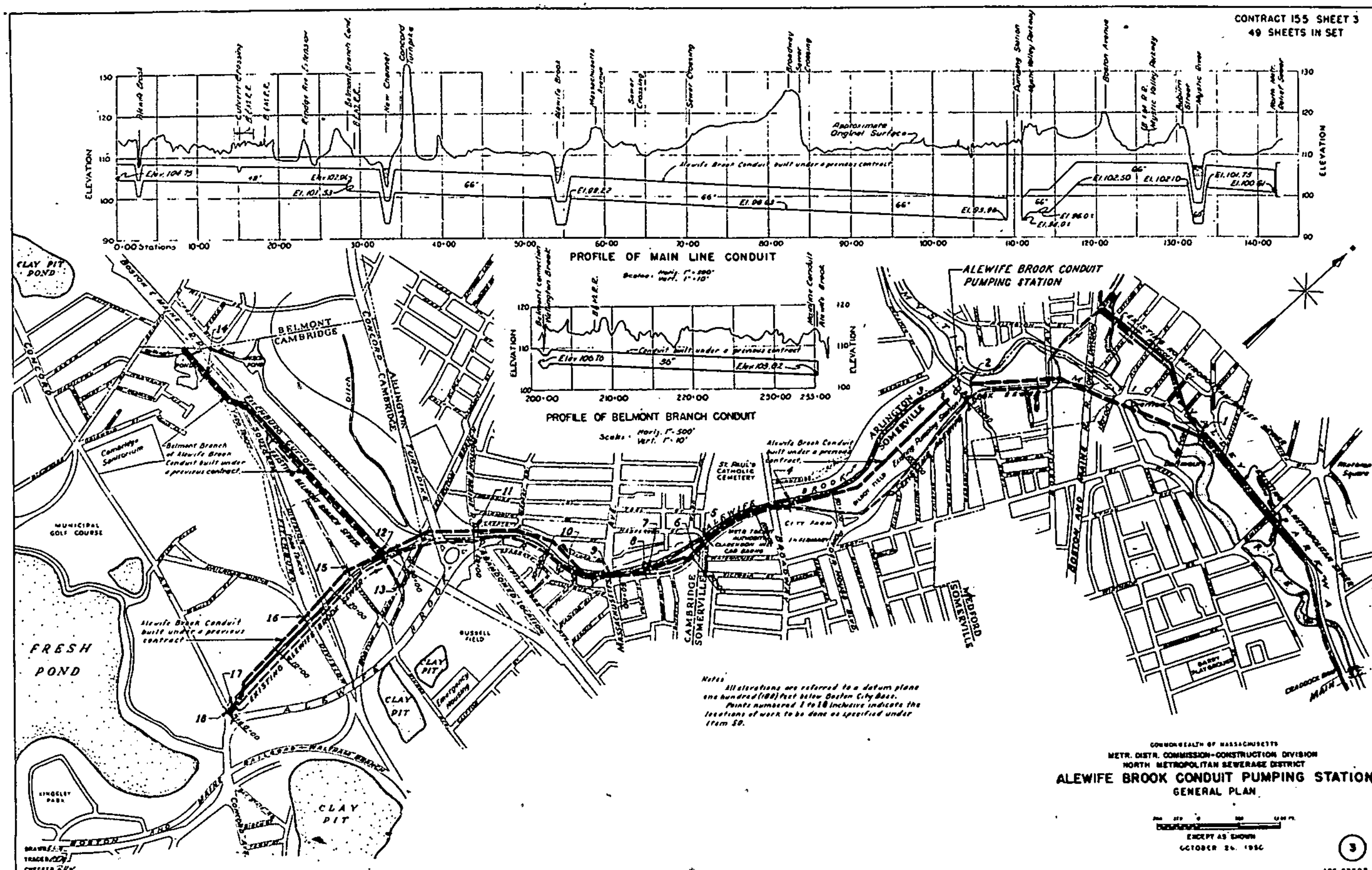


FIG. 1.—GENERAL PLAN.

tions from manufacturing or business enterprises which might be located within the area served.

It is interesting to note that in the Cambridge and Arlington areas at the upper end of the conduit where very few businesses of any kind existed when the work was started in 1949, a rapid growth in industrial development is taking place and already a considerable portion of the area has been put to use with the construction of processing plants, warehouses, and sizeable buildings where steel fabrication and other heavy industry is being carried on.

The basis for the design of the conduit with respect to area, population, dilution and capacity is shown in Table I, which indicates that the total capacity of sewer needed to provide for an estimated 1975 population was based on the gallons per capita per day to be contributed and a dilution factor of 10. An allowance of 13,000 gallons per acre per day from industrial sources was also included. These factors were recommended by the Consulting Engineers as reported in House Document 2465 of 1939. Although some of the areas served are referred to as having separate sewers, nevertheless, the effect of rainfall is to increase the amount of flow to be handled either because of actual connections to storm drains or by reason of the poor conditions of some of the laterals.

It appears that the additional conduit capacity to take care of the 10:1 dilution of sanitary flow corresponds to a contribution due to a low intensity rainfall of long duration equal to, or exceeding, 0.10 inches of rain per hour for the areas involved assuming an average run-off coefficient of 0.15 for Belmont, 0.30 for Arlington and 0.40 for Cambridge, Somerville and Medford. Apparently rainfalls in the Boston area can be expected to exceed this rate only about 1 to 1½% of the time. Pumping records, as well as studies of the areas served, indicate a minimum dry weather flow of about 8 m.g.d. may be expected in the years following the first use of the conduit.

The sizes, grades and slopes of the line are shown in Table II indicating slopes for the 66-inch pipe varying from .00085 to .00098.

The minimum velocity may possibly fall below 2 feet per second for short periods of time, but flushing action from peak flows on minimum flow days are expected to prevent any excessive accumulation of deposit in the conduit. If necessary, the main pumps can be

TABLE I

Alewife Brook Conduit—Design Data

Location	Area Acres	Population-1975 Density per acre	Population-1975 Total	Domestic Ave G.C.D.	Domestic Dilution Factor	Domestic Allowance in sewer G.C.D.	Domestic Allowance in sewer M.G.D.	Industrial 13000 GAD	Total Capacity MGD	Capacity of existing Sewer MGD	Req'd Conduit Capacity MGD
Belmont	2870	12	34,400	53	10	530	18.2	0.8	19.0		
Cambridge	1153	33	38,000	100	10	1000	38.0	5.1	43.1		
Arlington	1082	30	32,500	60	10	600	19.5	0.8	20.3		
Somerville	186	40	7,400	70	10	700	5.2	0.1	5.3		
Medford	237	21	5,020	52	10	520	2.6	0.1	2.7		
							Total		90.4	12.0	78.4

Summary of Estimated Discharge

Existing Alewife Brook Sewer	11.4 MGD
New Alewife Brook Conduit	66.2
Entering Pumping Station directly	11.0
Total entering Pumping Station	88.6
Entering existing discharge line	1.8
Discharge from entire area	90.4 MGD
To be pumped through new discharge line	78.4 MGD
To be pumped through existing discharge line	10.2 (1)
Total to be pumped	88.6 MGD

(1) Estimated capacity of existing discharge line.	12.0 MGD
Entering through Medford connections	1.8
Remaining capacity.	10.2 MGD

used to draw down the elevation of the pump suction well rapidly and induce a flushing action along the pipe line.

The pipe line, approximately 18,000 feet in length, consists of precast-concrete pipe, except for special sections of concrete construction at points where the new line crosses the old sewer, at manhole and special structures and at points where local conditions precluded the use of the precast pipe. Overflows from the conduit line into Alewife Brook have been provided at several places over weirs set at elevation 110.0. These overflows are located at:

	Location	Approx. Station	Type	Elevation
1.	Concord Avenue	0+30	Weir	110.
2.	Rindge Avenue	28+40	Culvert 24"x30"	110.
3.	At Siphon	32+30	Weir	110.
4.	At Siphon	55+72	10" pipe and weir	110.
5.	Tannery Brook	63+20	Weir	109.50
6.	Woodstock St.	73+00	12" pipe	110.
7.	Pumping Station	109+22	Weir	110.

Reinforced-Concrete Pipe for Conduit Line

The specifications required that the reinforced-concrete pipe meet the requirements of "A.S.T.M., C76-41, Standard Specifications for Reinforced-Concrete Culvert Pipe".

Sections of both standard strength and extra strength were used in size 36", 48", 54" and 66" in diameter, the extra strengths being used as needed in places where heavy surface loading might occur such as at road and railroad crossings. The 54" and 60" sizes were used at certain river-crossing siphons so that with these exceptions the conduit is made up of 36", 48" and 66" pipe. The pipe lengths are generally 8'-0" except for skew pieces or closure and the pipe and reinforcing is circular. The minimum radius on curves using skew-end pieces was 50 feet for 4-foot lengths and 100 feet for 8-foot lengths.

The joints are designed to be watertight. Tongue and groove sections were used throughout and the joints were made up by use of tylox gaskets for the 36-inch pipe and oakum caulking for the larger sizes. In all cases the joints were then filled with cement mortar on the inside and with an approved mastic on the outside. Inserts and threaded rods were provided for pipe sections at river

TABLE II
Alewife Brook Conduit—Profile Data

Location From	Location To	Station	Conn No	Design Discharge MGD	Size Inches	Length Feet	Slope	Rise or Drop	Elev. Hyd Gr.	Elev. Invert
		0+55.00							108.50	104.75
Concord Ave.			C-1							
			C-51	16.7	48	2797.00	.00064	1.80		
	Belmont		C-57							
	Branch	28+52.00							106.70	102.95
Belmont		Equality							106.70	101.53
Branch		28+56.00	Bel br							
			C-2	60.8	66*	2716.77	.00085	2.31		
	Near		A-28							
	Mass. Ave.	55+72.77							104.40	99.22
		55+72.77							104.40	99.22
Near			C-50							
Mass. Ave.		(79+50.00	C-3	64.8	66	2613.93	.00099	2.51		
		((79+51.48	C-22							
	Broadway	81+88.18	C-17						101.81	96.63
		81+88.18							101.81	96.63
Broadway			S-5							
			S-12	66.2	66	2795.83	.00098	2.75		
	Pumping Sta.	109+84.01							99.06	93.88

TABLE II *(Continued)*

Location From	Location To	Station	Conn No	Design Discharge MGD	Size Inches	Length Feet	Slope	Rise or Drop	Elev. Hyd Gr.	Elev. Invert
pumping sta.		110+81.57								94.0
				78.4	66	349.70	.020	6.35		
	Near Mystic Shops	114+31.27								100.35
				78.4	66	318.73	.00683	2.15		
	Near Boston Avenue	117+50.00								102.50
				78.4	66	1371.00	.00029	0.40		
	Mystic River	131+21.0								102.10
	Siphon			78.4	60	227.64		0.35		
	Mystic River	133+48.64								101.75
				78.4	66	828.36	.00137	1.22		
	No. Metr. Relief Sewer	141+77.0								100.53

*Except 54" in siphon, Sta 32+30 to Sta 34+26 and brook crossings for anchorage in concrete to overcome buoyancy. Elsewhere the backfill on top of the pipe is sufficient to keep the pipe in place when unwatered.

Manholes are located at inverted siphons, special structures, at changes in direction of the conduit line and at 350 to 400 feet intervals along the line. The manhole structures are reinforced concrete, cast in place, with brick barrel above. Ladder rungs of monel metal are set in the concrete and brickwork.

Most of the excavation was done in open cut and the pipe laid on the prepared foundation of crushed stone or gravel shaped to conform to the bottom of the pipe. Piles were required to support some of the 36" pipe on the Belmont connection, but on the main line the foundation conditions were generally better and no additional support was needed. Underdrains were employed to carry water to points convenient for pumping so as to keep the trench dry except at river crossings where a well-point system back of earth cofferdams accomplished the same results.

Tunnels were driven under the Concord Turnpike, Massachusetts Avenue and Broadway, at which places the tunnel inverts are below the roadways about 33 feet, 18 feet and 30 feet, respectively. These tunnels were constructed by means of hand digging from shafts at either end and are 145 feet, 88 feet and 301 feet in length, respectively. Steel liner plates were placed as the excavation progressed to form an 8-foot diameter opening to receive the pipe. Grout was placed in the area between the pipe and the liner plates after the pipe joints were made up.

The pipe line itself was constructed under two contracts, Numbers 154 and 169, completed in 1949 and 1950, respectively, and the pumping station built under Contract 155 was completed in 1952. Contract 155 also included the demolition and removal of the old pumping station and the switching of flows and pumping from the old station to the new station. Numerous connections to the new conduit and break-ins to the old sewer which could not be done as part of the conduit construction were deferred until the new pumping station was in operation and were included as miscellaneous work in the pumping station contract.

The specifications required that upon completion of a sizeable length of the conduit it should be unwatered and a satisfactory leakage test should be conducted at the Contractor's expense for at least

48 hours. The amount of leakage allowable was set at not more than 100 gallons per mile per inch of internal pipe diameter per day. I understand from the test data that the line as a whole met this requirement but that there was a portion of the line in which the leakage exceeded the allowable.

Alewife Brook Pumping Station

The new pumping station (Fig. 2) adjacent to the site of the old station, may be properly classed as a lift station in the system of

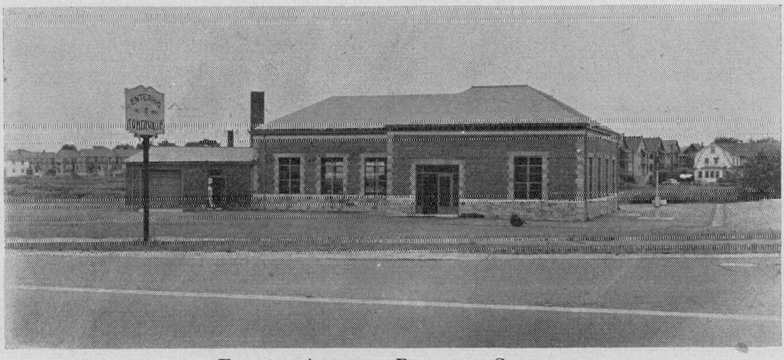


Fig. 2.—Alewife Pumping Station.

the North Metropolitan Sewage District. It replaces a structure built in 1895, which at the time of its recent abandonment contained, in addition to the pumping equipment, two coal-fired vertical steam generating boilers that were installed in 1933.

