JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

JULY - 1935

VOLUME XXII NUMBER 3

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XXII | JULY, 1935 | Number 3

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PAPERS AND DISCUSSIONS

OF GENERAL INTEREST

Published four times a year, January, April, July and October, by the Society
715 Tremont Temple, Boston, Massachusetts

Subscription Price, $4.00 a Year (4 Copies)
$1.00 a Copy

Entered as second-class matter, January 15, 1914, at the Post Office at Boston, Mass., under Act of August 24, 1912.

Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

The Society is not responsible for any statement made or opinion expressed in its publications.

BOSTON
WRIGHT & POTTER PRINTING COMPANY
32 DERNE STREET

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XXII | JULY, 1935 | Number 3

DESIGN AND PROGRESS ON CONSTRUCTION OF DAMS FOR QUABBIN RESERVOIR

BY STANLEY M. DORE, MEMBER*

(Presented at a meeting of the Sanitary Section of the Boston Society of Civil Engineers, held on May 1, 1935)

THE Ware-Swift rivers projects, under construction by the Massachusetts Metropolitan District Water Supply Commission for increasing the water supply of metropolitan Boston, includes a reservoir in the valley of the Swift River, a tributary, through the Chicopee River, of the Connecticut River. This reservoir has been named the Quabbin Reservoir, and is to be formed by two earth dams, one of about 4,000,000 cubic yards of embankment above the original surface, to be built across the Swift River at West Ware, and the other of about 2,500,000 cubic yards, now being built across Beaver Brook, the other low valley in the rim of the reservoir basin located about three miles easterly of the West Ware site. The former is called the Main Dam and the latter, for convenience, the Dike.

The Quabbin Aqueduct, now practically completed, is a concrete-lined, horseshoe-shaped, rock tunnel, with a cross-sectional area equivalent to that of a 12-foot 9-inch diameter circle, and is about twenty-five miles long, connecting this reservoir with the Wachusett Reservoir, a part of the existing metropolitan district supply. This aqueduct will take water from the east branch of the Swift River and from the Quabbin

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Reservoir, when completed, by gravity to the Wachusett Reservoir, and also provides for the diversion of the Ware River at Coldbrook to either of these reservoirs as desired. The easterly part of this aqueduct, formerly known as the Wachusett-Coldbrook Tunnel, was completed in 1931 and is described by Chief Engineer Frank E. Winsor in the November, 1932, issue of the "Journal of the Boston Society of Civil Engineers," and by Assistant Engineer Frank E. Fahlquist in the January, 1929, issue.

Sites for Dams

The Joint Board, so called, reported to the General Court in 1922 concerning the general location of the dams for forming this reservoir, preliminary investigations, including a number of borings, having been made in 1920 and 1921. These sites have since been further investigated by a large number of borings as described by Division Engineer N. LeRoy Hammond in the January, 1929, issue of this Journal. Boring samples were taken so that information was obtained regarding the location of the underlying rock surface, the kind of rock, the number and size of boulders, and the quantity and quality of the overburden. From these investigations, Dr. C. P. Berkey, the consulting geologist, concluded generally regarding these sites:

> The explorations now available, together with the data already in hand relating to the Swift River dam, indicate very understandable geological conditions. There is no doubt whatever of the substantial nature of the floor. No special difficulties are to be expected with it.
>
> The rock profile, however, shows a wide, smooth valley, comparatively deep, requiring an immense structure. The overburden is thick and porous, of glacial drift type. It is substantial enough to support a dam, but not impervious enough to hold back the water. Some design, therefore, that will form a cut-off is the only practicable thing in this project. On no portion of the site can this method be avoided.
>
> The quality of the overburden and its depth constitute the chief problem of this site (the Dike). The material is very porous and some of it is fine enough to slump badly during excavation. It is undoubtedly full of water. But there is every reason to believe that the material will support the contemplated structure. The problem is how to prevent circulation down the valley through this material. In my opinion it cannot be done without a complete cut-off wall.

The general sites chosen by the Joint Board are the logical locations for the dams for a reservoir of this size. The later bore holes, surveys and other investigations confirmed this choice and provided data necessary to determine the most economical locations of these structures.

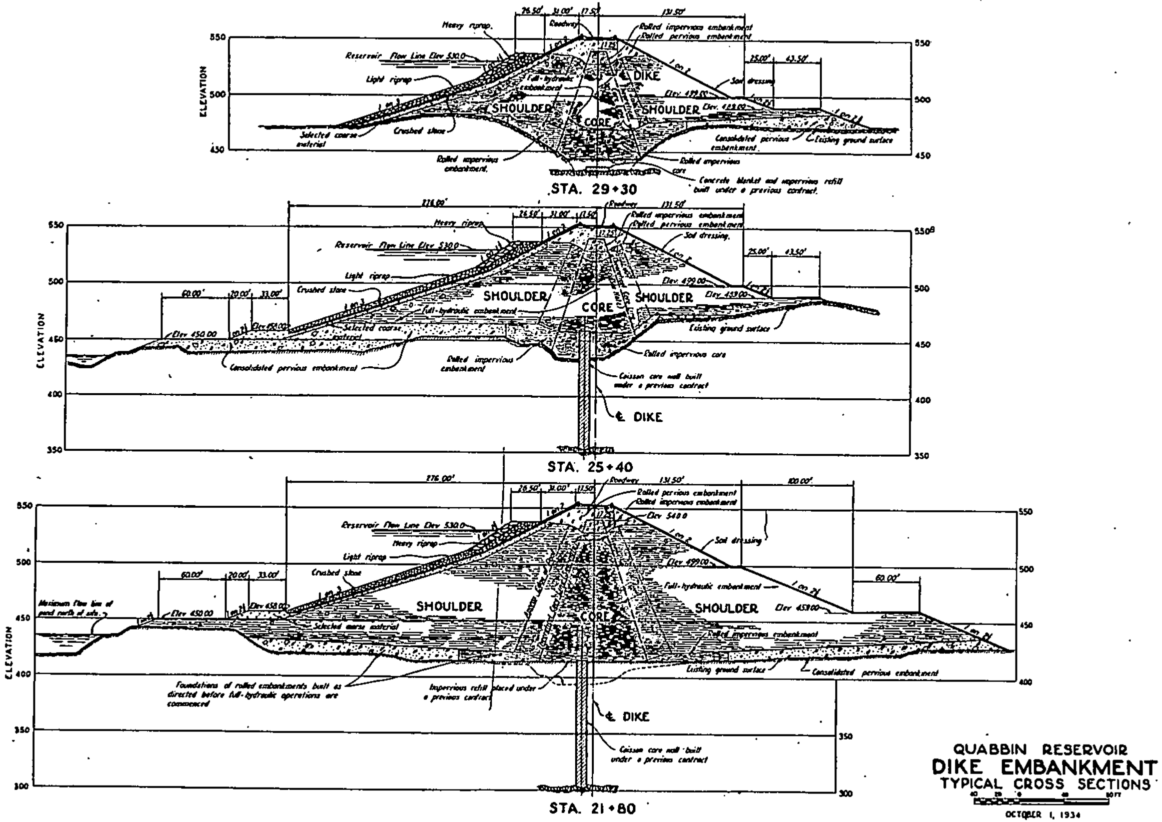


FIG. 1. — TYPICAL SECTIONS OF DIKE

Type of Dams

The recommendation of the Joint Board that earth dams be built at these sites has been adhered to because (1) the bedrock is covered deeply with permeable glacial overburden, making foundations to rock, which would be required for masonry structures, very expensive; (2) the valleys are wide and the dams long, so that the cross section of any type of dam built will have to be a gravity section, and for a masonry structure this would mean large quantities and high cost; (3) there is an abundance of materials close at hand suitable for construction of dams of the earth type; and (4) in this climate, with extreme, freezing weather in winter, an earth dam is of greater permanence than any other type.

Reservoir

The flow line of the reservoir, which fixes its size, was established by the Commission at an elevation 530 feet above Boston city base. The reservoir so formed will have a capacity of 415 billion gallons and a water surface area of about 39 square miles. The flow line will be about 104 miles long, exclusive of 47 miles shore line of 60 islands, and the average depth of water in the reservoir will be about 50 feet. The westerly arm of the reservoir extends 12 miles and the easterly arm 18 miles northerly of the Main Dam. The easterly arm extends 16 miles northerly of the Dike.

The Quabbin Reservoir, in addition to storing waters from its own drainage area of 185.8 square miles, will be required to store flood waters diverted from a drainage area of 98 square miles of the Ware River at Coldbrook, and probably waters diverted from time to time from a drainage area of about 43 square miles of the Quinapoxet River.

Cut-Off Investigations

The valleys at both dam sites are filled to a depth of about 125 feet with glacial drift. The materials are heterogeneous deposits of gravel, sand and silts, or combinations of them, and boulders and cobbles of varying sizes are present in many of the deposits. These deposits lie in pockets or lenses of varying dimensions, and there is no orderly relation of the locations of them.

Preliminary investigations conducted to determine the water-carrying capacity of these overburdens indicated that they might be highly permeable. Although it was believed stable dams could be built upon these materials without extending cut-offs entirely to ledge, it seemed advisable, by preventing the loss of water flowing beneath these dams, to obtain economic as well as structural advantages, it being estimated that quantities probably as large as 15 m. g. d. at the Main Dam and 10 m. g. d. at the Dike would be saved. Various types of cut-offs were considered, including open, unsheeted trench to ledge, the driving of sheet piling to ledge, the grouting of the foundations with cement-grout or with "dobie," concrete core wall to ledge in sheeted trench, and concrete core wall to ledge by open or by pneumatic-caisson construction.

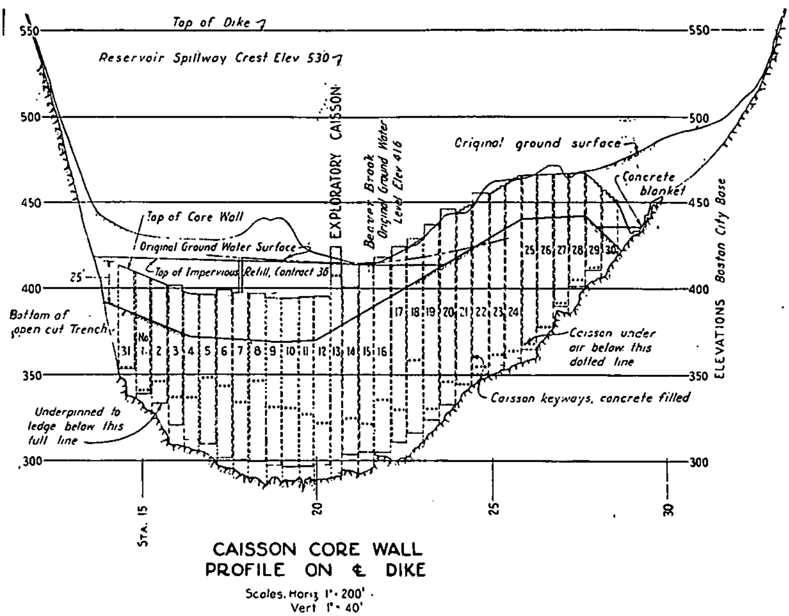


Fig. 2. — Profile on Center Line of Dike

The presence of a large number of boulders and cobbles was indicated by the difficulties with which the borings were made at each site, and it was concluded that the driving of sheet piling, if not impossible, would be extremely difficult and expensive, and, if completed, would probably furnish an unsatisfactory cut-off. Grouting the foundations, unless done so thoroughly as to be uneconomical, would give uncertain results. Comparisons of preliminary estimates of cost of an open, unsheeted trench to ledge refilled with impervious soil, sheeted trench refilled with concrete, and reinforced concrete caisson construction indicated that the latter two were much cheaper than the first, and that the last, if such construction were feasible, would prove cheapest by a substantial margin.

The ground water at the Main Dam site was approximately at the river level about 120 feet above the low point of ledge, and at the Dike, at the brook level, about 130 feet above the low point of ledge, and the need of some provisions for lowering the ground water gradients or for excluding the water from the cut-off work was apparent.

In order to investigate the qualities of the overburden more thoroughly, the feasibility and cost of open and pneumatic caisson construction and the possibilities of lowering the ground water by pumping, one exploratory caisson was sunk at each site in such position that it could be utilized as a portion of a concrete cut-off wall should the desirability of such a wall be confirmed.

Exploratory Caissons

A contract for the construction of these two exploratory caissons was executed with the Dravo Contracting Company on September 16, 1931, and was completed about a year later at a cost of $162,838.33.

The exploratory caissons as designed and constructed were of reinforced concrete and were 32 feet long by 12 feet wide, with three vertical chambers, a central chamber about 6 feet square used as a dry pump well for the pumping of ground water, and two end chambers 7 feet in diameter used as working wells for access to a working chamber below. Provisions were made for taking ground water through the sides and ends of the caissons to pumps in the central well.