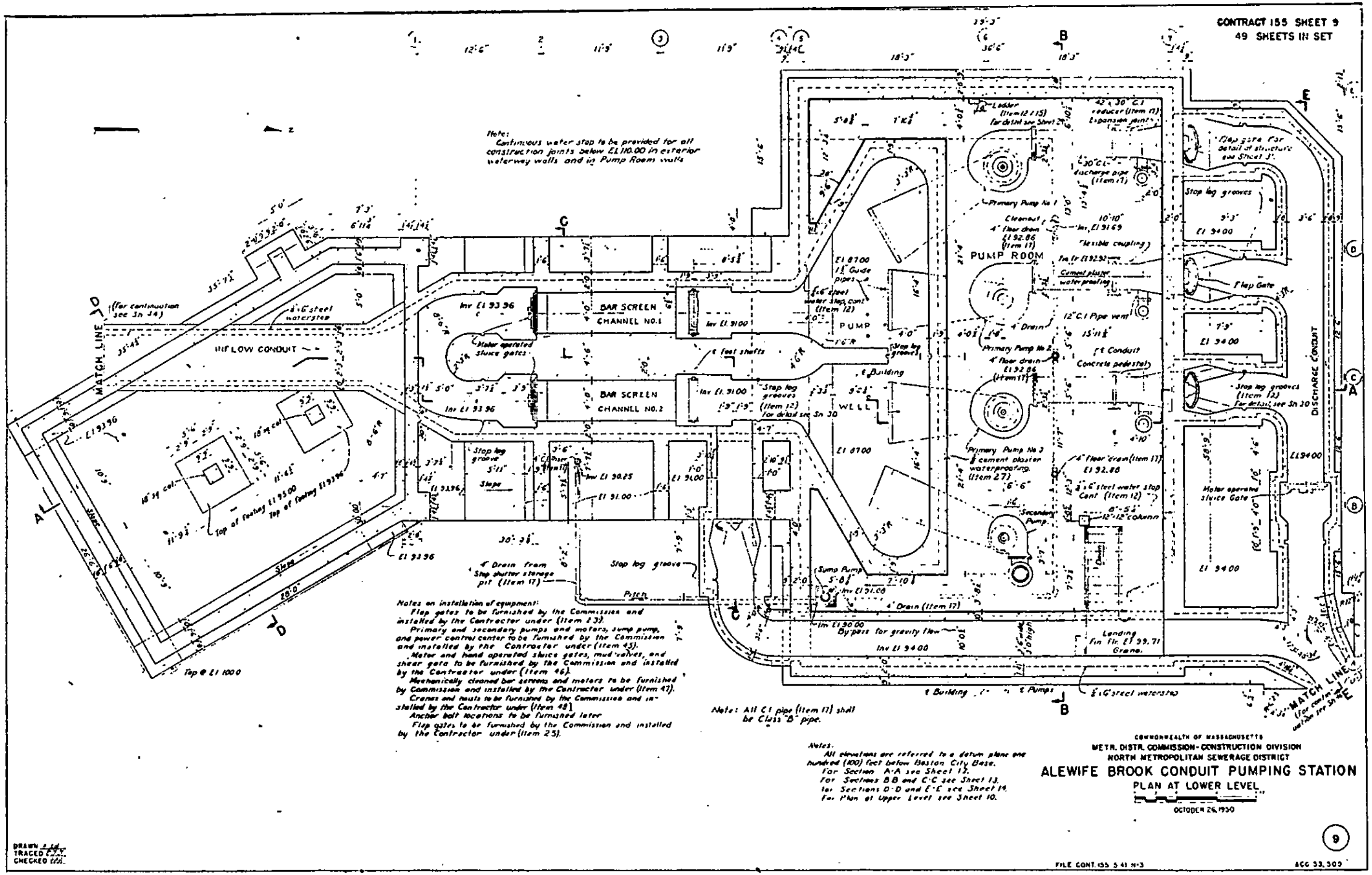
The steam plant served to power two engine-driven pumps and auxiliary equipment, along with furnishing heat for the buildings.

Preliminary studies indicated that the new pumping equipment and related auxiliaries would be of such size that the existing building would not provide sufficient head room for motor-driven vertical pumps, nor adequate floor area for horizontal pumps. Consideration was then directed to the possibility of making limited use of the existing building and constructing the necessary addition to accommodate the new equipment. This plan, however, was soon dropped when further study indicated that through the new relief sewer it would be possible to discharge by gravity a large part of the time and a single sump, common to all pumps, would greatly facilitate control, operation and maintenance requirements. The gravity discharge potential led to consideration of having this an automatic station which might operate unattended the greater part of each day. The economy of such a scheme seemed to justify complete abandonment of the old station and the concentration of equipment and controls in an entirely new building of modern functional design.

The Massachusetts Department of Public Health, whose approval of the plans is required by law, had requested that necessary provisions be included for utilizing the old Alewife Brook discharge sewer leading to the North Metropolitan Sewer and to the Deer Island outfall before putting anything in the new 66″ conduit. The reason being that until future construction is completed in approximately 1960, any flow in the new conduit below the pumping station will discharge into the tidal waters at Chelsea Creek via the North Metropolitan Relief Sewer with only such sanitary protection as chlorination applied in Everett can provide. Accordingly the design included a so-called secondary pump discharging into the old Alewife Brook Sewer and 3 primary pumps discharging through the new conduit. The arrangement of pumps and equipment is shown on Figs. 3, 4 and 5. The secondary pump is a vertical centrifugal 20-inch dry-pit volute pump of the mixed-flow type. It is driven by a 50 horsepower constant speed induction gear motor 1800/420 r.p.m. It draws from the common sump and discharges a maximum of 12 m.g.d. into the existing Alewife sewer below the pumping station.

Investigation showed that the condition of this sewer would not permit surcharging, and in order to avoid complicated controls for varying the pump discharge in accordance with the sump level, a constant speed pump was selected and an adjustable weir was placed in a side take-off from the pump discharge pipe. By setting the crest of the weir it will be possible to control the discharge into the old sewer preventing surcharge and possible damage therefrom. The excess pumpage passing over the weir will be returned to the pump well requiring some repumping, but this is of small consequence.

The primary pumping units consist of three 30 m.g.d. electrically-driven centrifugal pumps (Fig. 6). The specifications called for 3 pumping units capable of discharging continuously an aggregate total of 78.4 m.g.d. against a head of 15 feet; also with 2 pumps in operation, an aggregate total of 68 m.g.d. against a head of 10.2 feet, and each pump alone to be capable of discharging continuously as



CONTRACT 155 SHEET 9
49 SHEETS IN SET
Note:
Continuous water stop to be provided for all construction joints below El.110.00 in exterior waterway walls and in Pump Room walls
MATCH LINE D (For continuation see Sh 14)
INFLOW CONDUIT
BAR SCREEN CHANNEL NO.1
BAR SCREEN CHANNEL NO.2
PUMP WELL
PUMP ROOM
Primary Pump No 1
Primary Pump No 2
Primary Pump No 3
Secondary Pump
DISCHARGE CONDUIT
Motor operated sluice Gate
Flap Gate
Stop log grooves
Sump Pump
By pass for gravity flow
4" Drain from Stop shutter storage pit (Item 17)
Stop log groove
Pitch
Notes on installation of equipment:
Flap gates to be furnished by the Commission and installed by the Contractor under (Item 23).
Primary and secondary pumps and motors, sump pump, and power control center to be furnished by the Commission and installed by the Contractor under (Item 45).
Motor and hand operated sluice gates, mud valves, and shear gate to be furnished by the Commission and installed by the Contractor under (Item 46).
Mechanically cleaned bar screens and motors to be furnished by Commission and installed by the Contractor under (Item 47).
Cranes and hoists to be furnished by the Commission and installed by the Contractor under (Item 48)
Anchor bolt locations to be furnished later
Flap gates to be furnished by the Commission and installed by the Contractor under (Item 25).
Note: All C.I. pipe (Item 17) shall be Class "B" pipe.
Notes.
All elevations are referred to a datum plane one hundred (100) feet below Boston City Base.
For Section A-A see Sheet 12.
For Sections B-B and C-C see Sheet 13.
For Sections D-D and E-E see Sheet 14.
For Plan at Upper Level see Sheet 10.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. COMMISSION-CONSTRUCTION DIVISION
NORTH METROPOLITAN SEWERAGE DISTRICT
ALEWIFE BROOK CONDUIT PUMPING STATION
PLAN AT LOWER LEVEL
OCTOBER 26, 1950
9
MATCH LINE E

FIG. 3.

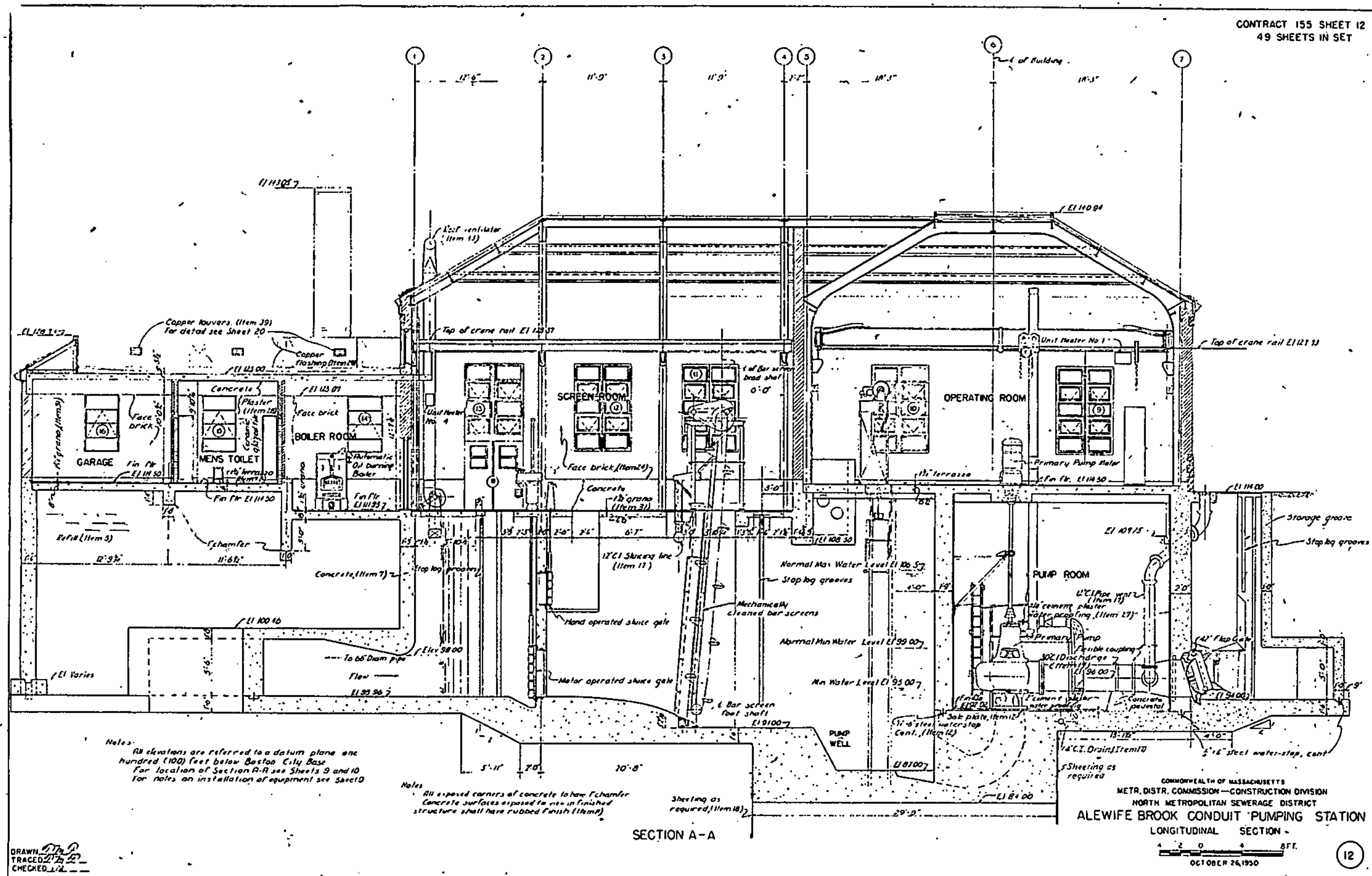

CONTRACT 155 SHEET 12
49 SHEETS IN SET
GARAGE
MENS TOILET
BOILER ROOM
SCREEN ROOM
OPERATING ROOM
PUMP ROOM
PUMP WELL
Top of crane rail
Unit Heater No. 1
Primary Pump Motor
Primary Pump
Mechanically cleaned bar screens
Hand operated sluice gate
Motor operated sluice gate
Normal Max Water Level
Normal Min Water Level
Stop log grooves
Storage groove
Notes:
All elevations are referred to a datum plane one hundred (100) feet below Boston City Base
For location of Section A-A see Sheets 9 and 10
SECTION A-A
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. COMMISSION—CONSTRUCTION DIVISION
NORTH METROPOLITAN SEWERAGE DISTRICT
ALEWIFE BROOK CONDUIT PUMPING STATION
LONGITUDINAL SECTION
OCTOBER 26,1950
DRAWN
TRACED
CHECKED
12

FIG. 4.

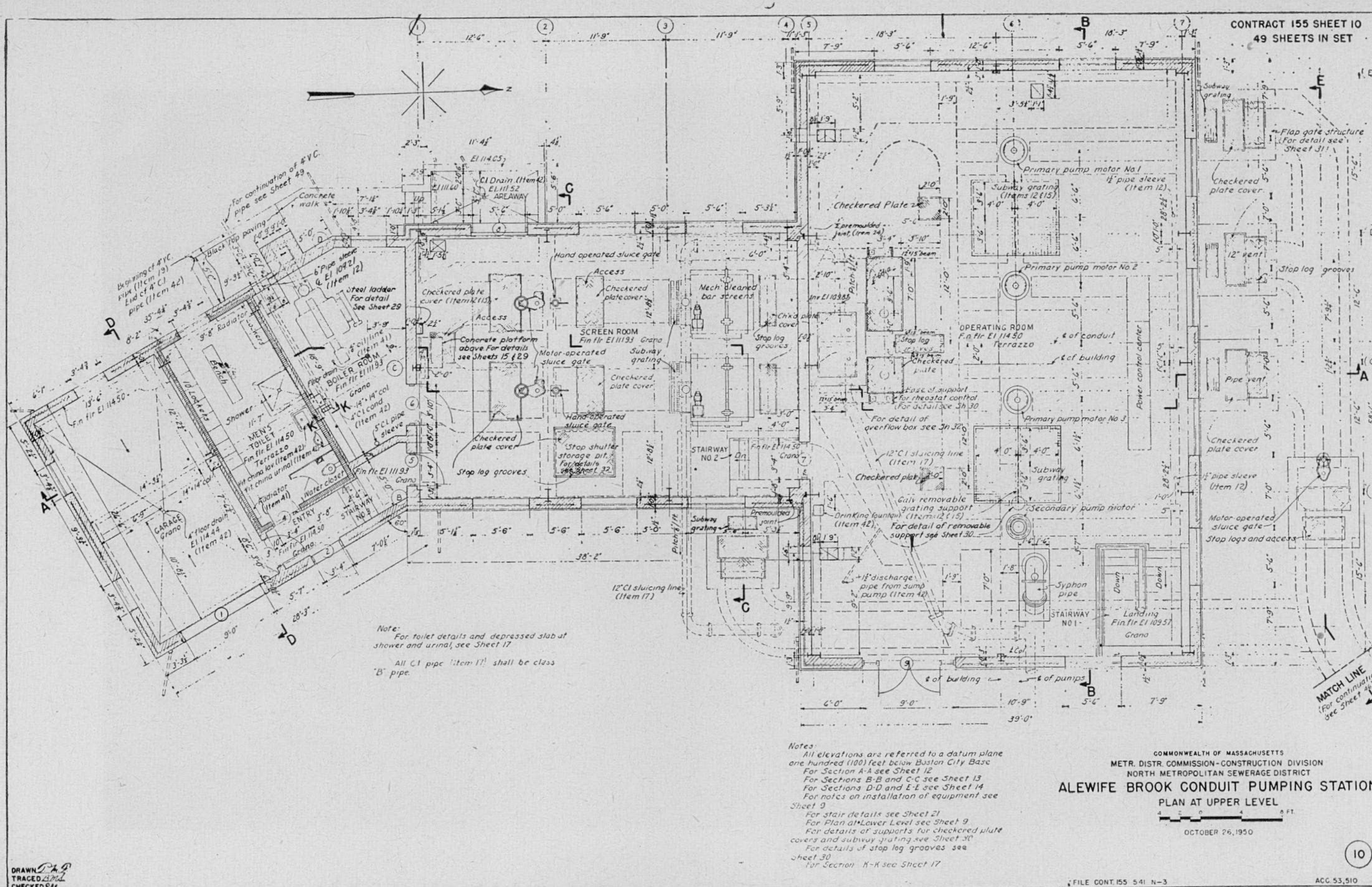

CONTRACT 155 SHEET 10
49 SHEETS IN SET
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. COMMISSION-CONSTRUCTION DIVISION
NORTH METROPOLITAN SEWERAGE DISTRICT
ALEWIFE BROOK CONDUIT PUMPING STATION
PLAN AT UPPER LEVEL
OCTOBER 26, 1950
10
FILE CONT. 155 541 N-3
ACC. 53,510
Notes:
All elevations are referred to a datum plane one hundred (100) feet below Boston City Base
For Section A-A see Sheet 12
For Sections B-B and C-C see Sheet 13
For Sections D-D and E-E see Sheet 14
For notes on installation of equipment see Sheet 9
For stair details see Sheet 21
For Plan at Lower Level see Sheet 9
For details of supports for checkered plate covers and subway grating see Sheet 30
For details of stop log grooves see Sheet 30
For Section K-K see Sheet 17
Note:
For toilet details and depressed slab at shower and urinal, see Sheet 17
All C.I. pipe (Item 17) shall be class "B" pipe.
OPERATING ROOM
SCREEN ROOM
BOILER ROOM
MEN'S TOILET
GARAGE
STAIRWAY NO 1
STAIRWAY NO 2
STAIRWAY NO 3
Primary pump motor No 1
Primary pump motor No 2
Primary pump motor No 3
Secondary pump motor
Mech. cleaned bar screens
Power control center
MATCH LINE
DRAWN
TRACED
CHECKED

FIG. 5.