The site for the exploratory caisson at the Main Dam was chosen where the depth of the ledge was only about 70 feet below the river level and 45 feet above the low point in the rock profile along the center line of the dam. Because other work on the stream control structures was then in progress near by, and because it was desirable to experiment with many of the construction operations in the sinking of the first caisson, the location chosen was considered more feasible than one at the deep part of the rock valley. The original surface at that location was about Elev. 415, and an open-cut trench was excavated to Elev. 400. The contract provided for a great deal of experimental work, and the first sinking was done by the open dredging method. This method proved to be costly and impracticable when the gravelly and cobbly deposits were reached, as the cobbles and small boulders would accumulate into a mass covering the digging areas and making further progress extremely difficult. The compressed air method was then adopted. This method was economical, allowed steady sinking progress and provided favorable conditions for sealing the caisson to ledge under air "in the dry." The caisson was sunk to Elev. 365 by the open dredging methods (using a crane and clamshell and orange peel dippers), water having been encountered at about the river level, Elev. 383. Because of the difficulties mentioned, the open dredging methods were then abandoned and air locks were installed over the working wells, and excavation below Elev. 365 continued by the compressed air methods. No difficulties were encountered in sinking the caisson to ledge, cleaning off the ledge and sealing the caisson to ledge, a maximum air pressure of about 33 pounds per square inch being used. A sample box as long as the caisson was deep was constructed near the site of the work, and in it representative materials encountered at the various depths were placed as a record for use of future bidders.

Attempts were made to lower the ground water surface adjacent to the caisson through openings in the sides and ends at the same time that the caisson was being sunk, but these attempts were not successful when sinking by compressed air methods, as the leakage of air into the volumes surrounding the caisson filled the voids with air, reducing the volume of pores available for flow of water, and as the air leakage rising through the soil tended to accelerate the flow of the finer particles into the pumping intakes, thereby clogging them. However, pumping from intakes or from the working chamber when air was not in use was a feasible means of successfully lowering the adjacent ground water.

The exploratory caisson at the Dike was located at a point in the valley where the rock gorge beneath was the lowest, about 130 feet below the brook level. The elevation of the original surface was only a foot or two above the ground water level. Excavation by open dredging methods for sinking this caisson was tried for a short distance, but was soon abandoned in favor of excavation by compressed air methods. Sinking progressed for a depth of about 63 feet, when it became evident that the ground water could not be lowered by pumping from the caisson itself. The brook level was about Elev. 415, and the low point in the rock valley below Elev. 290. As the air pressures required to keep out the water would be greater than the 50 pounds per square inch maximum allowed by Massachusetts laws, an open sump well about 26 feet square of wooden sheet piling was sunk at a location about 100 feet distant. This sump was carried to a depth of about 50 feet below the brook level, the ground water gradient being lowered for that sinking by pumping from the intakes and from the working chamber of the exploratory caisson. Pumps were then installed in the open sump and excavation continued from the caisson by compressed air methods. The ground water gradient was maintained in a lowered position by pumping from the sump, so that the caisson was sunk and sealed to ledge with a maximum air pressure of 48 pounds per square inch. In a manner similar to that at the other site, a sample box as long as the caisson was deep was constructed to care for representative samples of materials encountered.

Suction intakes were built in the underpinning of the caisson and connected to the pump well so that pumping could be carried on effectively from the caisson, after it was sealed to ledge.

Ground water measuring wells consisting of 2½-inch steel pipes sunk by wash boring methods to desired depths were located at many points in the valley at each site, and were used to determine the location of the ground water surfaces at those sites.

Upon completion of the exploratory caissons, pumps were installed in them and the ground water pumped to determine the permeability of the materials in the overburdens, and to observe the lowering of the ground water at each site.

The information obtained from the sinking of these caissons and the pumping carried on from them was particularly valuable, as follows:

1. The sands and gravels in the overburden are coarse and there is no stratification of like materials. The number of boulders and cobbles is large and the rock floor is sound.

2. Caisson construction for use as a cut-off wall is feasible for both sites, gives a definite satisfactory cut-off, and is the most economical.

3. The ground water can be satisfactorily lowered by relatively simple and easy means, so that the major portions of the concrete core wall at each site can be built below the normal ground water gradient in the dry.

4. The examination of materials excavated and determinations of permeability of the overburden from the pumping operations confirmed the previous investigations concerning the high permeable qualities of the materials. The explorations and studies also revealed that, at each valley site, the materials in the upper portions of the overburden were finer and less pervious than those in the lower portions, indicating the advisability of sealing the cut-offs to ledge.

Dike Cut-Off Wall

From studies based on these preliminary explorations, a cut-off wall for the Dike was designed to be built by excavating an open-cut trench to an economical depth, by sinking from the bottom of it reinforced concrete caissons, end to end, by sealing these caissons with con-

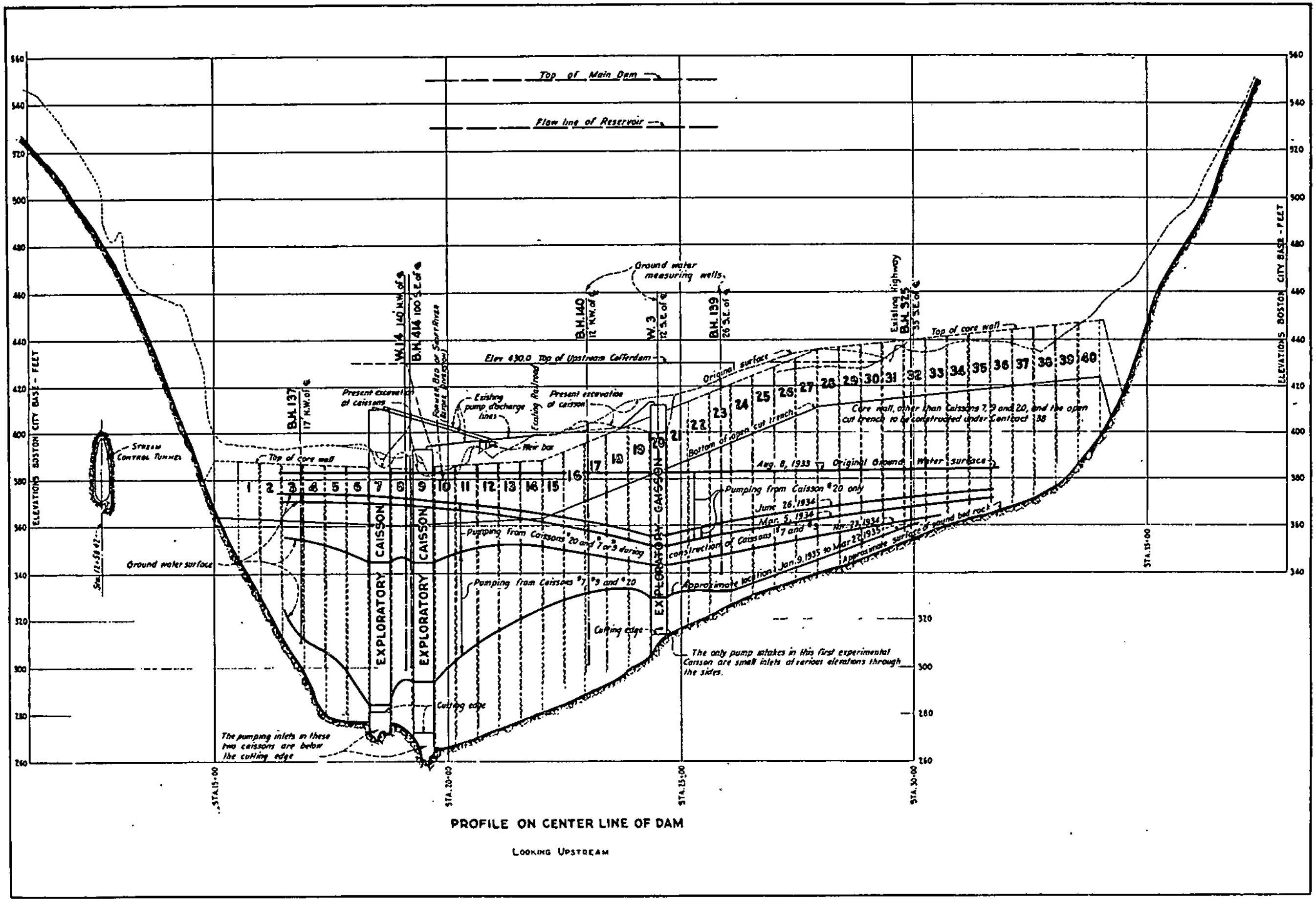


FIG. 3. — PROFILE ON CENTER OF MAIN DIKE, SHOWING GROUND WATER LOWERING

crete to each other and to ledge, and by filling the wells of the caissons and the open-cut trench with impervious soils. The caissons were made 45 feet long and 9 feet wide, and contained three access wells to the working chamber, each 4 feet in diameter. The width of 9 feet was chosen, after careful investigation and study, as the economical width, allowing room enough for excavation without increasing the quantities to be excavated to an uneconomical extent. The length was chosen as one which would not be so unwieldy as to interfere with the holding of the caissons in position while sinking, and which would not be so short that a large number of keyways would be required. The central well was for the access of men, the two end ones for the handling of materials. Recesses 18 inches deep were made in each end of each caisson, and adjoining caissons were to be sunk 18 inches apart in the clear, making an average working space of 4½ feet for excavation in the keyways.

A contract was executed with the West Construction Company for the construction of this core wall on December 28, 1932, it being completed in December, 1934, at a cost for the work at the Dike of $939,695.78.

In January, 1933, at the start of work on this contract, pumping from the open sump was abandoned, and the contractor installed other pumps in the exploratory caisson, connecting them with the intakes already in place.

Pumping from the exploratory caisson and open sump had been in progress since April, 1932, and in January, 1933, the rate of pumping was about 1,700 g. p. m., and the water surface had been lowered, at a distance of about 100 feet from the pumps, about 35 feet from its original position. The rate of pumping was increased to about 3,200 g. p. m., and that rate was maintained from this caisson until four months later, when other caissons had been sunk below the ground water gradient. Pumps were then installed in the working chambers of some of these caissons to supplement those in the exploratory caisson. During this period of four months the ground water gradient had been lowered sufficiently to permit the open trench excavation, this gradient being 60 feet down, about 100 feet from the pumps.

Beaver Brook, a tributary of the Ware River, was carried past the site of the work, during construction of the exploratory caisson and until the start of this contract, in a wooden flume about 350 feet long. This prevented seepage into the ground near the caisson. At the beginning of the work on this contract this brook was dammed at a location 500 feet upstream and the pumping discharge line carried to a point 400 feet downstream. The brook was dried up upstream for over 1,000 feet by subsequent pumping, and the level of Morton Pond, 1,500 feet upstream, lowered about 9 feet. Upon completion of work under the contract, an 18-inch pipe line was installed to carry the brook flow until its subsequent diversion across the divide into the Swift River.

Work on the open-cut excavation began in March, 1933, and suitable materials therefrom were placed in the cofferdam embankments located in the toes of the future Dike embankment, and other materials were wasted in a spoil pile southeast of the site.

The open-cut work progressed satisfactorily, so that by April the contractor was working on caisson construction. A concrete mixing

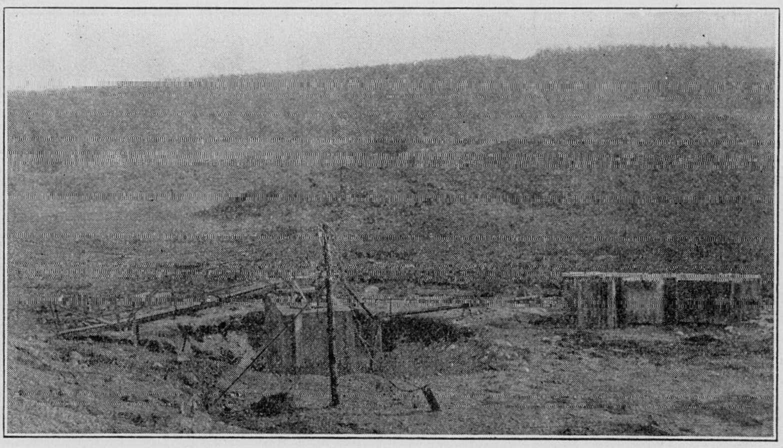


FIG. 4. — LOCATION OF DIKE, LOOKING EASTERLY ALONG CENTER LINE. CAISSON IN FOREGROUND

plant was erected about 1,800 feet downstream from the site of the work, and an excellent concrete aggregate pit opened about 3,500 feet southerly of the mixing plant. Aggregates were hauled from the pits to the mixing plant by trucks. There a crushing, screening, washing and batching plant prepared and delivered the materials into two 5 cubic yard transit-mixers which mixed the concrete and carried it to the caissons. The transit-mixers poured the concrete into buckets, which were lifted by a crane and dumped into the forms. Steel forms were used and lifts of 16 feet of caisson were constructed in one pour, which was usually made in a day and which consisted of over 200 cubic yards.

Forms were usually left in place at least 48 hours. The amount of cement used except for working chambers averaged about 1.5 barrels per cubic yard, and the mix varied between 1–2–3½ and 1–2¼–4, the compressive strength of which at 28 days test samples indicated to be about 4,000 to 5,000 pounds per square inch. Because of the heavy working stresses on the working chamber walls, the mix was made 1–1¾–3, the compressive stress at 28 days being about 5,000 and the cement content about 1.75. In underpinning walls 1–2–2 concrete was used, the cement factor of which was about 2. The cement content was purposely kept high as the core wall is to be used as a cut-off and a dense impervious mass is particularly desirable.