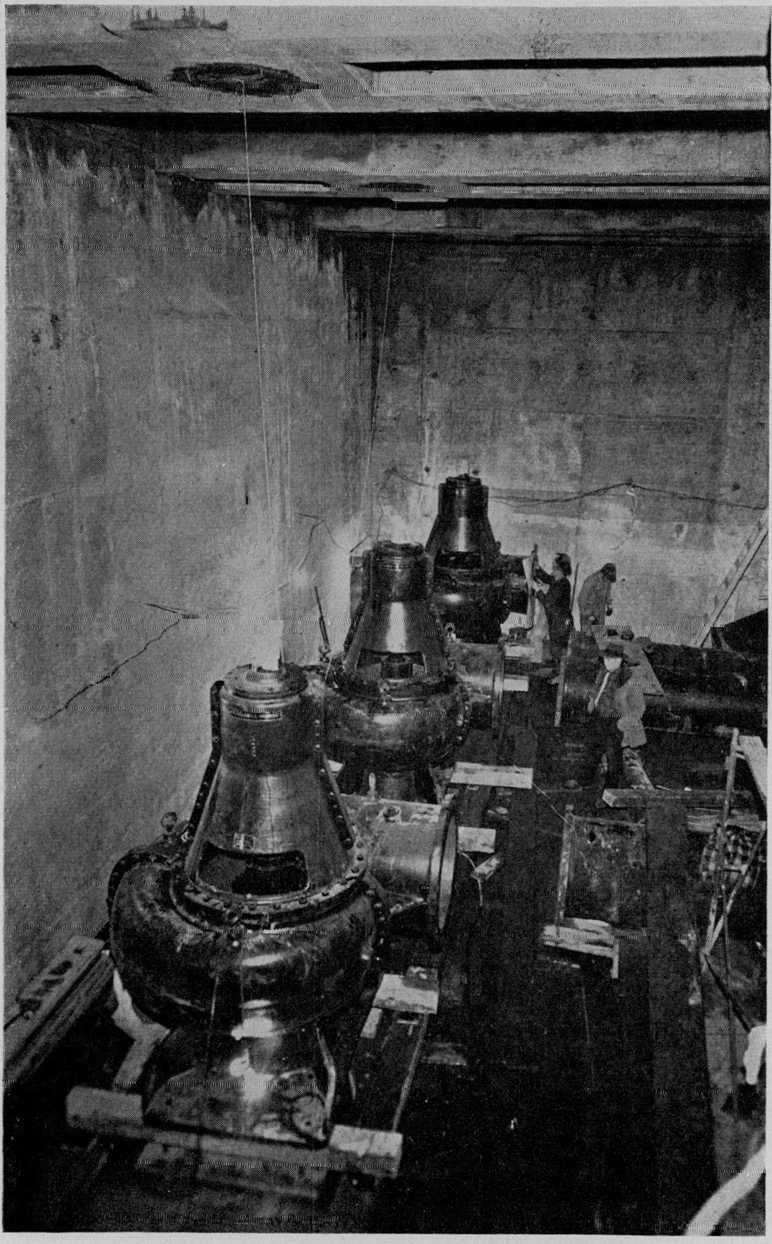


FIG. 6.—PRIMARY PUMPS IN PUMP ROOM.

low as 10 m.g.d. against a head of 11 feet. The pumps are identical, one to another, and it was presumed that the variation in discharge-head relationship would be accomplished at constant motor speed by control of the slip of a magnetic coupling. However, the pumps as furnished do not include this provision.

The manufacturer was required to design and furnish devices of approved type and make to control the rate of discharge automatically with provisions for manual control when desired.

Certain limiting conditions of quantity and elevation were stated in the specifications as follows:

When Required to Pump	Normal Maximum Level at Pumping Station	Normal Maximum Head (T.D.H.)
35 m.g.d.	106.5	3.0
50 m.g.d.	105.5	5.3
66 m.g.d.	101.5	10.2
70 m.g.d.	100.75	12.0
74 m.g.d.	99.75	13.2
78.4 m.g.d.	99.0	15.0

Invert of pump well at Pumping Station	Elevation 87.0
Minimum water level at Pumping Station with pumps under manual control	Elevation 95.0
Normal minimum water level at Pumping Station with pumps under automatic control	Elevation 99.0
Normal maximum water level at Pumping Station with pumps under automatic control	Elevation 106.5
Normal water level at remote control point required to start pumps under automatic control	Elevation 108.75
Maximum water level at remote control point requiring pumps to be at full capacity	Elevation 109.75

Some additional criteria which were used for design purposes were flexible and could be altered in accordance with the equipment to be furnished. These are:

Center line of pump discharge	Elevation 96.0
Base of pump setting	Elevation 91.75

The initial rate of pumping, when the normal water level at the remote control point reaches elevation 108.75, was set at approximately 35 m.g.d. at a maximum T.D.H. of 3 feet. Provision for adjusting the initial and subsequent rates of pumping were included in the design, in the event actual operating experience indicates a need for such adjustment.

The primary pumping units installed consist of three vertical-shaft, bottom suction, centrifugal, 30-inch volute pumps of the mixed-flow type, driven by vertical 100 horsepower wound rotor gear motors 1750/280 r.p.m. Variable speed is obtained by means of the wound rotor and a liquid rheostat. These pumps will provide flexible operation as well as adequate spare capacity in the event of a breakdown under high flow conditions.

The high point in the conduit below the pumping station is at elevation 102.5, and the invert at the connection with the North Metropolitan Relief Sewer is at elevation 100.6. It was estimated that up to 35 m.g.d. might be handled by gravity through the station, and therefore a by-pass channel around the pump well and pumps was included in the design. With the 12 m.g.d. that the 20-inch secondary pump will handle, it was apparent that the operation of the 3 larger pumps would be rather infrequent and this prompted the consideration of automatic control for these occasional demands.

Determining the location from which the automatic operation of the pumps might be controlled required detailed analysis of the flow profiles for various conditions in the conduit. It seemed desirable that the control point be so located as to be least subject to minor surges of short duration, as these could be dampened and absorbed in the line without surcharge effect. In this way the maximum use of gravity flow might be obtained. When increasing flow continues for a prolonged period, however, the flow level at the upper end of the Belmont Branch sewer will rise to a condition of impending surcharge and present a situation which should be avoided. This was the location decided upon as the control point for the automatic operation of the 30-inch pumps, such operation to be a function of the water level in a floatwell at this point.

Controls

The remote control equipment for operating the pumps is located in a manhole structure at the upper end of the Belmont Branch about 15,000 feet above the pumping station. This equipment consists of three Thermasul detectors which operate in conjunction with the floating liquid rheostats in the pump wet well. When the Thermasul detectors are immersed in sewage, signal impulses are sent over leased lines of the Telephone Company to start the floating liquid rheostats in operation. The detectors, set at elevations 108.50, 108.75 and 109.75, confine the range of automatic control within 1.25′ of variation in the flow line at the control point.

The thermo sensitive element is imbedded in a cyclinder around which is wound a resistance heater. This assembly is enclosed in a stainless steel jacket and mounted as a detector on the end of a pipe. When the element is in air and the heater is on, the temperature is raised to approximately 200° C. At this temperature, the resistance is low, and a series relay is energized. When the sensitive detector is immersed, the heat is carried away, the element resistance increases and the relay drops out.

The detectors are easily installed by simply clamping the extension tubing to a suitable support with pipe clamps. For low-level detection a "J"-shaped tube is used to prevent the liquid from draining off the entire length of tube and keeping the thermo element cool, even when it is out of the liquid.

At the pumping station approximately 15,000 feet from the floatwell where the initial signal or impulse is received, a lowering device called the pilot motor is energized. This device serves to lower and immerse the floating liquid rheostats, one for each of the three 30-inch pumps, into the sewage flow of the pump well.

The floating liquid rheostat (Fig. 7) consists of a stainless steel tank that floats in the sewage. This tank which telescopes inside a cover to form a sort of "diving-bell" assembly is partially filled with an electrolytic solution. The resistance of the liquid rheostat is a function of the degree of immersion of the electrodes in the electrolyte. The resistance decreases as more of the electrode area is covered by the electrolyte.

The diving bell arrangement is constructed over the electrodes to prevent the sewage from polluting the electrolyte. This enables the entire assembly to operate even while completely submerged. The weight of the electrodes and diving bell type of cover are sufficient to overcome the buoyancy of the floating tank. The pilot motor assembly is capable of lifting all three floating liquid rheostat assemblies completely out of the sewage for inspection. A hanger strap under the tank prevents the electrode from completely leaving the electrolyte when the pilot motor raises the electrodes and cover.

Guide rods are required to fix the travel of the entire assembly in a vertical motion and to prevent tipping or binding.

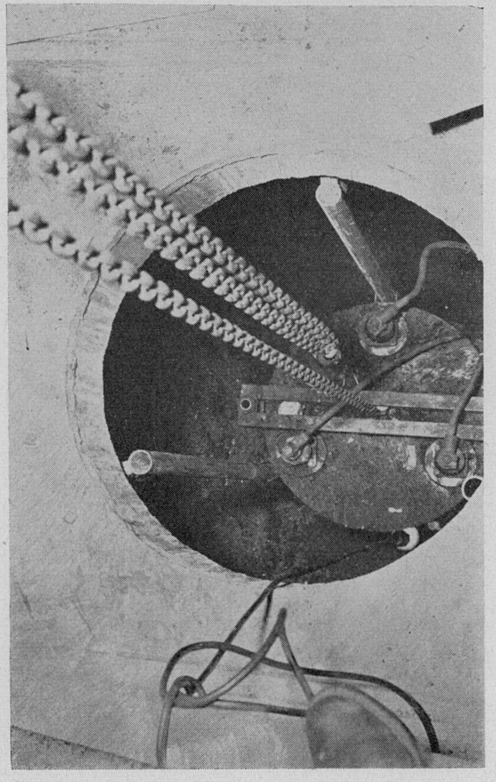


FIG. 7.—FLOATING TANK RHEOSTAT.

For any given position of the electrodes, the motor speed is governed by the degree of immersion of the electrodes in the electrolyte. If the level of sewage in the pump well should start to rise because of insufficient pump speed, more of the electrodes would be immersed in the electrolyte. This decreases the motor resistance and speeds up the pump motor. The speed of the pump motor will continue to rise until the pumping rate exactly equals the rate of inflow of sewage.

An emergency high level and low level automatic unit is provided at the Station to operate the primary pumps in the event of failure of the equipment at the remote control point.

Manual control of the pumps and related equipment is also provided so that it is possible to operate them whenever desired for flushing the line, unwatering or testing.

Typical Pumping Cycle

A typical pumping cycle as might be required under automatic control operation, may be described as follows:

With none of the 30″ pumps operating, a flow condition arises causing the water level in the floatwell to rise immersing the low level Thermasul detector. The signal is transmitted to the pumping station and serves to position certain relays for subsequent operational use in the overall control scheme, however pumping does not begin as yet. Continued rise in the floatwell will immerse the 2nd detector sending a signal to the station which starts the pilot motor lowering device and moves the tanks downward.

The action immerses the electrodes in the electrolyte of the tanks a sufficient amount to start the pump at a predetermined rate. After a time delay interval, 5 minutes, the level at the floatwell is tested again and if the 2nd detector is still immersed the pilot motor steps down the electrode, increasing the pump speed. As the electrodes are further immersed more pumps are put into service in an effort to maintain lower levels to meet the increased rates of sewage inflow. For exceptional rates of inflow, a third Thermasul detector which represents the surcharge point in the floatwell becomes immersed, causing the electrodes to lower without time delay and all three pumps run at maximum capacity. This continues until the extreme condition at the floatwell is remedied.

An emergency high level probe at the pump well will start the pumps in the event of failure of the equipment at the floatwell or interruption in the transmission to the pumping station, while an emergency low level probe serves to cut off the pumps thereby preventing uncovering the pump suction. An alarm bell tied into the emergency detectors will indicate the situation and focus attention to the alert.

The emergency high level probe acts similarly to the surcharge detector at the floatwell, and starts all pumps without delay, while the emergency low probe if uncovered, stops all pumps and raises the floating rheostats. Whenever this action takes place, a time delay occurs permitting the pump well level to rise within the regulating range, reimmersing the emergency low level probe and restoring the system to a responsive position for the automatic control.

Other features of the system include a sequence selector which designates any one of the three pumps to be the lead-off unit, permitting equalization of pump usage and wear. Hand-off-automatic switches provide for push button manual operation of the pilot motor and each of the pumps. The settings of the limit switches, timing relays and Thermasul detectors are adjustable in the field for closer adaptation to actual operating conditions.

Flow entering the pumping station must pass through either of two 4-ft. wide channels, each having a motor-operated sluice gate and a mechanically raked medium bar screen with 1½″ clear openings. At periods of high flow both channels become operative, such action being automatically integrated with the overall control system.

The screens discharge into a sorting trough from which the screenings are fed to a grinder of the hammermill type where they are shredded to a size and character suitable for pumping, and returned to the influent waterway ahead of the pump well and gravity by-pass (Fig. 8). Large objects such as pieces of wood, scrap metal and similar material unsuitable for grinding are removed and placed in covered containers for disposal elsewhere.

The operation of the mechanical rakes are controlled by a repeat-

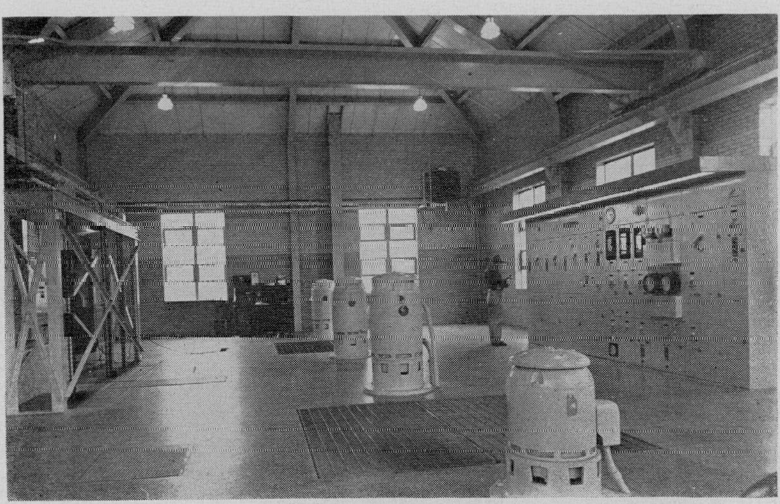


Fig. 8.—Screen Room—Alewife Brook Pumping Station.

ing cycle timer fully adjustable so that the ON and OFF periods may be varied from one minute to two hours.

On the discharge header from the 30-inch pumps, another motor-operated sluice gate, 42″x60″, is interlocked electrically with the pump controls in such a manner that gate opening precedes pump operation and gate closing follows pump shut down. A flap gate especially designed to minimize head losses and slamming is located on each 30-inch pump discharge and also on the gravity bypass to prevent short circuiting.

The pump and screen operating rooms of the station are equipped with traveling bridge cranes, one 5 tons and one 3 tons, respectively, hand racked, for routine maintenance and service requirements.

The station is serviced electrically by two 4160 volt lines from separate power sources of the Boston Edison Company and these terminate in an outdoor substation where the power is transformed to 440 volts at which service the pumps and other major items of equipment operate. In the event of a power failure from either source, the alternate 4160 volt line will be cut in by an automatic throwover switch.

The pumps and other general station service are controlled from their respective compartments in the floor mounted control center located on the operating floor of the pump room (Fig. 9).

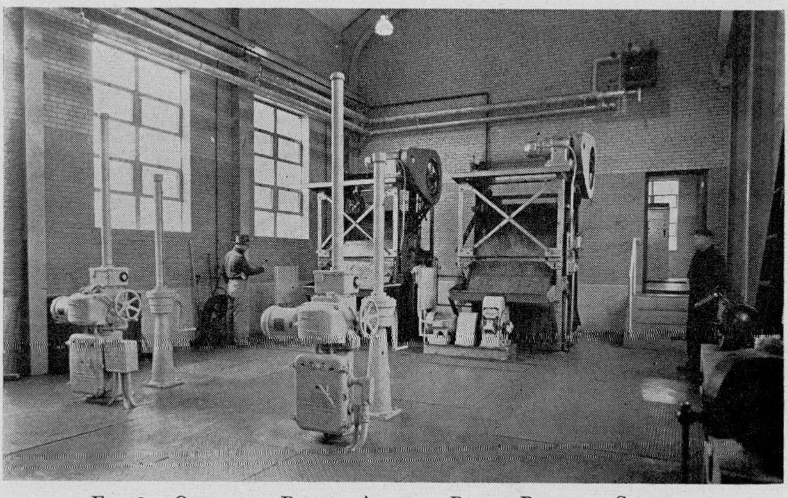


FIG. 9.—OPERATING ROOM—ALEWIFE BROOK PUMPING STATION.

Stop logs and grooves for same are provided throughout the station for isolating the various portions of the inlet and discharge channels and also for dividing the wet sump to facilitate inspection, cleanout or equipment maintenance. Several treadplate covered hatchways, conveniently located, permit easy access to these sections of the structure.

Adequate ventilation has been provided and consists of centrifugal and propeller type exhaust fans with motorized mixing dampers for controlling the air changes in the wet well, screen room, pump pit and operating room. Automatic heating of the pumping station is provided by an oil-fired steam boiler with indirect attachment for domestic hot water. Suspended type unit heaters in the various rooms permit individual thermostatic control and with "summer-winter" switches the units can be used as circulating fans in the off-heating season.

The equipment was purchased by the Commission at a cost of about $80,000 and was installed by the Contractor for the station.

Following is a listing of the principal equipment manufacturers and the purchase prices:

PUMPS:	
3 - 30″ Fairbanks Morse with General Electric motors, automatic controls and control center for 30″ pumps	$39,450
1 - 20″ Fairbanks Morse with General Electric motor	4,533
1 - Sump—Aetna Engineering Company	330
MEDIUM BAR SCREENS:	
2 - Mechanical thru-clean—Link Belt Co.	6,360
SEWAGE GRINDERS:	
2 - 7½ horsepower—Gruendler Crusher Company	2,444
BRIDGE CRANES:	
1 - 5 ton, 1 - 2 ton, Conco Engineering Works	3,890
SLUICE GATES:	
3 - Rodney Hunt Machine Co. motorized floor stands by Philadelphia Gear Works	9,999
2 - Rodney Hunt—manual operation	
FLAP GATES:	
4 - 42″ Daniel Russell Boiler Works—M.D.C. design	4,100
INTERVAL TIMER:	
1 - Eagle Signal Corporation	73
STOP SHUTTERS:	
30 - approximately 3′x4′, Quincy Ornamental Iron Works	3,843
CONTROL CENTER:	
1 - General Station Service—G & N Engineering Co.	5,000
TOTAL (Approximate)	$80,000

Removal of Old Pumping Station

The structures removed consisted of the main pumping station of brick construction, one story high and a brick chimney 64 feet high; a wooden shop building formerly a stable; an underground screen chamber and an underground coal storage area. Except for a very few items, the salvage from the demolition work became the property of the Contractor. A bid price for demolition was required, and the low bidder, Berke Moore Co. Inc., agreed to credit the M.D.C. with $400 for this item.

Some changes in the equipment of the old pumping station had been made since its original construction, and when finally removed it contained a 20-inch centrifugal pump rated at 12 m.g.d. at 14-foot lift, and a 12-inch centrifugal pump rated at 8 m.g.d. at 14-foot lift, each powered by a steam engine.

There was considerable miscellaneous work inside the conduit line included in the contract for the pumping station, which could not be done until the new pumps were in operation. This work consisted of clearing the new line of temporary bulkheads, breaking into the old sewer where the new and old lines intersected and the same kind of work in connection with other old sewer lines which now flow into the new conduit instead of into the old sewer. The old Alewife Brook sewer is being used however throughout its length and between points of connection with the new line the old laterals still discharge into the old sewer. Where the main lines intersected, reinforced concrete chambers were built around the old sewer which was strengthened and supported within the structure. The miscellaneous work called for the breaking up of the old sewer within these chambers at Stations 83+70, 70+41, 63+90 thereby diverting the flow to the new conduit.

By means of break-in manholes built into the old sewer upstream and downstream from the old station, the flow was by-passed to the new station and by use of the secondary pump raised to the force main portion of the old sewer and discharged thereby, as was formerly done, to the North Metropolitan Sewer. As described above the discharge of the three large pumps through the new conduit is carried to the North Metropolitan Relief Sewer which was built in 1939, and from which it is later discharged into Chelsea Creek. Future construction will carry this sewage to Deer Island.

At the completion of the construction the project was turned over to the Sewer Division of the M. D. C., of which Mr. Thomas A. Berrigan is Director and Chief Engineer, to be operated and maintained as part of the M. D. C. system.

Cost

The construction of the conduit line begun in 1948 and 1949 was at a time when materials were in short supply and prices for heavy construction were rising. Bids tended to exceed contract estimate and in fact the low bid received when the work was first advertised totalled $1,537,686 and exceeded the money then available for the project, and all bids were rejected.

The work was then divided and the downstream portion built under Contract 154 and the upstream portion built under Contract 169. Trench excavation and refill was paid for on the basis of a unit price per linear foot for various locations and the furnishing and laying of the pipe was also paid on a linear foot basis as bid.

Furnishing & Laying	Length	Contract 154 Wes Cons. Co. & Julian Cons. Co.	Contract 169 Pacella Bros. Inc.
36″ standard	220′		$12.00 per ft.
36″ extra strength	2480′		14.50 per ft.
48″ standard	1475′		16.50 per ft.
48″ extra strength	980′		19.00 per ft.
54″ standard	190′		23.00 per ft.
60″ standard	210′	$30.00	
66″ standard	600′		
	6320′	35.00	30.00 per ft.
66″ extra strength	425′		
	1880′	38.00	32.00 per ft.
Total of Bid prices		$917,155.75	$439,493.93

The new pumping station built under Contract 155 is of brick construction with granite trim. The bid price totalled $360,813.32. This figure included considerable work in addition to the actual construction of the building and the installation of the equipment furnished by the Metropolitan District Commission, such as the making of final connections up and down the conduit line, the diversion of flow through the new station and the removal of the old station. The cost of the additional work amounted to $16,500.

The cost of the facilities provided to eliminate the pollution in the Alewife Brook based on the contract prices is approximately as follows:

Conduit Line	$1,356,650
Pumping station	360,813
Equipment	80,000
Total	$1,797,463

Future Sewerage Projects

Of the five major sewerage projects mentioned above, three have been designed by the Construction Division of the M.D.C.; namely, the Sewage Treatment Plant at Nut Island which is in operation, the tunnel from Chelsea to Deer Island which is under construction, and the Alewife Brook project which is in operation. The No. Charles Conduit, and the So. Charles Conduit, two projects being done in collaboration with our Consulting Engineers, are in the design stage at present. Chapter 645 of 1951 provided for further sewerage work in addition to the projects authorized under Chapter 705 of 1945 and made a major change in the sewerage districts by eliminating the Boston Main Drainage District and designating that area as part of the South Metropolitan Sewerage District. This legislation contemplates a tunnel under Boston Harbor from Ward St. to the Columbia Circle area to Deer Island which has been completely designed by the Construction Division and is ready to be advertised; an enlarged treatment plant at Deer Island to handle the additional sewage; extensive headworks at Ward St., Columbia Park and at the tunnel shaft in Chelsea; large detention tanks near Boston University Bridge on the Charles River; and several other sewerage projects some of which *are* presently being designed by our Consulting Engineers. The time for the completion of projects authorized is July 1, 1958, and the total cost may reach $50,000,000.

The problem of the elimination and prevention of pollution is a continuing one and its solution is costly. It is felt that the present program of which the Alewife Brook Conduit is a small part will do much to bring the sanitary conditions of the Metropolitan District up to the best present-day standards.

I wish to express my appreciation to Mr. Edward W. Leary, Mechanical Engineer of the Construction Division of the M.D.C., for his assistance in furnishing data relating to the pumps and control mechanisms.

CIVIL ENGINEERING FEATURES OF THE KITIMAT PROJECT

BY J. S. KENDRICK*

(Presented at a joint meeting of the Boston Society of Civil Engineers and the Structural Section, B.S.C.E., held on November 18, 1953.)

ON THE northern coast of British Columbia, some four hundred miles north of Vancouver, at the head of a fjord about sixty miles long, lies the valley of the Kitimat River. In the valley an aluminum smelter is getting ready to start operating in the spring of 1954. Placing this smelter in operation is the objective of the Kitimat project, but most of the civil engineering problems lie outside the plant fence, and indeed outside the Kitimat valley.

The smelting of aluminum requires energy in large quantities—more energy per dollar of product than any other industrial process. Therefore, the aluminum smelting industry must look for large energy or power sources, preferably in locations where there is not too much demand from other users. It is rare to find large power sources adjacent to deposits of bauxite—the only commercial ore used in aluminum smelting—so the next best thing is to find a power source close to tidewater, so that the ore, in its natural state or as a concentrate, can be shipped cheaply to the power site.

These and other considerations led the Aluminum Company of Canada to explore hydro-electric resources which were known to exist in British Columbia. The first work done by the company, in 1948, was a general reconnaissance designed to verify earlier reports by government engineers, and to select some of the more favorable alternatives for detailed study. In 1949 and 1950 further engineering work was done, and in 1951 construction was started, with the objective of having 450,000 h.p. of installed capacity ready in the spring of 1954, together with enough smelter capacity to use the power, and the necessary harbour, roads, transmission lines, and other facilities.

This brief history gives no idea of the difficulties that were encountered in exploring and surveying this remote region, nor of the many alternatives that were examined and rejected before the project

*Engineer, Aluminum Company of Canada.

emerged in its present form. I will outline the project briefly before turning to the civil engineering features for more detailed description.

The coastline of British Columbia and Alaska is featured by a range of mountains lying right at the edge of the Pacific, with no coastal plain in between. The drainage from the eastern flanks of these mountains runs to the eastward, and is collected in a few rivers which cut through the mountains at such points as Vancouver and Prince Rupert. During glacial periods, the interior plateau was buried deeply under ice which broke through the mountains at numerous places at elevations several thousand feet above sea level, and flowed down into the ocean. The tremendous eroding power of this ice, descending thousands of feet, cut valleys back into the heart of the mountains. Many of these glacial valleys were cut below sea level, and now form the fjords which reach back from fifty to a hundred miles, to within a few miles of the interior plateau. Later alpine glaciation gouged a number of hollows in the plateau, which are now filled with lakes draining to the east. In a number of places, these lakes lie directly against the mountains, only a few miles away from tidewater at the head of an adjacent fjord. One such system of lakes forms the headwaters of the Nechako River, and is the basis of the Kitimat project.

The map (Fig. 1) shows the location of the principal engineering works associated with the project and important statistics are summarized in Table I. The Kenney Dam on the Nechako River impounds the waters of two tributary chains of lakes, and raises them to the elevation of Tahtsa Lake, where the main tunnel intake is located. This dam was completed in 1952. Ultimately, a second dam will be built on the Nanika River, and a tunnel will carry the Nanika water under the mountains and dump it into the main reservoir. The Nanika dam and tunnel will not be built until the last stages of the development.

The main tunnels, one of which is presently under construction, carry the water under the divide to the Kemano powerhouse, situated in the Kemano River valley. The powerhouse is underground, and the water discharges to the Kemano River through a short tailrace tunnel. There are separate tunnels for access to the powerhouse, and for the high voltage cables which carry the power to the surface.

There is no room for an aluminum smelter and townsite in the Kemano valley, and the nearest suitable place is at Kitimat, at the head

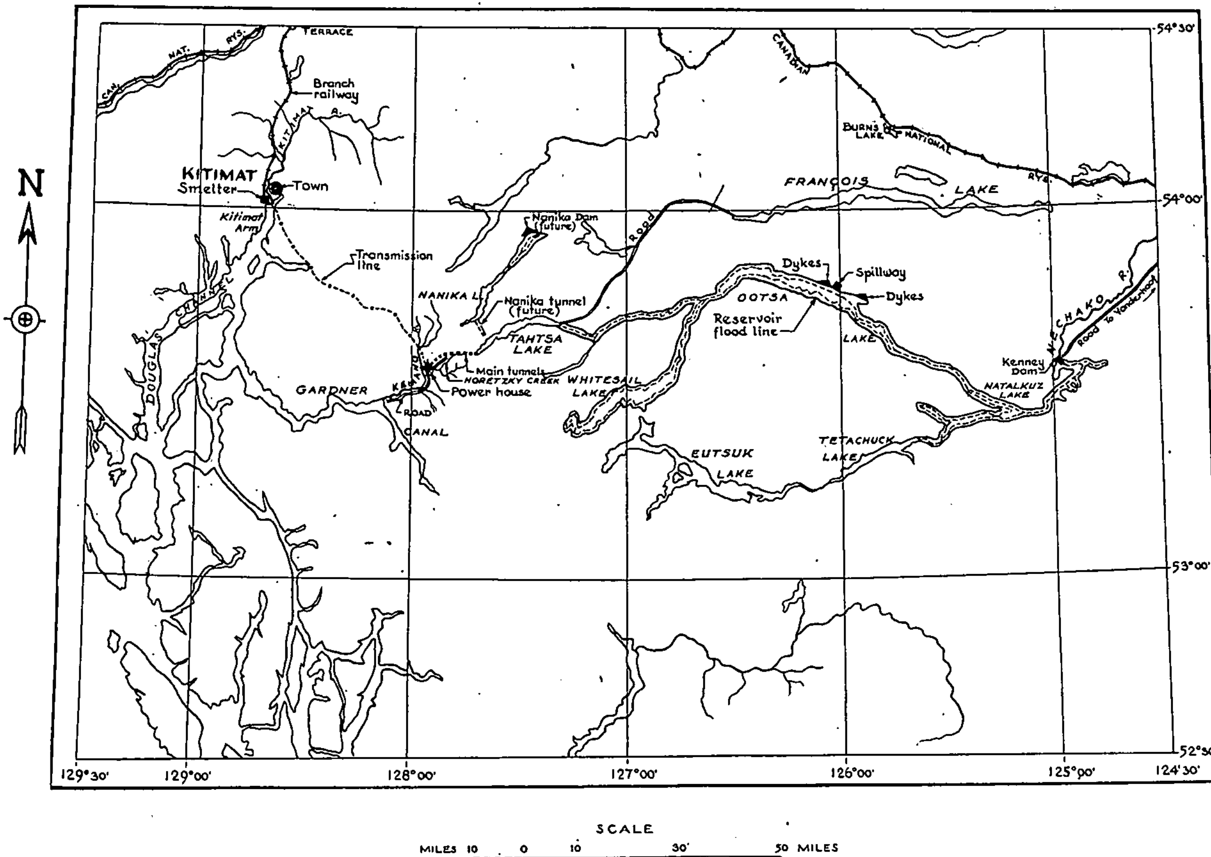


FIG. 1.—MAP OF KITIMAT PROJECT.