Alternate caissons were generally sunk to elevations near or on ledge before intermediate ones were started. A working crew of a foreman and eight men excavated the materials by hand, four men working

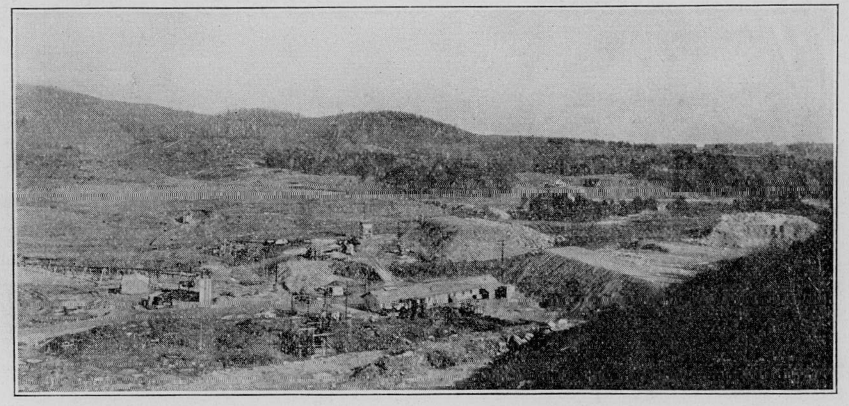


FIG. 5. — LOOKING NORTHEASTERLY AT DAM SITE

to a bucket located under each material shaft, which was 12 feet from the end of the caisson. The dead load of each caisson furnished weight enough to sink it, supplemented in some cases by "blowing" or the use of dynamite, but in no case was the use of a superimposed load required; however, the caissons were left projecting, for water cut-off purposes, 25 feet above the bottom of the open-cut trench, and this height furnished load to the sinking caisson.

The underpinning of caissons was accomplished under compressed air by building walls about 18 inches thick below the cutting edge to ledge, forming an underpinning chamber in which work of cleaning off and preparing the ledge surfaces was conducted. A seal of concrete was poured in this chamber to an elevation above the cutting edge, and after the concrete had set the air pressure was released. Grout holes were drilled through the seal into the ledge and the rock thoroughly grouted. The working chamber of the caisson was then filled with concrete to an elevation of about 2 or 3 feet above the ceiling of the working chamber in the access wells. The end joints between caissons were excavated to the ground water surface by placing wooden planks between the ends of two adjoining caissons at each of the upstream and downstream faces, and a concrete plug containing a 3-foot diameter access well was poured into the space between this planking. Below the ground water level the keyway excavation was carried on by underpinning methods under compressed air, air locks being installed above the

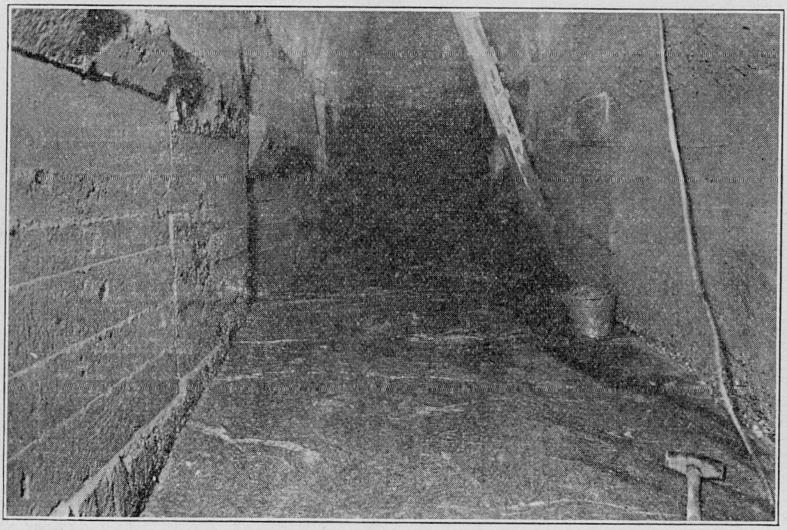


FIG. 6. — INSIDE VIEW OF CAISSON NO. 5, SHOWING BEDROCK (LOOKING WEST)

concrete plug, 18-inch walls being carried down at the faces of the adjoining caissons, and the chamber so formed being filled with concrete.

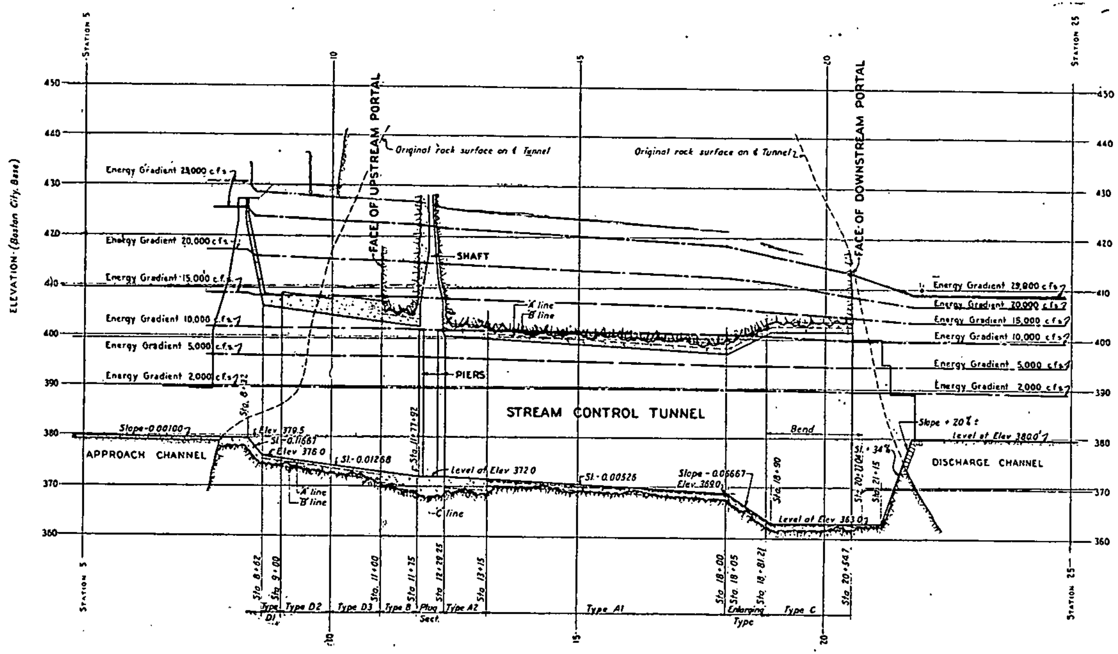
Pumping was continued during the caisson and keyway work and the ground water surface was lowered to a position 90 feet below its original location. This lowered position was maintained until completion of caisson work, at which time the pumping rate was diminished and the water surface allowed to slowly rise. The maximum air pressure used was 25 pounds per square inch, 70 per cent of the work being done in free air and 20 per cent under pressures less than 10 pounds per square inch.

In the summer of 1934 the caissons and the keyway work had been completed, and refill of the open-cut trench with impervious materials was then made. Impervious topsoils, obtained mostly from areas northwest of the Dike, were used. They were consolidated by rolling in 6-inch layers. Upon completion of the impervious fill to the tops of the caissons the wells in the caissons were filled with impervious soils, consolidated by dropping a heavy weight into each well as the filling of it progressed. The height of the impervious refilling was completed to an elevation above the original ground water position, so that pumping could be abandoned. The work on this contract was completed in December, 1934.

Stream Control Tunnel at Main Dam

To divert the Swift River from the site of future construction work for the core wall and embankment of the Main Dam, a tunnel through the hill at the westerly end of the dam was constructed. Several locations of a stream diversion conduit or tunnel were considered. The river is much nearer the westerly abutment, and the ground is high above the river level easterly of the river, so that a location through the easterly hill was out of the question economically. A cut-and-cover conduit might have been located on rock at the westerly end, but deep excavations of the overburden near the toes of the future dam made such a location undesirable as well as more costly than a tunnel. It was impracticable and uneconomical to get a straight tunnel, so one with one bend of about 90 degrees was finally chosen as the most desirable and economical. The stream control structure has deep portal cuts at each end and a concrete-lined rock tunnel about 955 feet long. In addition, the cut-and-cover section at the upstream end is about 275 feet long. The normal net section is horseshoe-shaped, 30 feet wide and 28 feet high, and will provide protection after the cofferdams are completed for floods up to about 25,000 cubic feet per second. The bend starts about 150 feet from the downstream portal and is about 120 feet in radius along the center line. The section of tunnel is enlarged gradually as the bend is approached to a section 30 feet wide and 38½ feet high, the water being carried around the bend at much slower velocities than in the rest of the tunnel, thereby reducing the loss of head at the bend.

The upstream portal cut includes an approach channel about 500 feet long, the bottom of which was lined with concrete, because of its nearness to the core wall of the dam, to prevent leakage of water from the channel into the cut-off construction, and the downstream portal



PROFILE

FIG. 7. — PROFILE ON STREAM CONTROL TUNNEL

cut contains a discharge channel over 1,000 feet long. The tunnel is provided with one shaft located near the center line of the dam in which will be built provisions for releasing water downstream, as required by Massachusetts legislation and by the United States War Department. Releases will be made into pipe lines, one of which, a 48-inch line, is cast in the side and invert of the tunnel concrete. Upon completion of the

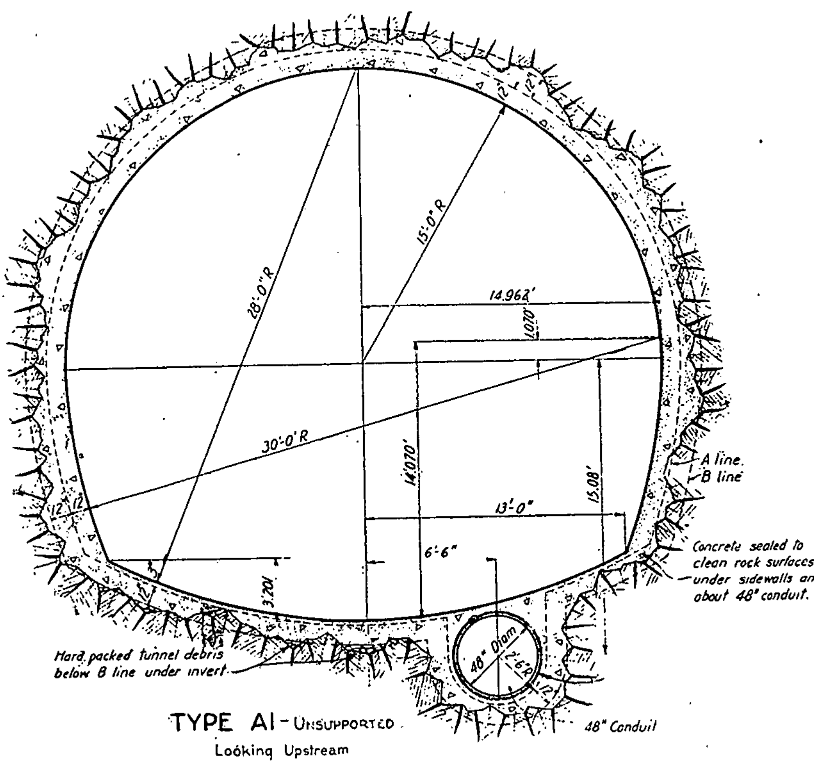


Fig. 8. — Typical Section of Stream Control Tunnel

dam the tunnel will be plugged with concrete at the base of the shaft for a distance of about 40 feet. Piers are now built in the tunnel beneath the shaft to facilitate the plugging operations. The control of releases will be located in a structure to be built at the downstream portal of the tunnel. During the plugging the river flow past the site will be maintained by building over the plug a siphon connecting to the 48-inch line.

A contract for construction of the stream control works was executed with the Northern States Contracting Company August 1, 1931, and was completed August 29, 1933, at a cost of $544,610.60. The contractor placed excavation from the portal cuts in fills in the toes of the future dam. Tunnel spoil was used in the upstream and downstream cofferdams, for riprap and paving for the tunnel intake and discharges, and for protection of the approach channel slopes, and the remainder was stored for use as stone fills in the cofferdams. No difficulties were experienced in the driving of the tunnel, which was large enough to permit the use of full-sized shovels and trucks in the handling of the tunnel débris. The rock was sound and no timber supports or "Guniting" was required. The tunnel was concrete-lined, steel forms being used, and a section near the center line of the dam was grouted tight. The river was diverted through the tunnel in June, 1933, by building low embankments across the river bed just downstream from the approach channel connection and just upstream from the discharge channel connection.

Cut-Off for Main Dam

In June, 1932, pumps were installed in the exploratory caisson at the Main Dam, and ground water measuring wells were sunk at various locations in the valley upstream and downstream from the site for measuring the effect of pumping upon the ground water gradient. Pumping at a rate of 600 g. p. m. for a period of two months showed but little lowering, so in July, 1932, well points were drilled through the sides of the caisson to enlarge the capacity of the intakes. More pumps were then installed, increasing the pumping capacity to about 2,200 g. p. m. At that rate pumping from that caisson was again started in August, 1933, and from that time to date has continued at a rate diminishing gradually, as the ground water has been lowered, to 170 g. p. m. in January, 1935.