TABLE I

Kitimat Project

Statistical Data	
General data	
Ultimate Installed Capacity:	2,240,000 H.P.
Ultimate Firm Power	1,670,000 H.P. or 1,240,000 K.W.
Ultimate Aluminum Production:	500,000 m.t.p.a.
Kenney Dam Type: Rock fill Height: 317 ft. Crest length: 1,550 ft. Volume: 4,000,000 cu. yds. Slopes: 1 on 2.5 upstream 1 on 1.75 downstream	*Reservoir* Surface area: 358 square miles Capacity: 20,000,000 acre feet
Nanika Diversion (future) Height of dam: 155 feet Length of tunnel: 3.8 miles Diameter of tunnel: 13 ft.	*Main Tunnels* Length: 10.1 miles Diameter: 2 @ 25 ft. (1 future)
Powerhouse Type: Underground Size: 1,100 ft. by 80 ft. by 135 ft. high Static Head: 2,590 feet max. Turbines: 16—4 jet impulse turbines guaranteed 140,000 H.P. Generators: 16—106,000 KVA 327 r.p.m.	*Transmission* Voltage: 287 KV Length of line: 48 miles No. of circuits: 4 part way 2 in difficult country Conductor: 4 circuits: 1,590,000 c.m. 1.545″ diameter ACSR 2 circuits: 3,364,000 c.m. 2.295″ diameter ACSR

of another branch of the fjord which leads to Kemano. There were two possible routes for a transmission line to connect Kitimat with the powerhouse. The more obvious route follows the shore line most of the way, a distance of about eighty miles. A saving of about 35 miles of distance was possible by carrying the line over a range of mountains between Kemano and Kitimat—more or less in a direct line. The lowest pass that could be found was about 5,300 feet high, and extremely steep, but since much of the shoreline route was precipitous anyway, the saving in distance made the overland route cheaper, and it was adopted.

At Kitimat, the smelter and a port for deep-sea vessels are being built. Since there was no settlement in the area other than a small Indian village, an entire town must be built to house and serve not only all the company employees, but also the commercial, professional, and trade people to serve the production workers.

This brief description gives a background for a discussion of some of the civil engineering problems of the project. The number and diversity of such problems can easily be imagined, and some of them can be mentioned only briefly in a summary such as this.

Starting with the dam, which is shown on the map (Fig. 1) at the easterly end of the drainage area, the first problem was to decide the location and type of structure. It was necessary to find a location somewhere downstream from the junction of the two chains of lakes which form the headwaters of the Nechako. For the first fifteen miles downstream from the outlet of Natalkuz Lake, the river flows east to northeast, then it makes a sharp turn and flows west for a distance of five miles. This twenty-mile stretch of the river is on a moderate grade, and the banks are for the most part glacial and fluvio-glacial materials, with the latter predominating. An old pre-glacial channel was discovered, roughly 300 feet below the present stream bed, and full of gravel. The presence of this old channel parallel to and below the existing one forced us to look farther downstream, where the river runs through a post-glacial rock canyon. A satisfactory site was found shortly below the head of the canyon. The foundation and abutment areas were all rock, under an overburden of glacial till. At the higher elevations on the left bank this overburden was fifty or sixty feet thick in places, but elsewhere it was moderate or absent.

The rock consists of recent volcanics which are known to postdate some glacial deposits, and which cover areas of hundreds of square miles in the district. These rocks occur as horizontal flows of lava, each flow being from 20 to 100 feet thick. Layers of breccia, and in some places lenses of unconsolidated volcanic ash are interspersed with the lavas. There are locations—one only a few miles from the dam—where similar rocks overlie glacial deposits, so an extensive programme of borings was undertaken. There were a number of voids between separate flows, and some in the flows themselves, but nothing serious. Some holes were extended downward until they encountered older pre-glacial rocks, to make sure there were no glacial materials beneath the site.

With this type of foundation, a wide range of dam types would have been suitable, but the obvious choice was a rock fill. The cost of cement delivered to this remote site, sixty miles from the railroad, weighed against any type of concrete dam. Also, the purpose of the dam is to raise the water permanently to an elevation 300 feet above the stream bed, which is a process requiring the full discharge of the river for 4½ years. The dam can never be dewatered for maintenance purposes, and must have a life measured in geological, rather than historical time.

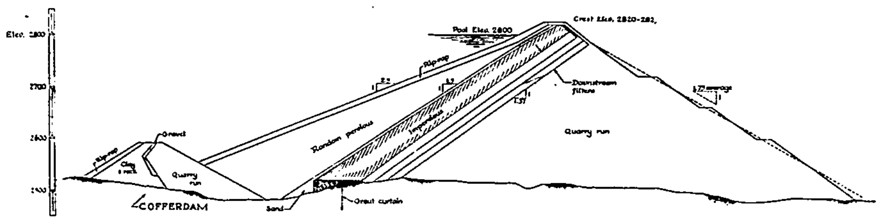


FIG. 2.—MAXIMUM CROSS-SECTION OF KENNY DAM.

The dam, shown in cross-section in Fig. 2, is similar in type to the Nantahala dam in North Carolina. The load carrying element of the dam is a dumped rock fill, with an average downstream slope of 1.75 to 1, and an upstream slope equal to the angle of repose. All the rock is sluiced, except the downstream part lying outside of the repose slope from the crest. On the upstream slope of the rock fill is placed an impervious earth layer, protected by filter layers. The filter layers on the downstream side consist of a sand layer grading from ¾ inch down to 200 mesh, a gravel layer ¾ inch to 3 inches, and a layer from 3″ to 10″. The last layer is mostly of cobbles, but the volume of cobbles from the screening operation was insufficient, and in the top 100 feet crushed rock is used. Over the impervious layer there is a layer of unwashed sand, on which a random previous section is placed to bring the upstream slope to 2½ to 1, and a layer of quarry rock is dumped on the upstream face to protect against wave action.

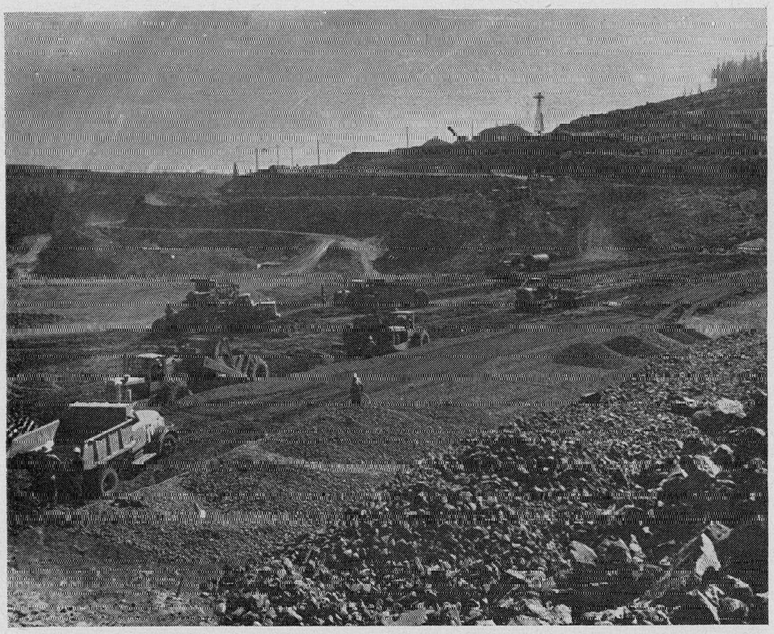
In the detailed design of the structure, the impervious diaphragm and filters received the most attention. The available impervious material was a glacial till deposit. Parts of the deposit ran too high in silt, and were avoided. Most of the material contained a scattering of boulders over six inches. It was considered necessary to remove these in order to permit efficient compaction with available equipment. Apart from these drawbacks, the material was excellent. Most of it was below optimum moisture content. Scarifying was required before the borrow pits could be irrigated, and some sprinkling was also done on the fill.

Before placing the fill, careful and expensive site preparation was required. The river was diverted through a 32 foot horseshoe tunnel in the left bank. Overburden was removed to rock over the whole foundation area. The rock profile after this operation included a number of steps with nearly vertical faces. These faces followed the vertical jointing in the lava flows. The river ran in a deep notch, cut into a layer of breccia. To eliminate the possibility of differential settlements in the rock fill, which might have produced cracks in the stiff impervious material, all these steps were eliminated in the vicinity of the impervious layer, and for some distance downstream. This was done by carrying out a major slashing operation on the walls of the notch, and minor slashing at higher elevations. In some places, the vertical jointing was so pronounced that it was difficult to slash back to a sloping face without shattering the rock, so some of the short vertical pitches, especially under the impervious layer, were faired out by pouring concrete against them. A concrete pad was also placed in the river-bed under the impervious layer, to fill a large hole in the bed, where earth fill could not be properly compacted. This is shown in the transverse section, Fig. 2.

There is a pronounced break in slope where the slashed slope of the former canyon meets the original rock surface. This break was rounded off, but since it was still the point at which maximum differential settlement was possible, an extra filter layer of ¾ inch to 1½ inch was inserted between the sand and gravel layers in this vicinity. Possibility of cracks in the impervious layer was further reduced by giving the whole dam a camber upstream, so that settlement would tend to compress the impervious layer. The crest is crowned to allow for vertical settlement.

Before starting to place the fill, the last step in the site preparation was to hand-clean and gunite the area the impervious layer was to rest on, and to grout the rock beneath. The gunite provided a good surface against which the impervious material could be compacted effectively, and also helped to spread the low pressure grout laterally. After low pressure grouting to a depth of 30 feet, deeper grout holes were bored to a maximum depth of 125 feet and grouted at higher pressures. This technique was considered better than using packers, because it avoided any trouble with eruptions of grout or "popout" of rock. The rock was, in places, prominently jointed, and there were also voids and lenses between lava flows to contend with.

The placing of fill was a fairly routine operation, with the main emphasis on volume. Nearly four million yards of materials were placed in six months. Quarry rock was obtained by coyote hole

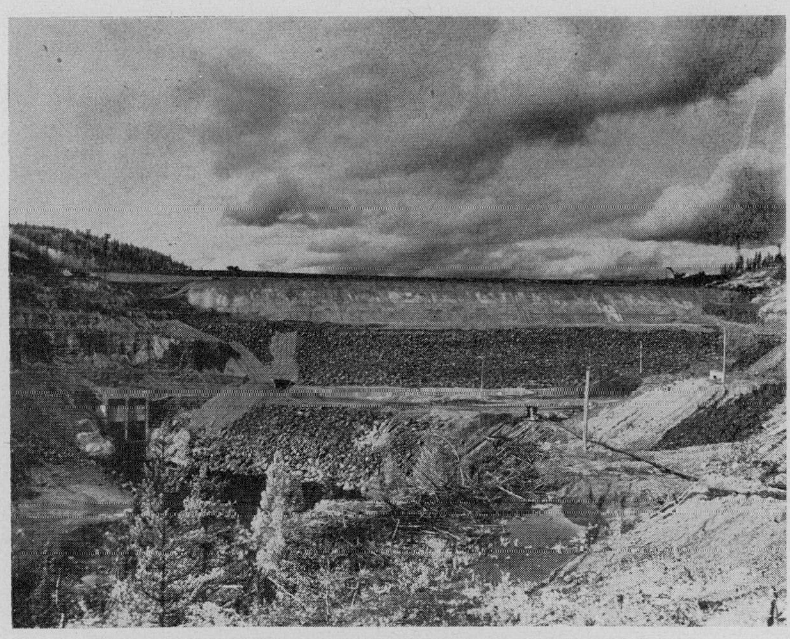


Kenney Dam—Equipment Working on Impervious Layer.

blasting. The quarry was located on the side of a prominent outcrop of basalt on the left bank. This rock is extremely hard, although some of it is vesicular, as would be expected. There was a good deal of waste from the quarry—not from the blast zones, but from weathered zones in the rock. The waste consisted mostly of loads of dirt with some rocks in them, and where there was an appreciable amount of sound rock in the waste, it was hauled to a segregation pile near the quarry and dumped. Most of the sound rock rolled down to the foot of the dump, and was recovered and hauled to the dam.

As the construction season wore on, there was a possibility that the weather would turn cold before placing of the impervious material was finished. After some experiments, it was found that, by the addition of common salt to the impervious material, it could be rolled satisfactorily at temperatures as low as minus 5°F, and would meet specifications in every respect. A stockpile of impervious material containing salt was prepared. The warm weather held out, and this prepared material was used on only one or two shifts, when the temperature was low enough to give the inspectors an excuse. There seems to be no doubt that this device would be successful in similar cases, if the need arose.

The gates of the diversion tunnel were closed in October 1952, and the four to five year filling period commenced. There is neither spillway nor outlet at the dam, and the entire flow of the river is being used to fill the reservoir. The spillway is a concrete structure, founded on rock, with two gates 35 feet wide by 35 feet deep, and a 70-foot fixed crest at pool level, located at one of several low saddles on the north rim of the reservoir. The other saddles are closed by earth dams.



KENNEY DAM, BEFORE CLOSURE OF DIVERSION TUNNEL GATES.

Spilled water will return to the Nechako River via the Cheslatta River, a tributary which enters a few miles below the dam.

Fortunately, there is a lake system thirty miles long on the Cheslatta River, and the district is practically uninhabited. The spillway discharge will be allowed to find its own way downstream. We have bought up all the land that will be affected, and provided local protection works to guard against erosion at the spillway. For the rest, the spillway discharge will cut its own channel, depositing the eroded material in the form of deltas in the lakes.

At the western end of the reservoir is the intake to the main tunnels, which will carry the water to the powerhouse. There will ultimately be two parallel tunnels of about equal capacity. Only one of these tunnels is being built at the present time, but the intakes for both are being built as one structure. This is a concrete tower, with a 14 x 26 foot fixed wheel gate for each tunnel. The No. 1 tunnel invert is 15 feet lower than the No. 2, to permit deeper drawdown of Tahtsa Lake during the reservoir filling period. The gates will be powered by engine-driven generators, but can be closed with power off.

The intake is being built in a hole excavated in an alluvial fan, which was just above lake level. A low dyke was built above the level of the fan. The fan comes from a steep mountain creek, and is therefore mostly of coarse materials. Some talus is also present. The tunnel intake excavation is kept dry by an extensive wellpoint system, supplemented by sump pumps.

No. 1 tunnel is designed to carry 3500 c.f.s., which is the discharge required to run eight powerhouse units at their expected long-term firm output. Tunnel costs were balanced against the value of power lost through friction at this discharge. Since the load factor on the plant is virtually 100 per cent, most of the energy will be generated with the design discharge flowing through the tunnel, when eight units are installed. The tunnel is, however, located low enough so that it can safely discharge 4500 c.f.s., which is the full-gate discharge expected from eight units. At the discharge end of the tunnel, a surge shaft has been driven to the surface at an elevation 50 feet above pool level. The surge discharge will be wasted. With the high load factor, the value of water lost during surges is negligible.

The hydraulic design of the tunnel was based on a nominal 25-foot horseshoe section, with the invert paved with concrete. Ten per cent of the length was assumed to be lined for structural reasons to a

22-foot 6-inch horseshoe, and ninety per cent to be unlined, with a 9-inch overbreak. Actual performance on the job differs from this assumption considerably. Overbreak in unsupported tunnel, which will remain unlined, has averaged 11 inches. As of Nov. 1, 1953, with 98% of the 53,100-foot tunnel length excavated, 23.5% of the driven length was supported; some of which is designed for lining to 19-foot diameter. In the eastern half of the tunnel, a modified section 22′-6″ wide x 25′ has been used part of the way. All these changes were brought about by rock conditions discussed later.

The tunnel is driven on a slope of .0025 downhill from the reservoir, as shown in Fig. 3. There are four main headings—one reached

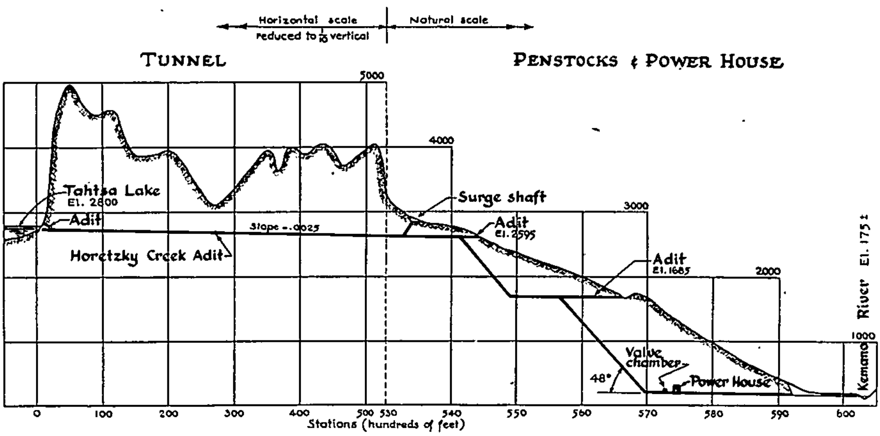


FIG. 3.—LONGITUDINAL SECTION OF TUNNEL AND PENSTOCK SYSTEM.

from each end, and two from the midpoint. At the Tahtsa Lake end access to the tunnel was obtained by driving an adit downhill from above lake level on a grade of 4½%. This adit was driven at an angle to the direction of the tunnel. From the adit intersection the heading was driven back to within about 100 feet of the portal location at the intake. The remaining distance was driven from the surface after excavation of the overburden at the intake had been completed. This work was carried out at the same time as the advance of the main heading to the west.

The geology of the tunnel and powerhouse area is complicated in detail, but broadly speaking the powerhouse, penstocks, and western part of the tunnel are in a granodiorite batholith, while the eastern part is in older volcanic rocks, much altered and fractured by the batholithic intrusion. The batholithic rock, although hard, makes for much better tunnel driving. It needs very little support, and there have been no water troubles of any consequence. The older extrusives are not so kind to us. There has been a lot of raveling of schistose rocks, and general weakness of the rock structure has forced the contractor to put in a lot more support than was originally expected.

The Tahtsa Lake heading advanced slowly for about 1400 feet from the adit intersection, requiring almost continuous support. The ground then became so difficult that a 16′ x 18′ pilot drift was pushed ahead for a further 700 feet. A good deal of this distance was driven unsupported, and after some changes a revised section of 21′-6″ was adopted, with intention of lining to 19 feet for hydraulic reasons. After about 3700 feet of driving, a complete review of the tunnel hydraulics was made, in the light of conditions then known to exist. This indicated that a 22 foot 6 inch x 25 foot size could be used for some distance, without reducing the tunnel capacity below design figures, assuming some lining for structural support. This size has been used for a total of 8300 feet, mostly in the Tahtsa heading.

It appears that there will be very little lining needed for hydraulic reasons, above what is required for structural support. In good rock, lining does not pay for itself. It is cheaper to reduce friction losses by driving a bigger tunnel than by lining. One exception is the invert paving, which is much cheaper per square foot than wall or archlining, and which also saves the cost of invert clean-up. As noted above, the invert of this tunnel is to be paved throughout.

The two headings working from the centre of the tunnel length towards the ends are reached by a short horizontal adit, driven at the point where the Horetzky Creek valley, which parallels the western half of the tunnel location, reaches tunnel grade. The adit is served by a road running up Horetzky Creek from the powerhouse location. It will be plugged close to the present tunnel, and can be used to drive the second tunnel at a later date.

There is one other heading in the tunnel, reached by an adit driven into the mountain above the powerhouse location. This adit is served by a cableway running up the mountain slope from a point near the powerhouse. This heading has been the easiest of all to drive. Most of its length is in the granodiorite of the batholith. It has required almost no support, and has progressed at a continuous average of over 200 feet per week. The best week's progress on a heading—282 feet in 18 shifts—was made in the heading driven west from the Horetzky Creek adit, but the Kemano heading, as the one reached from the powerhouse is called, has been the real money saver.

Just downstream from the surge shaft, the No. 1 tunnel splits into two 11-foot diameter conduits, with a butterfly valve in each. From this point, the penstock system shown in Fig. 3 starts. The penstocks were excavated by driving pilot raises from the powerhouse level, and from an adit at Elevation 1685. The pilot raises were roughly 5 feet by 10 feet, and were equipped with a bulkhead dividing the raise into two 5′ x 5′ compartments. The lower compartment was used as a chute, and the upper as a manway. After completion of the pilot raise, the bulkhead and manway were stripped, and the pilot raise slashed to full size, working downwards from a jumbo.

In order to have the blasted rock flow easily down the raise, the penstock is driven at an angle of 48° to the horizontal. A minimum rock cover equal to 40% of the head, including surges, was specified. To maintain this cover, it was necessary to include a short horizontal run in the penstock at the 1685 level.

The penstock is equipped with a steel liner throughout, although the rock will carry much of the bursting stress from the water pressure. The liner varies from 9/16 to 2½ inches in thickness, in the 11-foot diameter section.

The rock excavation was slashed to 15-foot diameter, to take the 11-foot I.D. liner. The liner sections arrive at the job as cylinders, up to 28 feet long depending on the weight. These cylinders are butt welded together in pairs by an automatic machine before being taken underground. The double-length cylinders are lowered into place, and are joined up by butt welds made by hand from the inside of the pipe. Two drain pipes are installed in the space between the liner and the rock to carry off ground water and possible leakage from the penstock. The balance of the space is then filled with gravel and grouted from inside the liner with a non-shrinking mixture, to form a concrete backing for the liner. Holes with threaded plugs are provided in the liner, and after the backing concrete has set, the plugs can be removed for additional pressure grouting behind the backing, if necessary. The plugs would then be replaced and welded over. Similar plugs close holes which give access to the drain headers for drainage during construction.

In due course, I hope this penstock will be the subject of a complete technical paper by those responsible for it. The job merits a much more detailed description than can be given in a general discussion such as this.

Each penstock, after descending to the powerhouse level, splits into four branches, each branch serving one unit. On each branch there is a 51-inch double-seal sphere valve, installed in the valve chamber shown in Fig. 4, which shows the excavation pattern in the

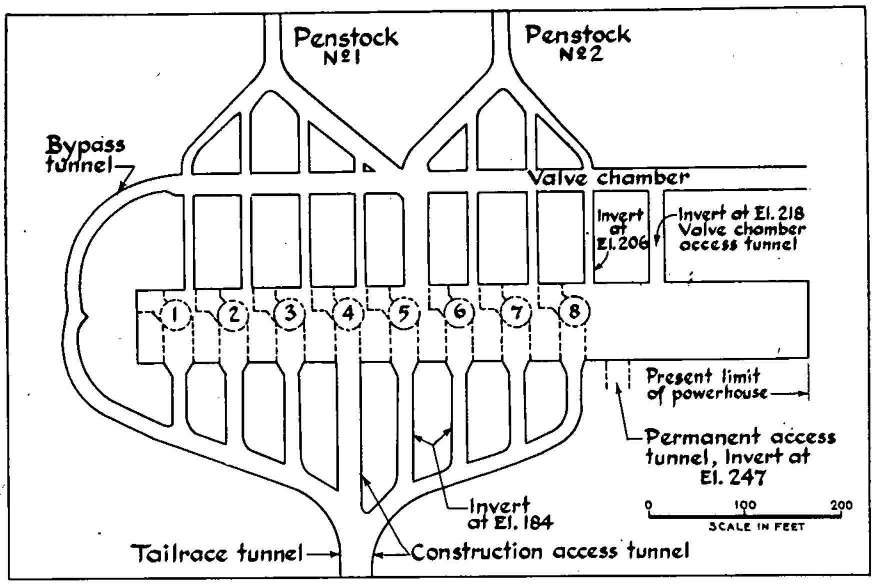


FIG. 4.—PLAN OF PENSTOCK AND TAILRACE MANIFOLD SYSTEM.

vicinity of the powerhouse. The sphere valve is reached by tunnel from the powerhouse, and is provided with an emergency by-pass tunnel discharging to the tailrace, in case of accident. The branch penstocks continue to the powerhouse as five-foot diameter pipes, and are concreted into individual drifts. There is one thirty-foot length which is not concreted, and is provided with Dresser couplings at each end, to allow for differential movement.

The powerhouse proper is an excavation in the rock, which will ultimately contain sixteen units, eight banks of transformers, a control and service bay, and, of course, all the auxiliary equipment necessary to the operation of the station. It will ultimately be 1100 feet long, but initially only 700 feet of it is being excavated.

The present length is connected to the surface by a tailrace tunnel, a tunnel for the high-voltage cable, and an access tunnel. The first two will be duplicated when the powerhouse is lengthened to its ultimate size. The roof of the powerhouse is lined with a concrete

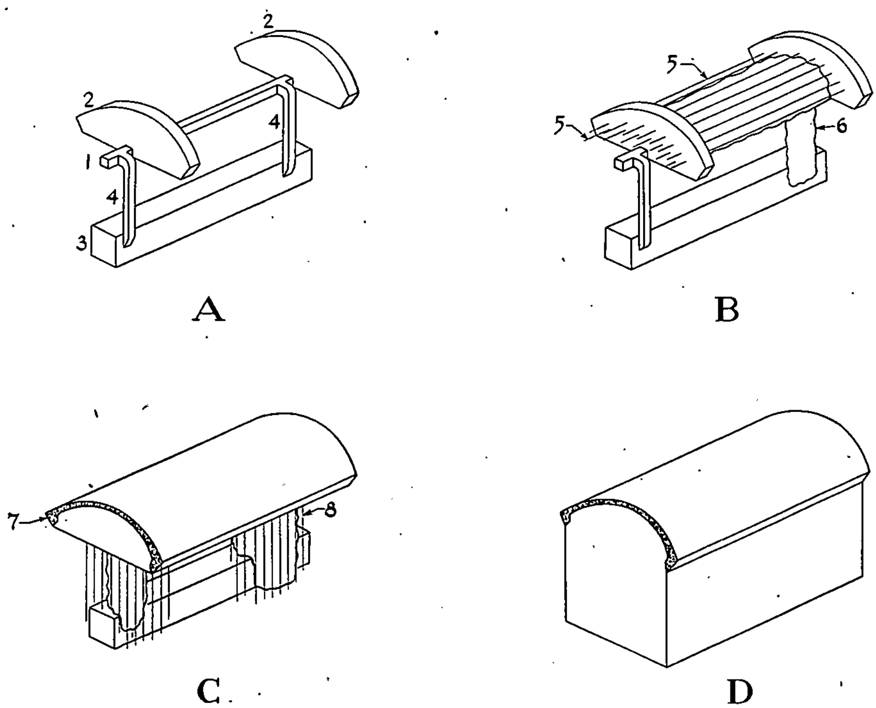


FIG. 5.—DIAGRAM SHOWING METHOD OF EXCAVATION FOR MAIN BLOCK OF POWERHOUSE.

A First stage, showing:
(1) Top centre drift, excavated from exploratory tunnel.
(2) Slots.
(3) Haulage drift, leading to tailrace tunnel.
(4) Transfer raises.

B Second stage. Arch section partially excavated, by long hole drilling (5) and blasting. Muck dumped to haulage drift through enlarged transfer raise (6).

C Third stage. Concrete arch lining (7) placed after completing arch excavation. Block being excavated by enlarging transfer raises, using vertical long holes (8).

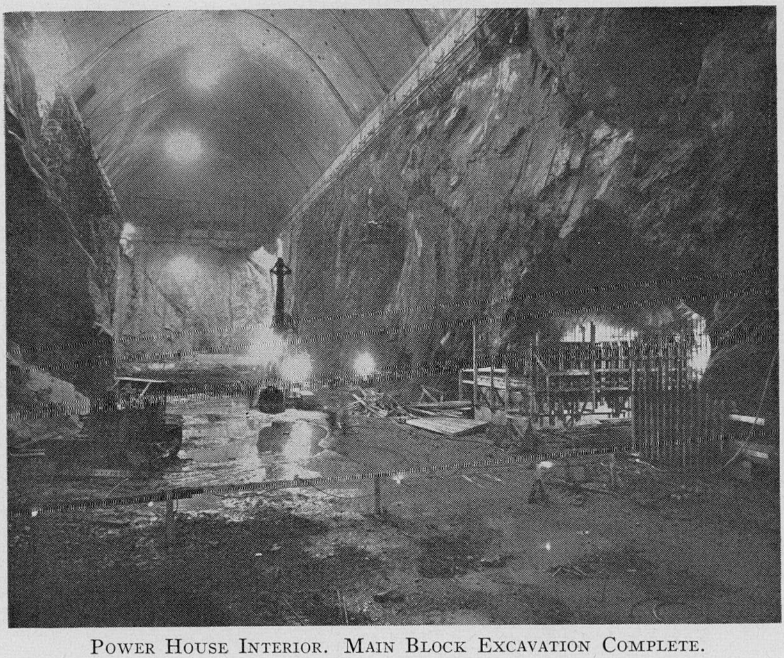
D Main block excavation complete. Wheel pits excavated later, below the floor of the main block.

arch, but the walls will have no structural support, except that provided incidentally by the beams of the floor system around the units.

In excavating the powerhouse, an exploratory drift was driven into the powerhouse location, at the elevation of the spring line of the roof arch. The tailrace and access tunnels were advanced at the same time. The subsequent steps in the excavation of the main block are shown in Fig. 5, which is self-explanatory. Below the floor of the main block are the wheel pits, each connected to the tailrace by a short tunnel.