Although the river was diverted in June, 1933, the pumpage from the caisson was being discharged into the old river bed about 400 feet distant. Studies indicated that about 1,000 g. p. m. of the 2,200 pumped was leaking in from the pond in the old river bed between diversion embankments. In November, 1933, a 24-inch spiral welded steel pipe line about 700 feet long was built, and the discharge line from the caisson emptied into it, to carry the pumpage to a point in the river upstream from the diversion embankment. Subsequent pumping there soon dried up the river bed between embankments, and more effective lowering of the ground water gradient was thereby obtained.

Under the contract for the Dike core wall two exploratory caissons, in addition to the one already built, were sunk at the Main Dam to further investigate the type of materials to be encountered and the extent to which the ground water could be lowered, and to permit the installation of additional effective pumping plants, the pumping plant already installed in the first exploratory caisson sunk at that site being insufficient to effect desired lowering. These two caissons were sunk so that pumping from one could lower the ground water surface near by while sinking from the other was in progress. The caissons were located in the line of the finished core wall, and the cost was materially reduced because of the reduction in ground water surface obtained by the sinking of them alternately. A distance of 48 feet was left between the ends of these two caissons so that an intermediate caisson can be sunk to fill the gap when the core wall is constructed.

At the start of sinking, the ground water surface had been lowered at these caissons about 15 feet below the river level. Pumping during sinking lowered the ground water surface there to about 40 feet below the river level, so that one caisson was sunk and sealed to ledge about 125 feet below the river level with a maximum pressure of 37½ pounds and the other with a maximum of 34 pounds per square inch. Pumping intakes were built in the underpinning of these caissons, and after the caissons were sealed to the rock, pumps installed in the working chambers were connected to these intakes. Discharge pipes from the pumps were carried up the access wells of the caissons and to a measuring weir located at the entrance of the 24-inch discharge line to the river, mentioned above.

With this layout, consisting of pumps installed in three caissons connected to discharge lines to the river, ground water was pumped at an average rate of about 3,500 to 4,000 g. p. m. from November, 1934, upon completion of the latter two caissons, to May, 1935. By January, 1935, this pumping lowered the ground water surface at the two caissons to an elevation about 90 feet below the river level, and since that time has maintained the water surface in the lowered position preparatory to the start of construction of the core wall for the Main Dam.

Proposals for the construction of the Main Dam core wall will be opened on May 7, 1935. This contract provides for the excavation of an open-cut trench 25 to 30 feet deep across the site and sinking from the bottom of it 37 reinforced concrete caissons (in addition to the 3 exploratory caissons already sunk) and sealing them to ledge and to each other to form a water-tight cut-off. The construction required under this contract is very similar to that already completed for the Dike.

Type of Earth Dam

Several types of earth dams have been considered in the studies for the Main Dam and Dike, including the following:

1. Rolled earth embankment without concrete core.
2. Rolled earth embankment with concrete core.
3. Rolled earth core protected by consolidated pervious embankments.
4. Semi-hydraulic fill dam.
5. Hydraulic fill dam.

A study of the materials available indicates that any one of these methods could be employed in the construction of these dams, there

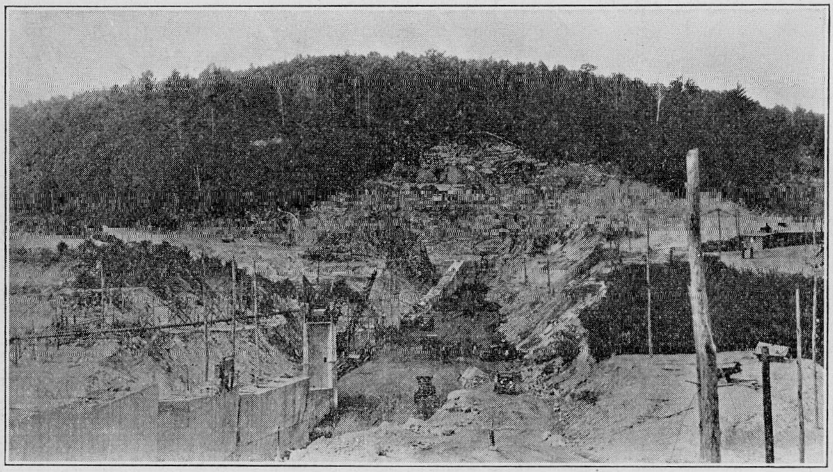


Fig. 9. — Impervious Fill at North Side of Core Wall of Dike (looking West)

being available sufficient quantities of variable ground moraine materials containing many boulders and cobbles and other suitable material for stability, and containing a sufficient quantity and quality of fines for a water-tight core.

The cobbles and boulders present in the available borrow areas prevent the economic handling of materials by rolled fill methods, even though, with careful selection, suitable materials with the proper quantities of fines can be found for both core and shoulder materials. The quantities of topsoils available are limited for economical construction of a core of these materials.

The construction by semi-hydraulic or by hydraulic fill is feasible, and careful estimates indicate very little difference in cost for each site if done by either of these methods, there being some economic advantage in favor of the full-hydraulic. Also this method is considered desirable structurally, as it gives a more uniformly graded structure, with less liability of any instability during construction.

The Dike Embankment

Areas upstream and downstream from the Dike site within a reasonable haul, and which surface conditions indicated might be expected to yield suitable materials for earth dam construction, were investigated to determine quantities of overburden available above the ledge, and samples from test pits and bore holes were taken for mechanical analysis and other tests of suitability. The quantities of the materials available in each of the probably usable areas were then further investigated by excavating a shovel cut to a face of 25 or 30 feet high. The qualities of the topsoils available within a reasonable distance of the Dike were also sampled and tested.

A soil testing laboratory of the Commission has been established in Enfield. Mechanical analyses, permeability, porosity, specific gravity, coefficient of friction, organic content and other soil tests have been made of borrow pit samples as needed.

A sluicing bin was constructed to test out samples from prospective borrow areas in order to ascertain what quantities and qualities of the various parts of the embankment might be obtained by washing those materials in a manner similar to that employed in the hydraulic work. This bin had a concrete floor and timber sides. It was 15 feet wide and nearly 50 feet long. The floor was sloped towards a depressed section used for a pool. Materials dumped on an apron at one end were washed with hose streams, the water running over the floor section to the pool, carrying the finer particles into the pool and depositing the coarse particles on the floor, forming a beach. The overflow from the pool ran into a sump, from which the water was pumped back to the hose nozzles. Thus the bin represented a half section model of the dam. About 20 to 25 cubic yards can be washed in this manner in this bin, and estimates made of the quantities and qualities of the washed products.

In the upland areas northeast and northwest of the Dike topsoils in sufficient quantity are available to furnish impervious material for refilling the open trench excavation about the concrete core wall, and for preparing the foundations for the core of the embankment above, but there are not economically available sufficient quantities for direct use for construction of the entire core.

Explorations of the ground moraine have indicated that sufficient quantities of suitable materials are probably available in areas northwest, northeast and southwest of the Dike for use in semi-hydraulic or hydraulic fill construction. Cost estimates indicated that with the materials available the embankment could be built by the full-hydraulic method more cheaply than by the semi hydraulic; and as the former has construction advantages, such as the more uniform and thorough grading and separation of sizes and more uniform and thorough consolidation of shoulders, it was chosen as the method of construction.

A contract for construction of this embankment was executed with The Arthur A. Johnson Corporation on December 5, 1934, the bid price being $1,446,655. There are roughly 2,700,000 cubic yards of embankment to be placed, of which 2,100,000 are to be placed by hydraulic methods, 320,000 cubic yards in foundations by rolled fill method, 140,000 cubic yards of riprap and broken stone, 100,000 cubic yards of selected coarse material on upstream face, and 40,000 cubic yards of soil dressing on downstream face.

Work on clearing of borrow areas, building of construction roads and rock excavation in abutments has been in progress so far this year, and work on preparation of foundations will be started this season. The contract calls for completion in 1938.

Borrow Pits for Main Dam

Explorations of possible borrow areas for materials for the Main Dam have been and are now being made in areas upstream and downstream from the site in a manner similar to that employed for the Dike. Sufficient quantities of suitable materials are available for hydraulic construction, and there is a sufficiency of topsoils upstream from the site to furnish impervious filling of the open trench and for the foundations of the core. The embankment for the Main Dam will contain about 4,000,000 cubic yards.

Spillway

The top of the embankment at both the Main Dam and the Dike will be at Elev. 550, or 20 feet above the normal full level of the reservoir.

The reservoir has two natural spillway sites, — one, a depression in the rock at the westerly end of the Main Dam, and the other in a high valley between two hills at the easterly end. The easterly location would require a larger rock cut, but the material quarried from this cut can be used for riprapping the upstream face of the dam.

The drainage area of the reservoir is that of the watersheds of the three branches of the Swift River, west, middle and east, and the drainage slopes of all three are largely brush land and woodland. Those of the west branch are much steeper than those of the other two, which are steep only at the headwaters and which are much more moderate below. Records of past floods indicate that the west branch yields its run-off quickly. Most of the flood flow from that branch passes the site of the Dam before the flows from the east and middle branches arrive. This condition gives a flood flow curve which has a flat peak of long duration. The maximum flood peak for the period of record of 21 years at the West Ware gaging station near the Main Dam site is about 2,380 cubic feet per second and occurred April, 1923, or about 13 cubic feet per second per square mile. This peak lasted, roughly, three days. The largest New England flood of record in recent years occurred in November, 1927, and was felt probably most severely in Rhode Island, in the vicinity of the Scituate Reservoir. Such a flood on the Quabbin Reservoir watershed, if it came at a time when the reservoir was full, would result in a spillway discharge of about 2,000 cubic feet a second for a spillway weir 400 feet long. Records of large storms in western Massachusetts have produced rainfalls as high as 12 inches. Such a rainfall in a storm similar to the November, 1927, storm might produce a spillway discharge of about 3,000 cubic feet a second. A run-off of 12 inches in 24 hours would result in a spillway discharge of about 9,000 cubic feet a second.

Studies of both spillway sites revealed that, considering the use of excavated rock as riprap, the easterly site was more economical, and that it offered the better location structurally, as a discharge channel in rock all the way from the spillway weir to the river would be obtained. Because of these economic and structural advantages the easterly site has been adopted for location of the spillway weir and channel, but the natural features of the westerly site are also to be utilized by preparing at a slight extra cost this latter site as an additional insurance against overtopping of the dams in case of an unanticipated extreme emergency.

The easterly spillway channel will probably provide for carrying floods up to 10,000 cubic feet a second, without flooding out the rock discharge channel, and floods of considerably greater magnitude, even up to 15,000, will be carried with no important scour of the earth banks above the rock channel. There is room at that site for a concrete overflow to be built in rock valley between hills about 400 feet long. With the reservoir full for flows over the spillway as high as 15,000 cubic feet a second the reservoir will not rise higher than 6 feet above Elev. 530. At the same time, at slight expense, by doing a little excavating and grading of the westerly weir site, and by building a shallow concrete cut-off to ledge there, an emergency overflow can be provided at Elev. 536 so that in case of an unanticipated extreme emergency, such as the clogging of the easterly spillway approach or discharge channels, or in case of unprecedented and extremely high run-off with a full reservoir, a material rise in the reservoir surface above Elev. 536 will be practically prevented.

Cross Section of Dams

The design of the section of the Dam is in keeping with general practice on large earth dams elsewhere, as can be seen from Fig. 8. A section of the Dike is shown in Fig. 1, and a tabulation comparing the Main Dam and Dike of Quabbin Reservoir with other large earth dams is given in the appended table.

The top width of 35 feet has been chosen in order to provide a considerable width through the embankment at the higher elevations near the flow line in order to permit continuing the sluicing properly to as high an elevation as possible. The freeboard of 20 feet between the spillway elevation and the top of embankment compares with 24 feet on the Conklinville Dam, New York; 24 feet on the Paddy Creek Dam, North Carolina; 20 feet on the earth dams at Ashokan Reservoir, New York; 20 feet at Cobble Mountain, Massachusetts (7 feet of which are flashboards); 19 feet on the Wyman Dam, Maine; 15 feet on the dikes of Wachusett Reservoir, Massachusetts; 15 feet on the Wanaque Dam, New Jersey; 14 feet on the Davis Bridge Dam, Vermont; 13 feet on the Scituate Dam, Rhode Island, and 12 feet on the Saluda Dam, South Carolina. The downstream face has slopes of 1 on 2, 1 on 2½, and 1 on 2¾, with berms 15 feet wide to intercept the drainage at intervals of 35 to 50 feet vertically. On the upstream slope a wave break of heavy riprap with a horizontal berm 5 feet above the spillway level has been used, following generally the design of the Wachusett Reservoir Dike and the Scituate Dam for the city of Providence, which has proved very satisfactory. Below this wave break a constant slope of 1 on 3, protected by riprap, has been carried to Elev. 458 for the Main Dam. Studies of the anticipated water levels during the filling of the reservoir and subsequent draw-downs during use indicate that to riprap below this elevation is not required. The wide berm at Elev. 458 is constructed of selected coarse material, with the idea it would take

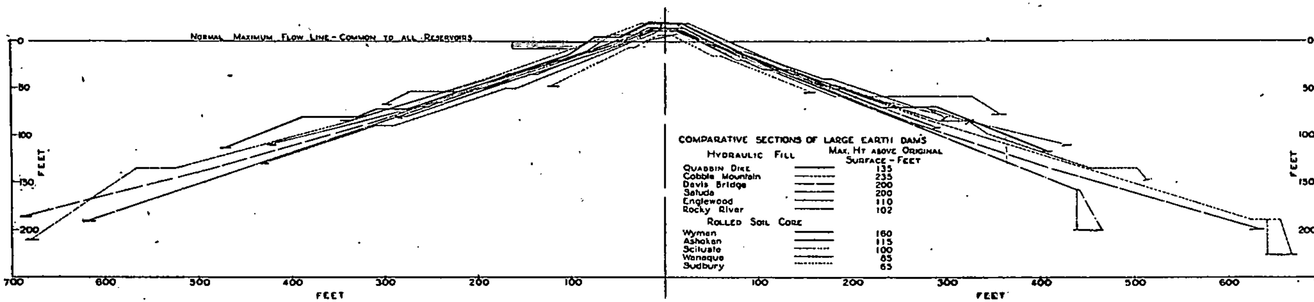


Fig. 10. — Comparative Sections of Large Earth Dams

its own slope under wave action during the filling of the reservoir, and that this slope would be sufficiently flat to prevent undermining the riprap below Elev. 458. The details of the upstream toes in both embankments are suited to the conditions expected during construction. At the Dike the upstream embankment is first carried to Elev. 450 to provide a dam to create a reservoir 15 feet or more in depth and force the waters of Beaver Brook northerly into the Swift River, and also made of ample width to provide space for the contractor's operations.

The width of the upstream and downstream cofferdams in the toe embankments placed at each site is governed to some extent by the economy of providing a place to dispose of materials taken from the open-cut trench across the valley. This is satisfactorily accomplished in both cases with the embankment dimensions as shown.

The dimensions of the core depend a great deal upon the characteristics of the beach and core materials which are washed from the borrow pit materials used.

Estimates based on experimental as well as analytical studies indicate that for the materials available for construction of these embankments, and for the probable dimensions and quality of the cores to be obtained, the amounts of seepage or percolation through these dams when completed will be negligible. The amount of seepage under the dams and through the concrete core walls, of course, is problematical, but the author believes that this quantity will also be relatively very small.

The slopes designed assure stability during construction, there being an ample factor of safety in the ability of the shoulders to resist outward pressures from the pool. For instance, the construction as contemplated requires that the shoulder materials have only an angle of internal friction of about 30 degrees for stability, assuming the core liquid for the entire height of completed dam. The assumption is, of course, on the safe side, as there will be some consolidation of the core, and the methods of construction should easily yield, with the material available, shoulders having a friction angle well over 40 degrees. The recent method of analysis by Professor Gilboy, described in the July, 1934, JOURNAL of this Society, gave a graphical solution consistent with other determinations, although the author believes that the assumptions necessary for a solution by this method may prove too conservative for a determination of stability for use in governing construction.

The dams are to be built about 3 feet higher at the center than at the ends. Although it is anticipated that subsequent settlement will be slight (probably less than ½ to 1 per cent of the height), this camber of the top of each embankment will prevent the appearance of sagging of the top, which is the usual illusion in case of a structure built perfectly level.

ORGANIZATION

The Metropolitan District Water Supply Commission, composed of Eugene C. Hultman, chairman, Charles M. Davenport and Thomas D. Lavelle, has charge of the development of this new addition to the metropolitan district supply. Frank E. Winsor is chief engineer, Karl R. Kennison, assistant chief engineer, Charles L. Coburn and Stanley M. Dore, assistant designing engineers, and Walton H. Sears, mechanical engineer. The field work is divided among three division engineers: William W. Peabody, in charge of the Dam and Aqueduct division; Richard R. Bradbury, in charge of the Coldbrook-Swift Tunnel division of the Quabbin Aqueduct; and N. LeRoy Hammond in charge of the Quabbin Reservoir division. X. Henry Goodnough and Charles T. Main are consulting engineers, and Dr. C. P. Berkey is consulting geologist.

BIBLIOGRAPHY

No attempt is made in this paper to cover the details of any particular phase of the work, but merely to outline briefly many of the general interesting features relating to the design and to the progress on the construction of the dams for Quabbin Reservoir.

A very complete bibliography of papers written on the Metropolitan Water Supply is appended to that paper entitled "Boston Metropolitan Water Supply Extension," by Karl R. Kennison, printed in the "Journal of the New England Water Works Association," Vol. XLVIII, No. 2. It includes a paper by Frank E. Winsor, entitled "Boston's New Water Supply," appearing in the June, 1934, edition of "Civil Engineering."

Comparative Statistics of Large Earth Dams with Fine Earth Cores in the United States

H. — Hydraulic fill. S. H. — Semi-Hydraulic fill. R. F. — Rolled-fill.

Name	State	Type	Date Completed	Maximum Depth of Water (Feet)	Maximum Height of Dam Above Cut-Off Trench Bottom (Feet)	Freeboard Above Top of Flash-boards (Feet)	Width of Dam (Feet)					Length Along Top (Feet)	Cubic Yards Embankment including Refill of Cut-Off Trench
							Top	Flow Line	75 Feet Below Flow Line	100 Feet Below Flow Line	125 Feet Below Flow Line		
Cobble Mountain	Mass.	H.	1931	222	263	21	50	115	537	704	903	730	1,800,000
Calaveras	Cal.	S. H.	1925	210	240	10	25	80	492	650	788	1,260	3,085,000
El Capitan	Cal.	S. H.	1933	197	217	20	25	105	438	570	695	1,200	1,700,000
Saluda	S. C.	S. H.	1930	188	208	12	25	91	502	639	778	7,838	11,085,000
Davis Bridge	Vt.	S. H.	1924	186	214	8	25	69	482	627	790	1,250	1,900,000
Bouquet Canyon	Cal.	R. F.	1934	175	225	10	50	110	560	710	860	1,200	3,000,000
Necaxa No. 2*	–	H.	1909	164	200	16.4	54	136	511	636	761	1,220	2,144,000
McKay	Ore.	R. F.	1926	155	165	10.5	23.5	63	344	438	532	2,700	2,300,000
Proposed Quabbin Dam	*Mass.*	*H.*	*(?)*	*150*	*190*	*20*	*35*	*140*	*580*	*740*	*1,000*	*2,640*	*4,500,000*
San Pablo	Cal.	H.	1922	135	170	15	50	110	670	820	–	1,225	2,084,000
Paddy Creek	N. C.	S. H.	1919	126	185	24	20	133	532	660	792	1,472	1,446,000
Magic Reservoir	Idaho	S. H.	1910	125	135	10	40	95	580	715	–	625	540,000
Swinging Bridge	N. Y.	H.	1929	115	140	10	25	85	535	685	–	963	850,000
Proposed Quabbin Dike	*Mass.*	*H.*	*(?)*	*115*	*180*	*20*	*35*	*140*	*620*	*800*	–	*2,140*	*3,000,000*
Soft Maple	N. Y.	H.	1926	108	135	12.5	25	94	506	643	–	840.	860,000
Englewood	Ohio	H.	1922	106	124	16	30	89	575	775	–	4,750	3,600,000
Rocky River	Conn.	H.	1927	90	112	12	20	80	518	–	–	1,000	700,000†
Henshaw	Cal.	H.	1923	100	150	10	20	65	412	537	–	650	410,000
Somerset	Vt.	S. H.	1913	90	105	10	22	77	483	–	–	2,080	1,000,000
Scituate	R. I.	R. F. ‡	1927	87	180	13	37	111	564	–	–	3,200	2,500,000

* In Mexico. † Including dike. ‡ Shoulders placed in water.

THE MASSACHUSETTS HIGHWAY ACCIDENT SURVEY

By Colonel Robert C. Eddy* and Alexander J. Bone†

Editor's Note. — *The general features of the Massachusetts Highway Accident Survey were presented by Colonel Robert C. Eddy, Director, at a meeting of the Highway Section, Boston Society of Civil Engineers, on April 24, 1935. From Colonel Eddy's paper and the full reports of the Survey, Mr. Bone has prepared this article, which emphasizes the engineering features developed in the various studies carried out by the Massachusetts Highway Accident Survey.*

The Massachusetts Highway Accident Survey was organized in December, 1933, as a Civil Works Administration project under the supervision of the Massachusetts Institute of Technology. The Institute donated the services of the Director, Colonel Robert C. Eddy, who organized and carried out the work in co-operation with the State Departments of Public Works and Public Safety. Later the Survey was continued as an Emergency Relief Administration project until September, 1934, when the supervision of the Institute ceased and the work continued as two Federal Relief projects, one under the direction of the Department of Public Works and the other under the direction of the Department of Public Safety.

The purpose of the Survey was to obtain all possible information regarding the causes and circumstances attending highway accidents, and to propose remedies leading to a reduction in the number of these accidents.

The Highway Accident Situation

The seriousness of the highway accident situation is apparent to any one reading the newspapers, which report almost daily some loss of life or injury occurring upon the highways. Fig. 1 shows the trend of highway accidents in recent years compared with highway use as indicated by gasoline consumption and motor vehicle registration. During the period 1926 to 1933, the number of people killed as a result of highway accidents has varied between 795 and 769 per year, following

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† Instructor in Civil Engineering, Massachusetts Institute of Technology.

roughly the trend of the registration and gasoline consumption curves. In 1934, however, the number of persons killed increased sharply to 921. The total number of accidents of all kinds occurring upon state highways likewise shows a large increase from 3,639 in 1930 to 5,064 in 1933. As most state highways are rural roads carrying fast traffic, the speed factor appears responsible for this increase. One of the major projects

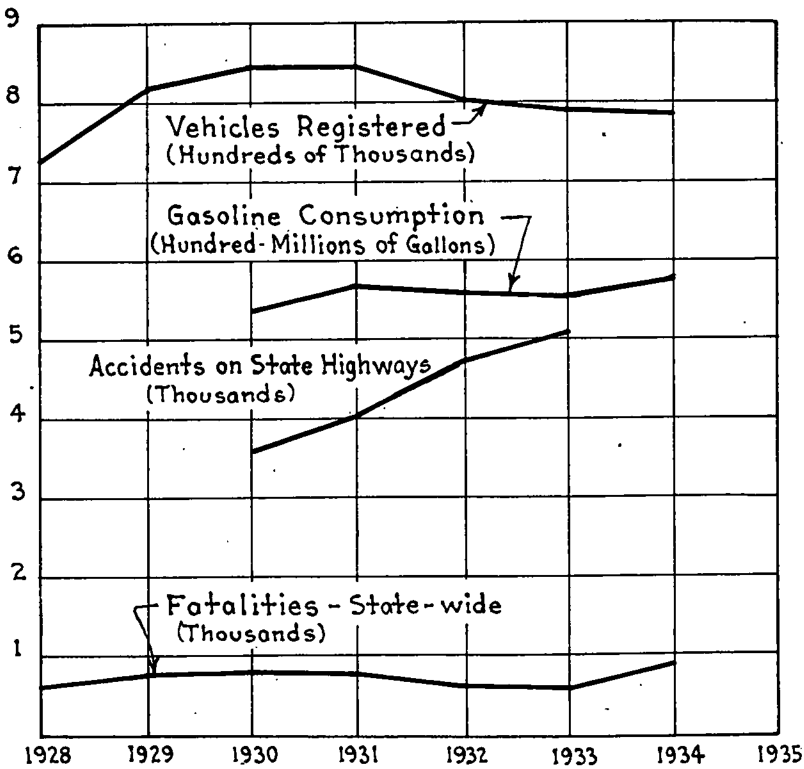


FIG. 1. — TREND OF HIGHWAY ACCIDENTS AND HIGHWAY USE IN MASSACHUSETTS

of the Survey was to determine the actual speed of cars on state highways under various driving conditions.