The trickiest part of the powerhouse excavation was trimming the main block to the neat lines of the design. The granodiorite rock is cut by several joint systems, which intersect the powerhouse walls at an acute angle. There were a number of potential slip planes, especially on the upstream wall.

The neat line blasting was done with extreme care, and when it was completed, doubtful rock areas were secured by pinning. There were some places where slips occurred before pinning was complete, which damaged construction equipment and delayed completion of the excavation. At several points where some of the many tunnels



Power House Interior. Main Block Excavation Complete.

enter the powerhouse, some overbreak occurred, and heavy concrete arches were poured at the portals to secure the roofs of the tunnels. In other places, buttresses of rock were left inside the powerhouse neat lines until neighbouring rock was secured.

The completed powerhouse is shown in cross-section in Fig. 6. At present, three of the ultimate sixteen units are being installed.

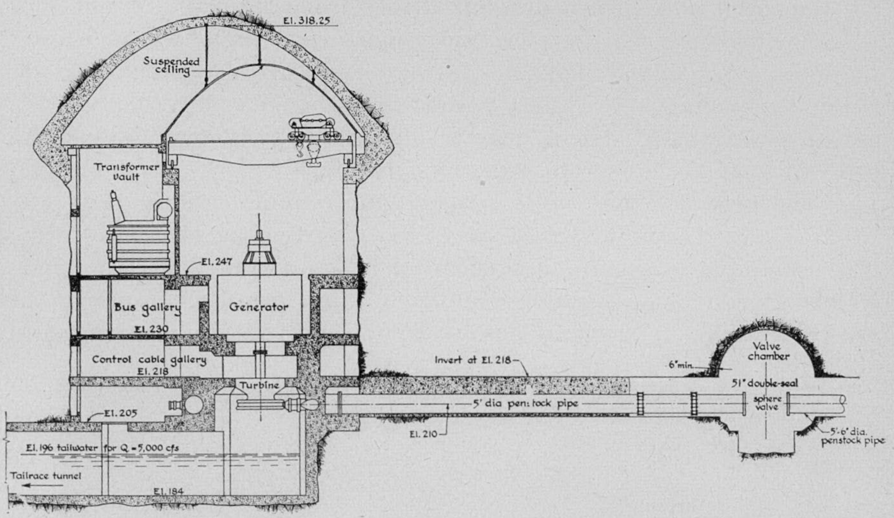


FIG. 6.—CROSS-SECTION OF POWERHOUSE ON UNIT CENTER-LINE.

Each unit consists of a four-jet impulse turbine of 140,000-150,000 h.p. capacity, driving a 106,000-122,000 KVA generator. The lower ratings are the amounts guaranteed by the suppliers, and the higher ratings are probable maxima, with lower efficiency and higher than normal wear on the machines. For each pair of units there is one bank of transformers, located in vaults within the powerhouse chamber. From the transformers, the electricity is carried to the surface through insulated cables located in the cable tunnel mentioned previously.

The transmission line, although not unusual in length, is carried through extremely rough country. For a few miles, it goes up the valley of the Kemano, then climbs over a mountain pass 5,300 feet high, and drops down into another river-valley. The route from this point to Kitimat, although it offers many difficulties, is not much different to other mountain transmission lines. For that reason, this discussion will focus on the ten-mile "pass section" where the steep grades, heavy snowfall, and icing conditions produce problems which may well be unique.

The first step was to build a road over the route. The steepest parts are passable only to heavy four-wheel drive vehicles and crawler-mounted equipment, and the road can be kept open for only about three months of the year, although crawler equipment can be operated to some extent over the snow for another month or so. Only two tower lines could be built in the available space, and it was decided to use single-circuit towers, with a power loading of 600,000 KW per circuit. The conductors used are the largest A.C.S.R. sections ever made, being $2\frac{1}{4}''$ in diameter, with an ultimate strength of 135,000 lbs. For one line of towers conventional, but extremely heavy, steel towers are used. For the other circuit, a design has been developed in aluminum. The cross-arm is an aluminum plate girder, supported at two points, like the top arm of the Greek letter π. Each support point is at the apex of a pair of aluminum tubular legs, and at one support point

Transmission Line Route in Winter. Helicopter at Tower Site.

there is an inclined transverse bracing leg. It is expected that when these towers are completed and tested in service, the designers will publish a complete report on them.

For both tower lines, the conductors are sagged to carry a live vertical load of 40 lbs. per linear foot at the breaking strength of the conductor. Towers are designed to carry an ultimate load equal to any possible combination of conductor loads, together with live loads due to wind, ice, and snow creep on the tower itself. Prototypes of both the steel and aluminum towers were tested to destruction.

In constructing the line, there were some tower sites that could only be reached by helicopter. The usual procedure in such cases was to land some men and equipment on the spot, and set up a high line to bring the heavier tower materials up. The stringing of the conductors has followed tower erection closely during the 1953 season, but neither job is complete as yet.

The transmission line terminates at the smelter location, on the delta of the Kitimat River. The delta occupies the entire width of a

KITIMAT SMELTER SITE.

valley about two miles wide. As is usual in such cases, there is a wide tidal flat in front of the delta, running out to extreme low water level, then dropping fairly steeply to deep water. Above high water, there was a heavy growth of timber. The delta contains the usual sand and silt deposits, but there are coarse sands and gravels mixed in with them. The coarser materials come partly from low alluvial fans deposited by two side creeks which come down the mountain slopes close to the sea front, and partly from the main river, which flows on a grade of 20 to 40 ft. per mile, and carries a heavy bed load of gravel when it is in flood.

It was decided to locate the smelter close to the mountain wall on the western side of the valley, well away from the present river mouth. The location is partly on the fans from the two side creeks, and partly on the river delta proper. The first problem was to locate the harbour facilities required for ocean shipping. It was decided to dredge a cut through the tidal flat, and to build the wharf along one side of the cut, as shown in Fig. 7. A temporary wooden wharf was first built beyond the tidal flat, on the west shore of Kitimat Arm, to

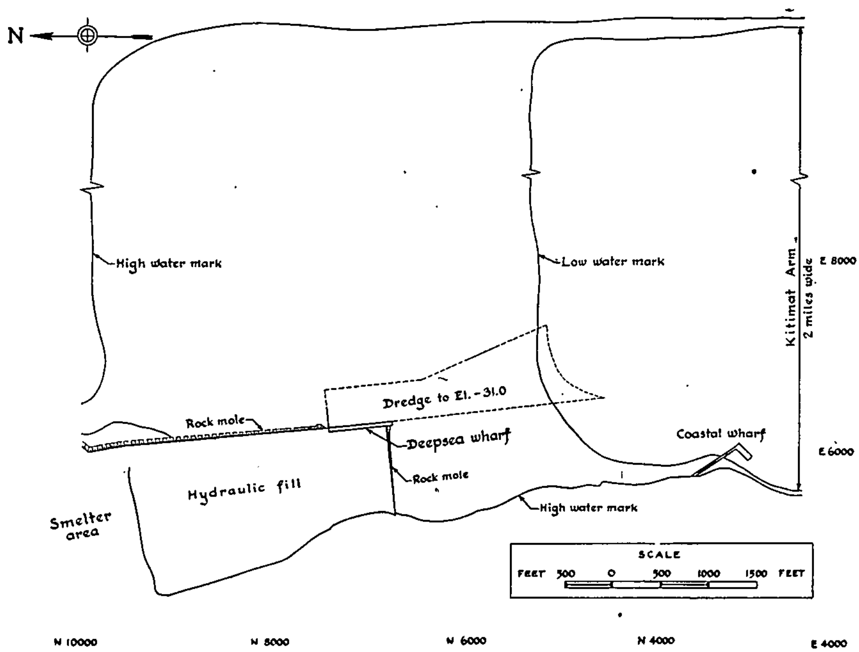


Fig. 7.—Plan of Kitimat Harbor.

serve construction forces, and to look after coastal traffic after construction is finished.

The dredged material has been used to reclaim part of the tide flat, being confined by the wharf and by rock moles. This area will be used for storage, but no important buildings will be built on it in the next few years, because settlements are not expected to be uniform.

In dredging the cut, some very silty material was wasted, but most of the time the suction dredge worked in sand, with some gravel, and some silt. The two rock moles were built first, and joined by a temporary dyke running behind the ultimate wharf location to retain the pumped material until the wharf was in place.

The wharf consists of three concrete caissons, floated into position and scuppered on a carefully levelled bed of crushed rock in the bottom of the dredge cut. A cross-section of the completed wharf structure is shown in Fig. 8. The concrete caissons, each 250 feet in

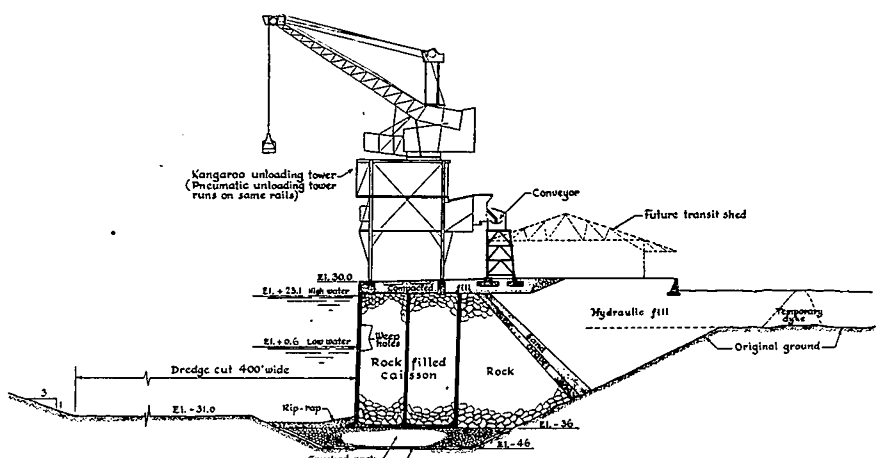


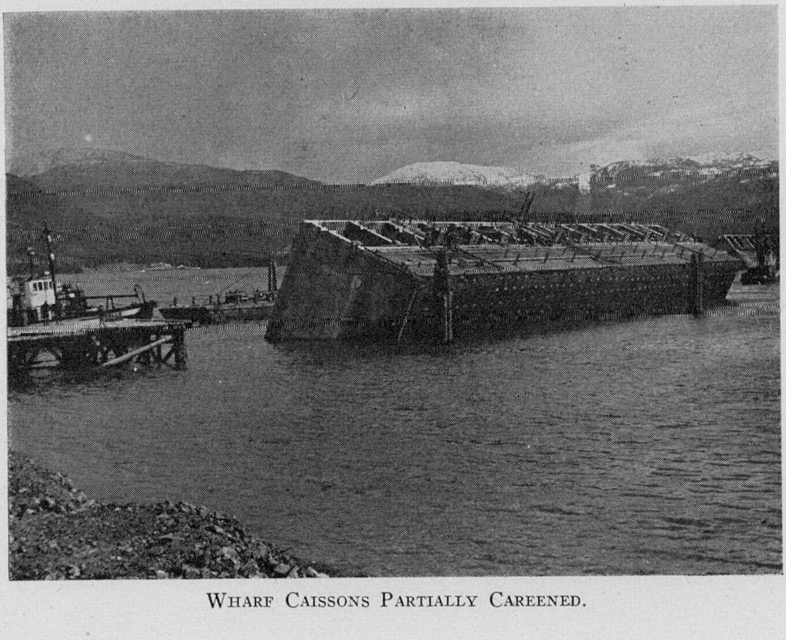
FIG. 8.—CROSS-SECTION OF KITIMAT WHARF.

length, were cast in an excavation near the shoreward end of the tide flat. A low dyke was built around the excavation, and it was kept dry by a wellpoint system.

In order to minimize excavation and dewatering costs, the caissons were built on the flat, with the ultimate wharf face uppermost. In this position, careful attention could be given to the finish of the wharf face, which will be subject to freezing and thawing action as well as exposure to salt water.

The caissons are divided by transverse bulkheads, which will support crane rails, tracks, and other superstructure loads, and by a longitudinal bulkhead. In the "as cast" position, with the caissons on their side, the longitudinal bulkhead was poured as a slab. Between the transverse bulkheads, two temporary wooden bulkheads were built vertically, one to close the open side (the ultimate top of the wharf) up to the longitudinal bulkhead, which was high enough to float the caissons, and one down the centre line to divide the caisson into cells, so that the caissons could be careened after being floated out.

There was a good deal of honeycomb in the thin transverse bulkheads, particularly around weep-hole forms and other tight spots. After the forms were stripped, defective areas were chipped out and repaired with gunite. When the repairs were complete and the wooden bulkheads in place, the excavation was allowed to fill with water and the seaward wall was breached. The caissons were towed out on two extremely high tides, and partially careened by pumping water into the appropriate cells. This partial careening lifted the wooden bulkheads out of the water, and reduced the danger of leakage.



WHARF CAISSONS PARTIALLY CAREENED.

One at a time, the caissons were taken to their final location, where careening was completed, and they were carefully sunk in place between guide piles. Some minor adjustments of position were made by partially refloating, and when the position of all caissons was approved, they were filled with rock. The wharf face has two rows of weep holes in it, to permit free ingress and egress of tidal water, and the rock filling is highly pervious, for the same reason. The weep holes were closed by wooden plugs during the floating and careening operation.

The final operation on the wharf construction was to fill the area behind the wharf. A dumped rock and gravel fill was placed next to the caissons, and the balance of the hole between the wharf and the dyked hydraulic fill was filled by bringing back the suction dredge and pumping in more hydraulic fill.

On the wharf dock are two railroad tracks, and a pair of crane rails for the unloading towers, which straddle the railroad tracks. One unloading tower carries a Kangaroo crane which can be used with either a cargo hook or a clamshell to handle a wide variety of cargoes. The other tower is equipped with a pneumatic unloader, specially designed for high speed discharging of bulk aluminum oxide.

While the dredging and wharf construction were proceeding on the waterfront, the smelter was starting to take shape ashore. The main feature of the smelter is the row of buildings housing long lines of reduction cells. These buildings must be on a site which is level in both directions. It is also desirable to have a low water table, to avoid excessive leakage currents. Since the chosen site is on the two low alluvial fans mentioned earlier, a fill of 1,800,000 cubic yards was required, to level the area. The maximum depth of this fill is 30 feet.

It was realized that placing a fill of this weight on a thick layer of delta materials involved the possibility of serious settlement. The time schedule did not permit the fill to be placed soon enough so that most of the settlement could occur before building construction was started, so initial grades were based on a settlement forecast. This forecast was on the low side, particularly in one part of the area. It is only fair to the forecasters to point out that there was not time for as complete a programme of foundation exploration as they would have liked. In many places, it was necessary to raise previously placed concrete footings, and to reset anchor bolts. However, this was much cheaper than delaying the whole programme of smelter construction and trying to rush it at the last. There is only one group of tall buildings on the site, and the steel frames of these buildings have been built slightly off plumb to allow for an expected tilt due to differential settlement.

There is nothing unusual about the smelter buildings, but it is worth mentioning that the number of repetitions in these very long buildings favored extensive use of pre-cast concrete for walls, columns, and some of the many ducts required. The upper walls and roofs of the main buildings are steel framed, clad with aluminum sheet.

In this area, remote from any habitation, a complete town had to be built to house smelter workers and their families, as well as commercial, professional, and government workers. The town will ultimately house up to 50,000 people, and the planning of this community in a wilderness has been a task of the utmost importance and difficulty. There have been few outstanding civil engineering problems in the town, and its planning is a story which lies outside the scope of this paper, but no account of the Kitimat project as a whole should close without mentioning the town briefly.