The worth of safety effort is illustrated by the examples shown in Figs. 2, 3 and 4. Fig. 2 shows the surprising fact that automobile fatalities among children have decreased during the last ten years, whereas fatalities among the supposedly more responsible adults have increased. The lower rate among children is undoubtedly the result of an effective

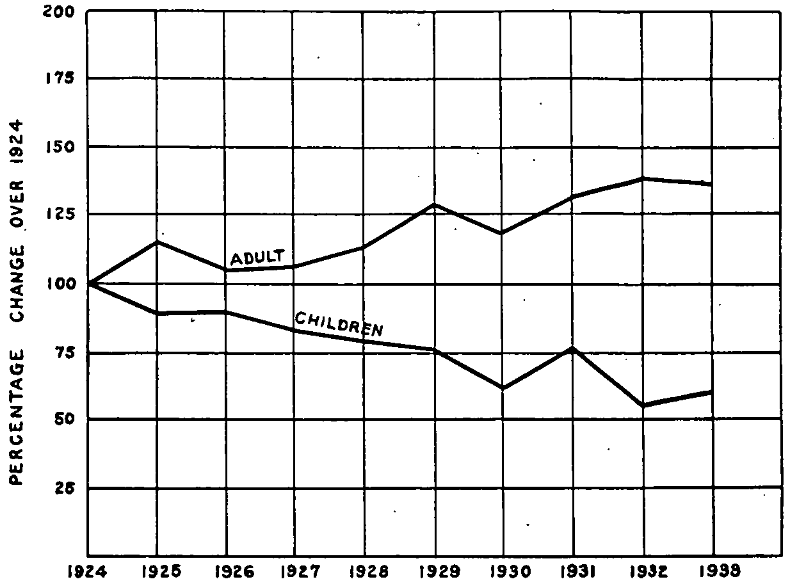


FIG. 2. — CONTRAST IN TREND OF ADULT AND CHILD TRAFFIC FATALITIES IN MASSACHUSETTS

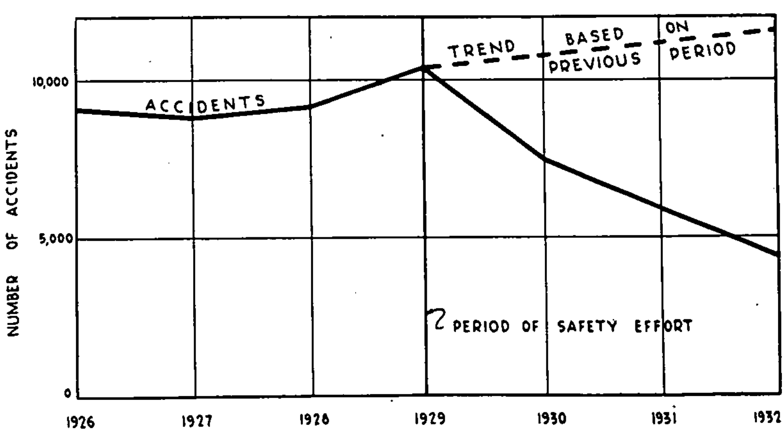


FIG. 3. — ACCIDENT RECORD OF GRAND RAPIDS, MICHIGAN, BEFORE, DURING AND AFTER 1929 SAFETY EFFORT

safety campaign in the schools. Fig. 3 shows the reduction in highway accidents accomplished by the city of Grand Rapids, Michigan, as a result of a planned safety program. Fig. 4 shows accident reduction in industry during the period 1926–34 compared with an increase in highway fatalities during the same period. Safety work in industry has long been well organized. Evidently there is a need for greater safety effort if the accidents on Massachusetts highways are to be reduced.

Winter Traffic Counts

In order to correlate highway accidents with traffic volume, a state-wide count of traffic was made in December, 1933, and again in

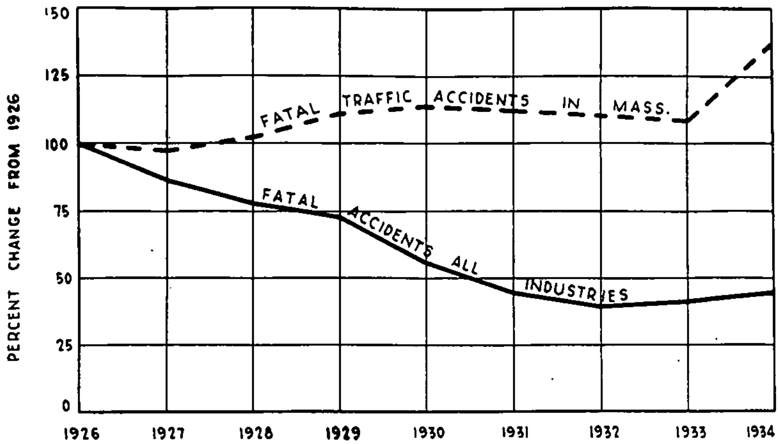


Fig. 4. — Comparative Success in Accident Prevention in Two Different Fields

January, 1934. The Department of Public Works has been making counts of traffic during one week in August at three-year intervals since 1909; but no state-wide counts had previously been made during the winter. The counts of the Survey were supervised by the traffic engineers in each highway district, and made to conform with the August counts, so that the winter and summer counts could be correlated and a fairly accurate estimate made of the seasonal variation in traffic flow and the total annual traffic for all state numbered routes. From these data state-wide traffic flow maps have been prepared showing average daily traffic for August, December and January, and annual traffic as of 1933. These traffic flow maps are not only useful in studying the highway accident problem, but are also essential in planning the highway construction program, for traffic control, and for economic studies.

Speed Studies

An extended study was made of the speed of vehicles on through routes in order to discover the speeds at which cars commonly travel on the straight stretches, called straight-a-ways, and at hazardous places, such as curves, intersections, railroad crossings, and other places where drivers might be expected to slow down. The studies were made in two parts, which are referred to as short time speed studies and continuous station speed studies. In the short time studies the speed of a sample of fifty cars was measured at each of 3,000 selected locations throughout the State. Traps were set under the direction of the State Police at the desired locations, and the times required by cars to pass over the length of trap (usually 220 feet) recorded. Later the times were converted into speeds in miles per hour. The traps were made as inconspicuous as possible, so that drivers would not be aware that they were being clocked. Recorders were instructed to record only cars which were running normally, *i.e.*, single cars or the first car of a string. In this way only volitional speeds were recorded.

Table I gives a summary of the average speeds found on straight-a-ways and at the different hazards investigated. Two sets of averages are shown for the hazards, — the first for approach speeds, and the second for speeds through the hazard. Inasmuch as a single average covers up the speed range and tells nothing about the speeds of the fastest and slowest cars, two additional average speeds are shown, one for the fastest 15 per cent and the other for the slowest 15 per cent of all vehicles recorded. At the right of the table is shown the "pace," *i.e.*, the range of speed within which most vehicles travel. Table I gives the results of observations made on week days only. Similar studies were made on Sundays. These observations showed a lower average speed on straight-a-ways (37 miles per hour instead of 39), and a higher speed through intersections (34 miles per hour instead of 32). Otherwise the results were quite similar to those in Table I.

TABLE I. — STATE-WIDE AVERAGES FROM SHORT TIME SPEED STUDIES, JANUARY TO MARCH, 1934

Summary by Different Hazards on Week Days

Location of Hazard	Average Recorded Speed in Miles per Hour								Per Cent of Average Through Speeds
	Approach to Hazard				Through Hazard				
	Low 15%	Fast 15%	Average	Pace	Low 15%	Fast 15%	Average	Pace	
Straight-a-ways	–	–	–	–	28	51	39	33–43	100
Public places	25	44	34	28–38	25	46	35	31–41	90
Schools	23	43	32	27–37	24	43	33	26–36	85
Hillcrests	25	47	36	32–42	23	46	33	29–39	85
Curve	25	45	34	29–39	24	41	32	27–37	82
Intersection	25	45	35	24–34	23	40	32	27–37	82
"Y" fork	23	43	33	28–38	24	41	32	27–37	82
Bridges	23	41	31	26–36	23	39	31	25–35	79
Underpasses	22	39	30	25–35	20	36	28	23–33	72
Railroad crossing	25	46	32	27–37	21	37	28	22–32	72

Vehicle speeds are so influenced by local conditions, such as the topography, type, width and condition of the pavement, and also by the nature of the traffic, whether long distance, commuting or pleasure-bound, that a consolidation of many local speed studies into general averages is less significant than an individual study where all the conditions are known. In order to make the best use of the speed data obtained from the short time counts, charts called speed-accident diagrams were prepared, which show a continuous profile of the speeds recorded at the different hazards and on the straight-a-ways along each highway route. The number of accidents are also plotted at their approximate locations with respect to the speed checking stations, and the traffic volume is also shown wherever it was measured. Fig. 5 shows the speed-accident diagram prepared for a portion of Route No. 1, the Newburyport Turnpike. This is a three lane highway carrying an average traffic of four to five million vehicles per year. The diagram for this route includes nearly every type of hazard, and clearly illustrates the influence of these hazards upon vehicle speeds. The small isolated circles on the speed diagram show the maximum speed recorded at each observing station — many of these fall within the 60–70 mile per hour range.

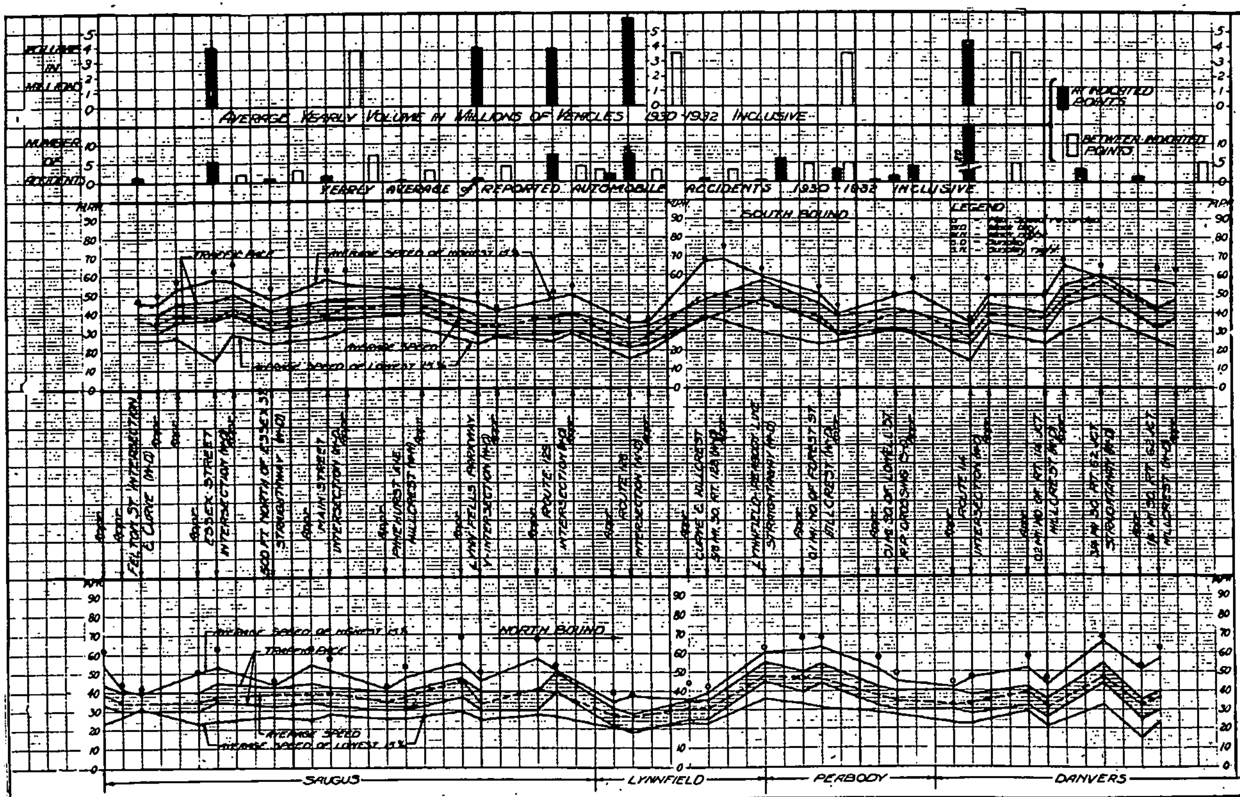


FIG. 5. — SPEED–ACCIDENT DIAGRAM.

Route No. 1 — Newburyport Turnpike — from Saugus–Melrose line to Danvers

In the continuous station speed studies, as many passing vehicles as possible were timed over periods of four to six hours at 260 selected locations on different state routes. The stations were located at straight stretches of road where speed might be excessive, at hillcrests where the view was limited, at sharp curves (less than 250-foot radius), and at long radius curves (over 250-foot radius). The periods covered by the studies were classified as follows: daytime, 8 A.M. to 2 P.M.; evening, 4 P.M. to 10 P.M.; night, 10 P.M. to 2 A.M.; and Sunday, 9 A.M. to 3 P.M. Studies were made on all types and widths of road surface commonly found on the highway system, including concrete, rough-textured macadam, smooth macadam, and for 2-lane, 3-lane and 4-lane widths. The speeds were measured from traps as described for short time speed studies. At the same time, the total number of vehicles passing the station was recorded, and also the number and nature of all driving violations observed. All observations were classified according to the type of vehicle, as follows: passenger car, light truck, heavy truck or bus.

As with the short time studies, each location proved to be a problem in itself, and general averages are not particularly significant. Table II shows state-wide averages, including all four types of locations separated according to the time of the studies.

TABLE II. — STATE-WIDE AVERAGES FROM CONTINUOUS STATION SPEED STUDIES

PERIOD OF OBSERVATION	Per Cent Violations	Average Speed	Average Speed, Top 15%	Average Speed, Low 15%	Pace	Maximum Speed	Minimum Speed
Daytime	3.49	33.1	43.8	23.3	28–38	75.0	10.0
Evening	4.73	32.8	43.8	24.1	27–37	81.0	10.0
Night	0.64	34.2	44.7	25.2	30–40	77.3	10.7
Sunday	5.59	32.3	43.2	24.4	28–38	81.0	10.0

Violations are recorded as the per cent of total traffic passing the station for which violations were observed. The highest average speeds were found for the night period. On the straight stretches the pace and the average of the fast 15 per cent of cars was slightly less at night, but over the hillcrests and around curves the pace and average speed of the fast 15 per cent was higher at night than in the daytime. Two possible explanations are offered for this. At night cautious drivers cannot see the hazard as well as in the daytime, and therefore come upon it faster than they otherwise would; on the other hand, drivers who want to drive fast may take advantage of the fact that the headlights of an approaching car show its presence around curves or over hillcrests before it could be seen in the daytime. This added protection against oncoming cars may encourage these drivers to maintain a greater speed over these hazards at night than in the daytime.

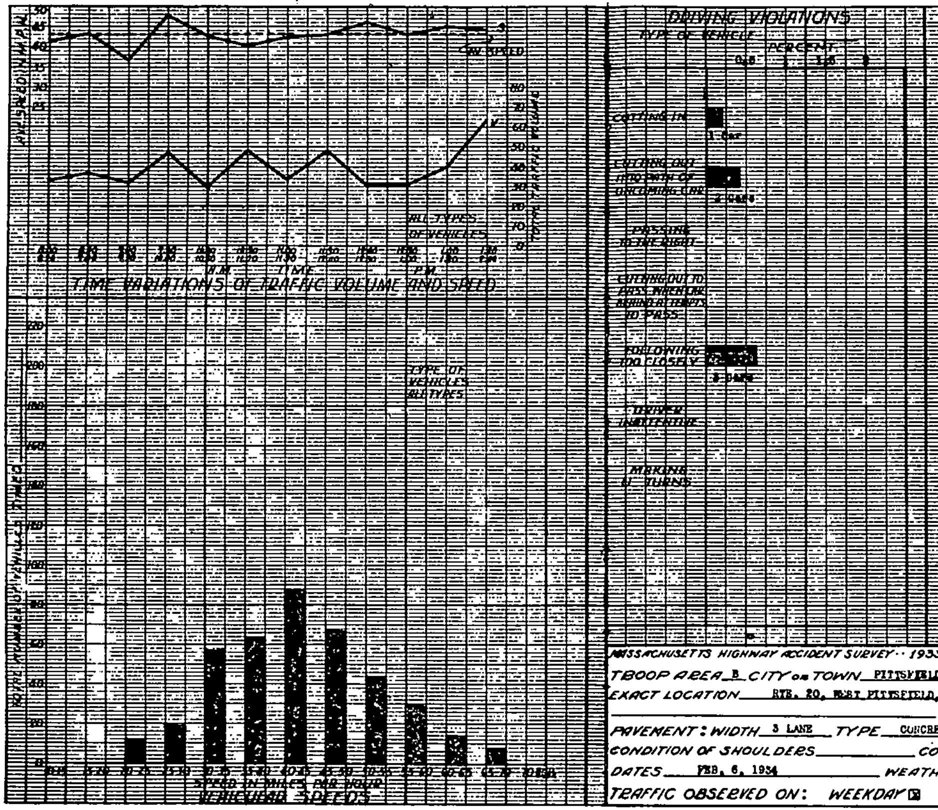
The results obtained at the individual locations were compiled and plotted on sheets similar to that shown in Fig. 6. This figure shows a typical summary sheet for all types of vehicles observed during a daytime study. It is but one of a set of such sheets which have been prepared for this station showing similar data compiled separately for passenger cars, light trucks, heavy trucks and busses, and also for evening, night and Sunday observations.

In order to show the relative speeds of passenger cars, trucks and busses on straight-a-ways, hillcrests and curves, Fig. 7 was plotted from observations at six typical stations at each of these locations. Differences in speed are often a contributory cause to highway accidents, particularly over hillcrests and at curves where the faster vehicles are held up by the slower ones because passing is hazardous. Under these conditions the drivers of the faster cars are tempted to take unusual chances in order to pass the impeding vehicles.

An inspection of Fig. 7 shows the bus to be the fastest vehicle on straight-a-ways and curves, but to be slowed down considerably by hills. The light truck (up to 2-ton capacity) maintains a speed slightly less than that of passenger cars. The heavy truck (over 2-ton capacity) is much slower, particularly at hillcrests. At certain locations where the grades are long and steep a greater spread in speed was found between the passenger cars and commercial vehicles than is indicated by the average curves in Fig. 7. For example, over the hillcrest in Topsfield on the Newburyport Turnpike, 90 per cent of all heavy trucks travel slower than the slowest passenger car.

The fact should be recognized that all speed studies were made during the winter months, January to March, 1934, when the temperatures were abnormally low and snow lay on the ground most of the time. The results obtained, therefore, may not be wholly representative of all year average speeds.

In order to obtain a more accurate determination of high speeds than could be expected from the trap method, an electrical speed measuring device was developed in co-operation with the staff of the Electrical Engineering Department of the Massachusetts Institute of



TOTAL TRAFFIC VOLUME BY LANES.

TYPE OF VEHICLE ALL TYPES

TIME OF DAY	W. BOUND RIGHT LANE	W. BOUND LANE LINE	IN CENTER LANE	E. BOUND LANE LINE	E. BOUND RIGHT LANE	TOTAL
A. M.						
8.00-8.30	15	1	4	6	7	33
8.30-9.00	21	1	4	5	6	37
9.00-9.30	18	0	2	3	9	32
9.30-10.00	21	3	1	17	5	47
10.00-10.30	14	0	0	4	12	30
10.30-11.00	23	5	0	3	17	48
11.00-11.30	14	1	0	[illegible]	16	[illegible]
11.30-12.00	22	0	0	1	25	48
P. M.						
12.00-12.30	12	0	0	2	17	31
12.30-1.00	16	1	0	3	11	31
1.00-1.30	18	2	[illegible]	2	17	40
1.30-2.00	26	0	[illegible]	7	27	[illegible]
TOTAL	220	12	16	57	169	
TOTAL TRAFFIC						474

Sheet 1 of [illegible] ③

MASSACHUSETTS HIGHWAY ACCIDENT SURVEY · 1933-1934 · DEPT OF PUBLIC SAFETY

TROOP AREA B CITY OR TOWN PITTSFIELD TRAFFIC STATION NO. 1-C-1

EXACT LOCATION RTE. 20, WEST PITTSFIELD, 1½ MILES EAST OF JUNCTION OF RTE. 41.

LOCATION TYPE STRAIGHT-A-WAY

PAVEMENT: WIDTH 3 LANE TYPE CONCRETE SURFACE CONDITION ICE

CONDITION OF SHOULDERS ____ CONDITION OF LANE LINES: ____

DATES FEB. 6, 1934 WEATHER FAIR

TRAFFIC OBSERVED ON: WEEKDAY ☒ SUNDAY ☐ NIGHT TIME ☐

FIG. 6. — TYPICAL SUMMARY SHEET FOR A CONTINUOUS STATION SPEED STUDY

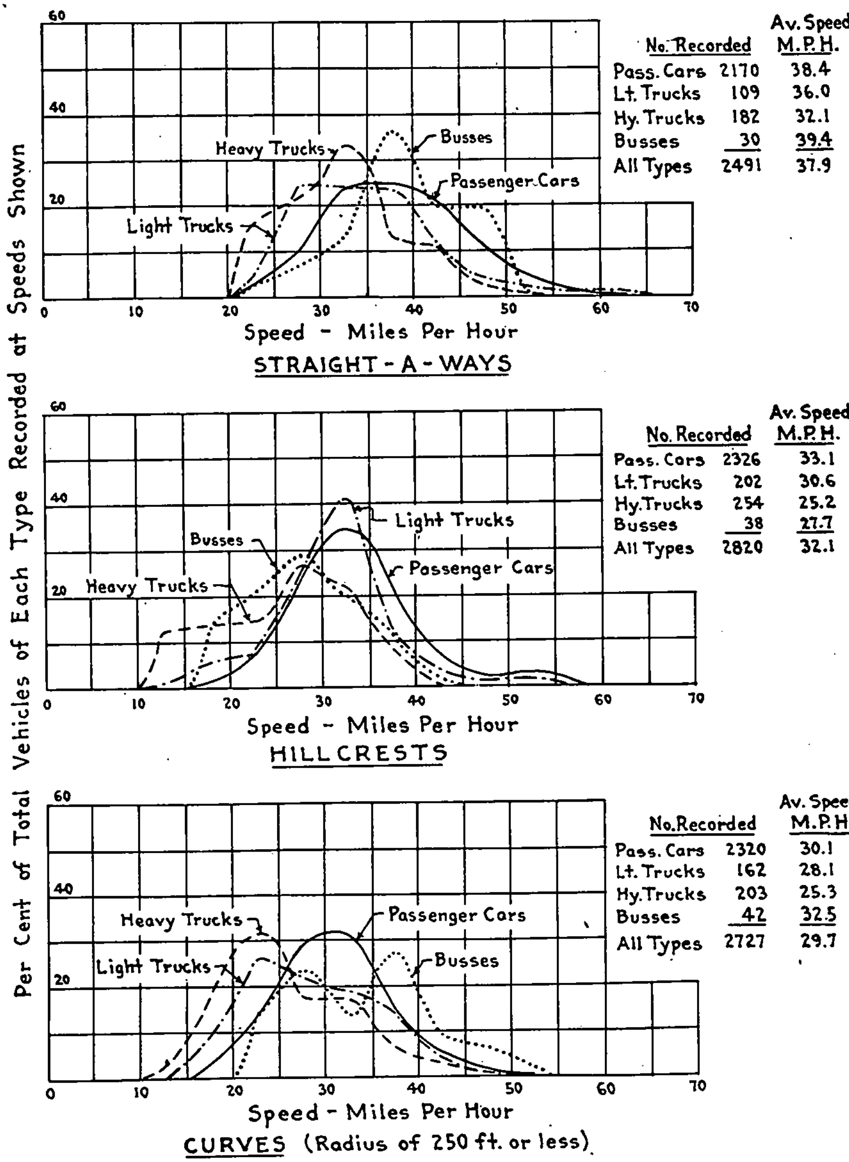


FIG. 7. — SPEED RANGE DIAGRAMS — COMPILED FROM RECORDINGS AT SIX TYPICAL LOCATIONS ON STATE HIGHWAYS FOR EACH CLASS OF HAZARD

Technology. This device records accurately the interval between passages of a vehicle over parallel bands placed across the roadway. From the known distance between bands and the time interval the speed can readily be computed.

Pedestrian Visibility and Highway Illumination

Great danger attends the pedestrian walking at night on the highway, particularly on unlighted, paved roadways carrying fast traffic. His safety depends to a great extent upon the distance at which he can be observed by the driver of an approaching car. Recognizing the importance of this factor, the Survey conducted a special study to determine this distance for a wide range of actual driving conditions. All tests were conducted at night, using the more common types of road surface (rough-textured macadam, smooth macadam and concrete), both lighted and unlighted, as well as with and without opposing headlights. The tests were made, first, with the pedestrian wearing dark clothes, and second, wearing varying sizes of white cloth or reflecting buttons.

A crew of three men was used for each test. One man acted as driver and observer of the pedestrian, the second man rode with the observer and recorded the data, and the third man acted as pedestrian. A second car was used to provide opposing headlights as desired. The test procedure was, roughly, as follows: the pedestrian stood at the right side of the road facing away from the direction in which the test car was to approach, the test car then retreated for a distance of about a half mile and then turned around and approached the pedestrian at a constant prearranged speed. When the driver first caught sight of the pedestrian he tapped his horn, at the sound of which the recorder started a stop-watch, which he stopped at the instant the test car passed the pedestrian. From the time interval so recorded and the speed of the test, the distance between the pedestrian and the test car at the time the pedestrian was first seen was computed. This distance was called the "visibility distance." Table III gives a summary of the average visibility distances obtained for lighted and unlighted road surfaces under the different test conditions.

From a pedestrian visibility standpoint the three types of surfaces investigated rank in the following order of decreasing visibility: concrete, rough-textured macadam, smooth macadam. For unlighted roads and no opposing headlights the difference in visibility distance between types of surface is slight, being 201 feet for concrete, 197 for rough-textured macadam, and 195 for smooth macadam. For lighted roads or with opposing headlights the concrete gives longer visibility distances than the other types, as indicated by the results in Table III.

In the presence of an approaching car with poorly adjusted headlights (that is, glare) all visibility distances were reduced. For example, the average visibility distance for unlighted surfaces, and with the pedestrian wearing dark clothing, was reduced from 197 to 125 feet, with a minimum observation of 28 feet for the most unfavorable condition. A car traveling at 40 miles per hour takes only 0.48 second to travel 28 feet. If the driver of such a car requires 0.6 second to react, it is evident that he could make no move to avoid an accident if a pedestrian should appear in his path at so short a distance.

The pedestrian can do much to protect himself on the highway. He has the ability to increase his visibility distance from 50 to 100 per cent by wearing light clothing or displaying an unfolded white handkerchief, or by using a reliable type of reflecting button.