The town lies on the slope and crest of a low ridge which crosses the Kitimat valley about two miles up from the river mouth. It will be separated from the smelter by a deep belt of trees, and by the Kitimat River, which was bridged during 1953. It is laid out on the neighbourhood system, with main traffic routes by-passing the residential districts, and the business centre located on the edge of town nearest to the smelter. Generous provision for parks and greenbelts has been made, and the design allows for easy disposal of the annual snowfall of 20 ft. The planning was done by consultants engaged by the Aluminum Company of Canada, but its implementation is in the hands of an elected municipal government.

The Kitimat project is scheduled to go into operation in the spring of 1954, only three years after the start of construction, and only five years after an active start was made on the engineering work. It will be obvious that to uncover and solve in that time the many problems connected with the works described in this paper required the skills of many engineers, working for the owners and for consultants and contractors. This paper is a report of some of their work. Many parts of it will undoubtedly be the subjects of full reports by the people best qualified—those who were directly responsible for the design and construction. In the meantime, in acknowledgement to some of them, I have prepared Table II, which lists consultants on

TABLE II

Consultants Engaged on the Kitimat Project

Consultant	*Location*	*Responsibility*
British Columbia International Engineering Company	Vancouver, B.C.	Overall design of power facilities
Dr. K. Terzaghi	Winchester, Mass.	Consultation on Kenney Dam and saddle dams
Dr. A. Kaech	Switzerland	Penstock arrangement
Aluminum Laboratories Limited	Montreal, Que.	Design of aluminum transmission towers
		Consultation on other features
F. R. Harris & Co.	New York, N.Y.	Consultation on wharf design and construction
Mayer & Whittlesey	New York, N.Y.	Town planning at Kitimat
Swan, Rhodes & Wooster	Vancouver, B.C.	Design of townsite structures and utilities

more important parts of the work. For the owners, the Aluminum Company of Canada, the project is under the direction of Mr. P. E. Radley, as Project Manager. Mr. W. L. Pugh, as Chief Engineer, is responsible for the design of smelter and harbour facilities. British Columbia International Engineering Company is represented by Mr. W. G. Huber, Vice-President and General Manager. Mr. Pugh and Mr. Huber have checked this manuscript, and their assistance in eliminating errors is gratefully acknowledged.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

OCTOBER 14, 1953.—A Joint Meeting of the Boston Society of Civil Engineers with the Northeastern Section of the American Society of Civil Engineers and the Structural Section of the BSCE was held this date at Tufts College, Medford, Mass. Members of Student Chapters and Civil Engineering Students of the New England Colleges were especially urged to attend.

A catered dinner was held in Cousens Gymnasium, Tufts College from 6:00 to 7:00 P.M. Student delegations were present from Tufts College, Northeastern University, Massachusetts Institute of Technology, Brown University, University of Rhode Island and the University of Massachusetts.

Following the dinner President Ginder presented a Trio of Northeastern University Students who sang several numbers to the delight of all present.

President Ginder called the meeting to order at 7:30 P.M., and extended a cordial welcome to the students and expressed appreciation of the cooperation of the officers of the student organizations and of the faculty members in making this event so successful.

President Ginder called upon the Secretary to announce the names of applicants for membership in the B.S.C.E.

The Secretary also announced that the following had been elected to membership:

Grade of Member.—Bruce P. Eaton, David H. Hamilton, Robert L. Meserve.

Grade of Junior.—Richard W. Amon, Leon A. Antosh, David P. Bell, Stanley P. Belonos, Earl H. Christopher, Joseph M. Costanza, Robert V. Costello, Kenneth W. Henderson, Henry E. Lesser, John P. Mogan, Dante F. Montuori, Herbert D. Nickerson, Cesareo Perez, Gino P. Perrotta, John W. Singarella, Deane F. Tolman, Richard G. Walsh, Victor H. Weidman, John H. Williams.

President Ginder introduced Howard M. Turner, President of the Northeastern Section of the American Society of Civil Engineers and asked him to conduct any necessary business for ASCE at this time.

President Ginder called on Mr. C. J. Kray, Clerk of the Structural Section to conduct any necessary business for that Section at this time.

President Ginder then introduced the speaker of the evening Prof. Abel Wolman, of Johns Hopkins University who gave a most interesting talk on "The Engineers' Responsibility with Respect to Natural Resources".

Two hundred sixty members and guests attended the dinner. Two hundred seventy five attended the meeting.

The meeting adjourned at 8:45 P.M.

ROBERT W. MOIR, *Secretary*

November 18, 1953.—A Joint Meeting of the Boston Society of Civil Engineers with the Structural Section, BSCE was held this evening at the American Academy of Arts & Sciences, 28 Newbury Street, Boston, Mass., and was called to order by President Chester J. Ginder, at 7:10 P.M.

President Ginder stated that the Minutes of the October 14, 1953 meeting would be published in a forthcoming issue of the Journal and that the reading of the minutes therefore be waived unless there was objection.

The President announced the death of the following members:

Erastus Worthington who was elected a member September 21, 1887 and who died October 17, 1953.

Everett N. Hutchins who was elected a member May 21, 1924 and who died October 26, 1953.

The Secretary announced the names of applicants for membership in the BSCE.

The Secretary announced that the following had been elected to membership:

Grade of Member.—Roger C. Collette, James W. Chilson, Jerome Degen, Nelson W. Gay, William R. Hooper, Charles A. Knapp, Alice M. Lichwell, Kenneth A. Lucas, Raymond C. Pressey, Yale Shapiro.

Grade of Student.—Gino N. Cosimini, Paul R. Bowser, Wendell B. Strum, Joseph J. Breen, Richard D. Howard.

President Ginder announced that this was a Joint Meeting with the Structural Section and called upon C. J. Kray, Clerk of that Section to conduct any necessary business at this time.

President Ginder then introduced the speaker of the evening Mr. J. S. Kendrick, of the Aluminum Company of Canada, who gave a most interesting illustrated talk on "Civil Engineering Features of the Kitimat Project."

A short discussion period followed after which the President announced that a collation would be served in the Lounge on the floor above.

A rising vote of thanks was given the speaker.

One hundred members and guests attended the meeting.

The meeting adjourned at 9:05 P.M.

Robert W. Moir, *Secretary*

SANITARY SECTION

October 7, 1953.—A meeting of the Sanitary Section was held at 7:00 P.M. at the Society Rooms after an informal dinner at Patten's Restaurant. Forty-eight members and guests attended the meeting. Nineteen members and guests attended the dinner.

Chairman John S. Bethel, Jr. presided. Chairman Bethel announced that Mr. Richard Gould will discuss Recent Developments in Sewage Treatment in New York City at the December 2 Section Meeting and that Mr. Frank Flood will give a paper on the Los Angeles (Hyperion) sewage treatment plant with a discussion by Prof. Clair N. Sawyer at the Joint Meeting with the Society on January 27, 1954.

Mr. Chester J. Ginder, Construction Division, Metropolitan District Commission, presented a paper on the design and construction of the "Alewife Brook Conduit and Pumping Station." This interesting paper included descriptions of new remote pump control equipment.

The meeting adjourned at 8:20 P.M.

Ariel A. Thomas, *Clerk*

December 2, 1953.—Chairman John S. Bethel, Jr., called the Meeting to order at 7:05 p.m., at the Society Rooms after an informal dinner at Patten's Restaurant. Sixty-seven members and guests attended the Meeting. Thirty-one members and guests attended the dinner.

Chairman Bethel announced that Frank Flood will present a paper on the

Los Angeles (Hyperion) Sewage Treatment Plant at a Joint Meeting being arranged by the Society on January 27, 1954. This paper will be discussed by Professor Clair N. Sawyer. Chairman Bethel also announced that the Annual Meeting of the Sanitary Section will be on March 2, 1954, at which time a panel consisting of Professor Leslie Silverman, Charles R. Williams, and Richard Dennis will discuss Air Pollution.

A nominating committee consisting of:

Frank L. Heaney, Chairman
William E. Stanley
Fozi M. Cahaly

was elected and directed to present a slate of Officers and Members of the Executive Committee to the Section at the Annual Meeting on March 2, 1954.

Mr. Richard H. Gould, Director of Sewage Disposal, Department of Public Works, New York City, presented a paper titled, "Recent Developments in Sewage Treatment in New York City." His challenging paper covered sludge thickening, sludge digestion, and variations of the activated sludge process.

The Meeting adjourned at 8:10 P.M.

ARIEL A. THOMAS, *Clerk*

STRUCTURAL SECTION

NOVEMBER 18, 1953.—A joint meeting of the Boston Society of Civil Engineers and the Structural Section was held at the Academy of Arts and Sciences at 7:00 p.m.

The President of the Boston Society of Civil Engineers, Mr. Chester J. Ginder, introduced the speaker who was Mr. J. S. Kendrick of the Aluminum Company of Canada.

Subject of the illustrated talk was "Civil Engineering Features of the Nechako-Kitimat Project" for the ultimate installed capacity of 2,240,000 H.P.

The following problems were called to the attention of the audience:

1. Selection of the site and construction problems of rock and clay Kenney Dam 317 ft. in height (volume 3,700,000 cubic yards) providing reservoir capacity of 20,000,000 acre feet and reversing the flow of the Nechako River.
2. Ten (10) miles of tunnel 25 feet in diameter, constructed through solid rock to the power house, descending in an unusual drop of 2600 feet.
3. Underground Powerhouse built in rock, size 1100′ x 80′ x 135′ high with 16 jet impulse turbines and 16 generators.
4. 287 KV transmission line 48 miles long supported on huge towers erected in rough and inaccessible terrain with terrific variation in elevations carrying the current to the aluminum plant. The unusual size of the Aluminum Conductors used is 2.295 inches in diameter, reinforced with a steel core.
5. A dangerous access road on extremely steep grades with very small curves.
6. Aluminum plant buildings of Reinforced Concrete precast construction being erected on fill, waterfront structures with unloading and loading facilities.
7. Housing Developments and City Planning.

The audience acknowledged the excellent talk by raising a vote of thanks to Mr. Kendrick.

Ninety-eight members were in attendance. Collation was held after the meeting.

C. J. KRAY, *Clerk*

NOVEMBER 20, 1953.—A meeting was held at 1:30 P.M. to inspect the construction of the Boston Central Artery Project in the area of the North Station.

Dr. Charles H. Norris, Chairman of the Structural Section introduced Mr. E. W. Kumpel, District Engineer, Massachusetts Department of Public Works, who gave an account of the general interest in the construction of the Central Artery.

Details of design and construction of viaduct, ramps and a two-deck bridge over the Charles River were viewed and discussed.

Mr. Kumpel conveyed to the Members of the Structural Section information on construction cost, details of construction and behavior of roadways on bridges under his supervision in the District.

Forty-two (42) members were present.

C. J. KRAY, *Clerk*

HYDRAULICS SECTION

NOVEMBER 4, 1953.—The Hydraulics Section of the Boston Society of Civil Engineers met in the Society rooms after a large group of the members had dined at Patten's Restaurant.

Chairman Lincoln W. Ryder called the meeting to order and the minutes of the previous meeting were read and approved. The following were then elected as members of the nominating committee, following the usual custom of including the three most recent chairmen of the section: Mr. Byron O. McCoy, Mr. Elliot F. Childs, and Mr. John G. W. Thomas. They will report at the annual meeting of the Section in February.

There being no further business Chairman Ryder then introduced the speakers of the evening namely Mr. Allen J. Burdoin of Metcalf & Eddy, and Mr. Thomas R. Camp, of Camp, Dresser & McKee. Their topic was "True Siphons in Water & Sewage Work" with Mr. Camp emphasizing their use in the water works field and Mr. Burdoin covered the sewerage practices. Both talks were illustrated with slides.

Sixty-three members attended this most interesting meeting which adjourned at approximately 8:45 P.M.

RALPH S. ARCHIBALD, *Clerk*

SURVEYING AND MAPPING SECTION

OCTOBER 28, 1953.—The twenty-first meeting of the Surveying and Mapping Section was held at the Society Rooms at 7:00 P.M.

The meeting was called to order by Chairman C. Frederick Joy, Jr. The minutes of the April 1, 1953 meeting were read by the Clerk and approved.

Upon a motion made and seconded, the Section voted to authorize the Chairman to appoint a nominating committee to submit a slate of officers for the coming year. Chairman Joy accordingly appointed H. J. Shea, John J. Vertic and George W. Hankinson to serve on this committee.

The Chairman then introduced the speaker of the evening, Mr. John W. Leslie, Military Branch, U.S. Army Engineers, who spoke on the subject "Surveys and Federal Construction in Connection with Airfields in New England."

Mr. Leslie described the activities of the Corps of Engineers requiring basic surveys and pointed out that whereas surveys for flood control and river and harbor work can be carried out in a leisurely manner, those for military installations must be completed within a very short time limit. Because of time and personnel limitations the Corps of Engineers has been obliged to delegate much of this surveying to contractors.

Mr. Leslie concluded his talk with the following questions for discussion:

(1) Should topographic surveys be run by the grid system or by plane table?

(2) Should special areas such as building sites be rerun to obtain a more accurate survey?

(3) Should street profile be surveyed or taken from the basic contour map?

(4) To what extent can we depend upon a lump-sum bid based upon a contour or grid survey?

(5) Is it desirable to have contractors make their own surveys?

After a lively discussion of these topics the meeting adjourned at 8:30 P.M.

There were 25 members and guests present.

ALEXANDER J. BONE, *Clerk*

ADDITIONS

Members

James R. Carlin, 14 Roosevelt Avenue, Beverly, Mass.
John O. Chesley, 52 Pinckney Street, Boston, Mass.
J. Walter Chilson, 33 Fales Street, Franklin, Mass.
Charles J. Christy, 8 Woodland Street, Worcester, Mass.
Roger C. Collette, 19 Brooklawn Terr. E. Lynn, Mass.
Jerome Degen, 52 Barrett Street, Malden, Mass.
Augustine J. Crawford, 54 Conant Street, Danvers, Mass.
Bruce P. Eaton, 4 Oakland Road, Danvers, Mass.
Carmine E. Fulchino, 33 Kilburn Street, Revere, Mass.
Nelson W. Gay, 9 Firard Road, Stoneham, Mass.
David Hamilton, 838 Worcester Street, Wellesley 81, Mass.
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Yale Shapiro, 629 Nantasket Avenue, Hull, Mass.
Roland E. Warren, 17 Bradshaw Street, Medford, Mass.

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Leon A. Antosh, Union Street, Millis, Mass.
Stanley P. Belonos, 40 W. Long Street, Columbus, Ohio
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Deane F. Tolman, 64 Harvard Avenue, W. Medford, Mass.
Richard G. Walsh, 19 Pickett Street, Beverly, Mass.
Victor H. Weidman, 26 Pearl Drive, Pittsburgh, Pa.
Kenneth Weiner, 247 Callendar Street, Dorchester, Mass.

DEATHS

John F. Vaughan, December 17, 1953
John J. Casey, January 4, 1954
George E. Russell, December 11, 1953

ERRATA VOL. 40, NO. 2, APRIL, 1953

"The Equations of the Continuous Frame," by Thomas C. Coleman

ERRATA

Page 133, In Equation (B), "$C_x K_x \phi_y$" should be "$C_x K_x \phi_x$".

Page 134, In Equation (D) and in the next line, the expressions in parentheses should be "$(1—C_x C_y)$" in all cases.

Pages 142 and 143, In the column headed "Source" in Table IV, all plus signs "+" should be division signs "÷".

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