Highway lighting as commonly installed was found to have but little effect upon pedestrian visibility when the pedestrian was between lights. In certain cases where the lights were far apart and of low intensity the pedestrian visibility was lower than on an unlighted road, because of the glare of the street lights. To be really effective as an aid to accident prevention, it was found that the highway illumination should be of sufficient intensity to allow driving with dimmed headlights. An example of excellent lighting of this type is the installation of sodium vapor lights on a portion of the Worcester Turnpike in Newton. A pedestrian visibility of 1,200 feet was found for this lighting, which is far in excess of any values given in Table III.

TABLE III. — GENERAL SUMMARY OF VISIBILITY DISTANCES, UNLIGHTED AND LIGHTED PAVEMENTS

Key to lamp spacing and rating:

(a) Average of 3 locations { 265 feet one side, rating 800 lumens; 500 feet one side, rating 800 lumens; 250 feet one side, rating 600 lumens }

(b) 1 location: 150 feet staggered, rating 6,000 lumens

(c) Average of 2 locations { 700 feet one side, rating 800 lumens; 525 feet one side, rating 800 lumens }

	Pedestrian wearing —			Average of A, B and C
	A, Dark Clothes	B, Small Area White	C, Large Area White	
1. No opposing car:				
Unlighted rough macadam	197	300	387	295
Unlighted smooth macadam	195	291	377	288
Unlighted concrete	201	320	393	304
Lighted rough macadam (a)	200	296	327	274
Lighted concrete (b)	253	288	340	294
Lighted concrete (c)	134	196	241	190
2. Opposing car with legal (normal) beam:				
Unlighted rough macadam	166	272	334	257
Unlighted smooth macadam	139	230	281	217
Unlighted concrete	172	284	348	268
Lighted rough macadam (a)	159	241	279	226
Lighted concrete (b)	296	318	301	305
Lighted concrete (c)	127	194	225	182
3. Opposing car with legal (depressed) beam:				
Unlighted rough macadam	184	292	356	277
Unlighted smooth macadam	178	285	347	270
Unlighted concrete	192	315	368	292
Lighted rough macadam (a)	173	288	318	265
Lighted concrete (b)	271	333	342	316
Lighted concrete (c)	134	210	253	199
4. Opposing car with illegal (raised) beam:				
Unlighted rough macadam	125	225	270	206
Unlighted smooth macadam	95	164	206	155
Unlighted concrete	147	252	301	233
Lighted rough macadam (a)	121	197	224	181
Lighted concrete (b)	271	291	289	284
Lighted concrete (c)	98	174	198	157

NOTE. — Pedestrian located midway between street lamps. Values are averages for all test speeds.

Reaction-Time of the Driver

A factor of great importance in the analysis of accidents is the reaction-time of the driver, *i.e.*, the time which elapses between the moment an operator sees a need for action and the instant when he is able to make physical response. One of the projects of the Survey was to determine this reaction-time for a large number of persons under actual driving conditions.

Special electrical apparatus was designed and built in the laboratories of the Massachusetts Institute of Technology for measuring the reaction-time interval, utilizing the time characteristics of a condenser discharging through a resistance. Most of the tests were made using two cars following each other in traffic. The timing device was installed in the leading car. Application of the brake to this car closed the stop light circuit and simultaneously started the measurement of the time interval. Upon observing the illuminated stop light of the leading car, the driver of the following car, who is the person under test, applied his brake. This operation emitted an electrical impulse which was picked up by a radio receiver in the leading car and terminated the measurement of the time interval. With these cars, 2,245 tests were made, using 180 different operators. The results of these tests are shown summarized in Table IV.

Table IV. — Summary of Reaction-Time Tests using Two Cars

	Number Tested	Reaction-Time (Seconds)		
		Average Minimum	Average Maximum	Mean
Professional drivers	37	0.478	0.674	0.565
Other men drivers	107	0.500	0.859	0.634
All men	144	0.494	0.811	0.616
Wellesley students	15	0.503	0.735	0.599
Other women drivers	21	0.607	1.090	0.795
All women	36	0.564	0.940	0.713
All drivers	180	0.508	0.837	0.636

The average reaction-time for all drivers tested was found to be 0.636 second. The professional drivers and the Wellesley student group had shorter than average times. Other men had about average, and other women had longer than average times. The range of reaction-times observed is shown by the curve in Fig. 8. In this plot the abscissæ correspond to seconds of elapsed time, and the ordinates represent the number of observations falling within each 0.020 second interval on the time scale. Fig. 8 shows that the greatest number of observations came within the 0.50 to 0.60 time interval, and also that there were many observations greatly exceeding the average. For example, about 25 per cent of the reaction-times observed exceeded 0.68 second, 10 per cent exceeded 0.85 second, and 5 per cent exceeded 1.00 second.

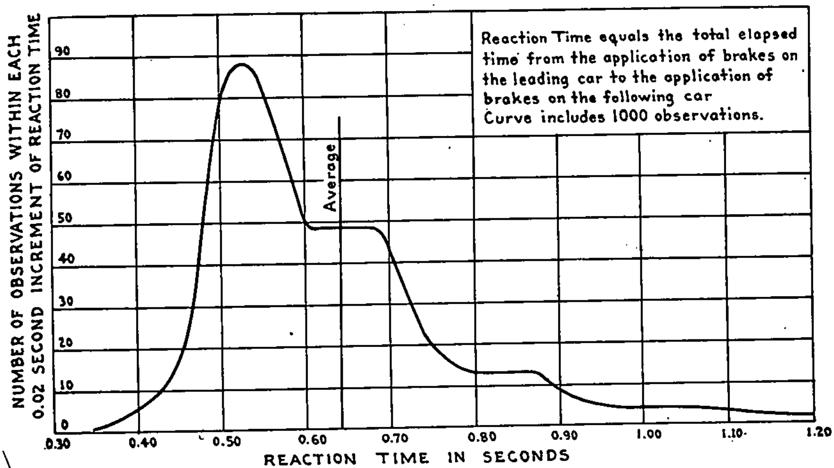


FIG. 8. — DISTRIBUTION OF REACTION-TIME OBSERVATIONS

The results discussed so far were obtained under short test conditions where the driver knew he was being tested, and was, therefore, unusually alert. Another series of tests was run over a course of about twenty-five miles, which more nearly approximated normal driving conditions, as the driver could not maintain unusual alertness throughout so long a test. The reaction-times obtained from these latter tests averaged 0.82 second, which probably more fairly represents the reaction-time of the average driver under normal conditions.

Other tests were conducted with the stop light on the leading car covered. Under these conditions many drivers required an average of one and one-half seconds to observe that the leading car was slowing down and to respond by applying their brakes.

The significance of the reaction-time is made apparent by considering the distances traveled at different speeds for the range of reaction-times as illustrated by the following table:

TABLE V. — DISTANCES COVERED AT DIFFERENT SPEEDS IN REACTION-TIMES

Speed (M. P. H.)	Distances in Feet for Reaction-Time in Seconds		
	0.5	1.0	1.5
40	29	59	88
50	36	73	109
60	44	88	132

Driving Habits and Law Observance

A program was developed in consultation with the Department of Public Safety, whereby over 3,000,000 observations were made on the highways to determine the extent to which motorists respect established traffic laws and regulations. The results of these observations are in the hands of the Department for their use in planning law enforcement and in recommending future legislation. The more common violations encountered are discussed below.

The observance of stop signs was noted for 75,000 cars entering main thoroughfares from intersecting ways marked by a "Stop and Enter" sign. Of these cars, over half failed to stop as required, and a third of those who failed entered faster than 15 miles per hour. Such signs were found to be much better observed in thickly settled than in sparsely settled regions.

Half a million vehicles were counted passing through intersections controlled by traffic signals. Of these, 8 per cent violated the signal. Half the violating cars overran the stop line, 10 per cent started early in anticipation of the "go signal," a quarter passed through in disregard of the red lights, and the remainder passed through in the change period.

In Massachusetts, when the paths of two vehicles cross at an intersection, the car which first enters the intersection has legally the right of way. In case two cars enter at the same time, the car on the right has the right of way. In a count of traffic at 140 selected intersections, over half the motorists who, with proper speed precautions, would have been entitled to the right of way were deprived of it by others who raced for it and took it.

Disregard of the dictates of safe driving, such as failure to keep to the right when the view ahead is obstructed, overtaking and passing another car at such a point, and stopping on the paved portion of the road, was observed at 500 locations. Half a million cars were checked and nearly a tenth of their drivers assumed grave risks in such violations of accepted rules of the road.

Characteristics of Motorists

A study was made of the driving characteristics of a representative sample of 10,000 licensed drivers, based upon the records of the Massachusetts Registry of Motor Vehicles. A tabulation was prepared of all accidents, court convictions for traffic offences, police and other complaints recorded against each driver of the sample 10,000. The results of this study lead to the following conclusions:

There is a wide variation in the tendency among drivers to have accidents. Some drivers are more prone to have accidents than others. Some such number as 1,500 of the 40,000 accidents recorded yearly in Massachusetts will be distributed among her 10,000 worst drivers, the rate being 15 per hundred. Some 6,000 accidents will be distributed among 90,000 drivers of intermediate driving quality, or 7 per hundred. The remaining 32,500 accidents will happen to the other 900,000 drivers, about 3½ per hundred. The margin of safety observed by each driver in his operation of a motor vehicle will determine the group in which he will be classified. Chance will determine who in each group or class will have the accidents in any year.

It is impossible, in advance, to point out any particular driver who is going to have an accident in a given year, and therefore impractical to rule any driver off the road on the grounds that he is about to have an accident.

It must not be inferred from this, however, that the recording of accidents and other evidence of dangerous driving is useless. On the contrary, not only must the accident-prone driver be found and dealt with, but all drivers must be brought to realize that the Registry is informed and takes cognizance of infractions of safe driving, and that no accident or complaint escapes attention. As the distribution of accidents is largely by chance, the only hope of effecting a substantial reduction is to persuade all drivers, and particularly those prone to accidents, to provide a larger margin of safety in their habitual manner of driving.

Eighty per cent, at least, of all accidents happen to drivers who have had no previous record. In most cases, one such experience is enough to teach the driver involved how to avoid further accidents. If a driver fails to benefit from one experience and repeatedly has accidents, then disciplinary measures must be used; but for the most part, the attitude of the Registry should be one of education and help.

A special study was made of a group of drivers involved in fatal accidents during 1933. This investigation showed that the fatal accidents were in most cases accompanied by excessive speed, and also that a disproportionate number of drivers under 25 years of age were involved. Whether an accident be fatal or not is again largely a matter of chance, except that the chances of fatal accident are greater for the fast driver than the more moderate driver.

Questionnaire Sent to Motorists

In order to obtain an expression of opinion from motorists regarding accident hazards and related factors questionnaires were submitted to 12,000 motorists selected to give a fairly representative 1 per cent sample of the driving public. A complete text of the questionnaire and a summary of the answers received is given in the Appendix.

The following replies to questions are of particular interest:

Fifty-one per cent of these motorists favor re-examination of operators at least every five years.

Eighty-one per cent feel that operators should not be permitted to drive before they are 18 years of age.

Eighty per cent favor inspection of cars at least twice a year.

Seventy-four per cent believe in erecting signs to show permissible speeds on the highways.

Ninety-two per cent recommend required hand or automatic signals to indicate turns or stops.

The high percentage of replies in favor of compulsory hand signals is interesting in view of the fact that the violation studies showed a general disregard for this rule on State highways where it is already compulsory.

General Conclusions

The following conclusions summarize the attitude toward accident prevention developed by those most intimately connected with the Survey.

The largest primary factor in highway accidents is the mental attitude of the driver. A certain small number of accidents occur through untoward circumstances which the driver could not possibly foresee. Sometimes brakes or steering mechanisms fail suddenly, rocks or trees fall into the roadway, hazards are mismarked in unexpected places; another car suddenly and unavoidably brings disaster to the most skillful and cautious driver. Except for accidents of this type, which are comparatively few, the driver can, if he is willing, avoid all accidents. No matter how bad the road, how sharp the curve, how blind the intersection; no matter how poor his brakes, how smooth his tires, how slippery the paving, he can, if he will, proceed safely. All these other factors in accidents are secondary in that they cause accidents through their effect on the driver. They are hazards only because they impose upon the driver delay which he finds irksome, so, to avoid delay, he takes chances that result in accidents when luck fails him.

All drivers believe they maintain a margin of safety in their driving, some a wider margin than others. Those who drive with less margin of safety are the accident-prone drivers. The margin of safety betokens a willingness to incur delay in the presence of a hazard in order surely to avoid an accident. Thus the mental attitude of drivers is the primary factor in accidents. It should be possible, through education in which law enforcement may take a prominent part, to instill in all drivers a greater willingness to preserve a wider margin of safety and thus reduce the number of accidents. This is the direct and most important approach to highway safety.

With a given margin of safety generally observed among drivers, the elimination of hazards is a means, not of avoiding accidents, but of expediting traffic. But the delay necessary to negotiate a hazard with safety is often vexatious, and drivers are prone to sacrifice their margin of safety rather than reduce speed. It is for this reason that elimination of a hazard, besides expediting traffic, reduces accidents.

Reduction of highway accidents thus falls into two fields, — education and engineering. In the educational field enforcement, that is, the imposition upon offenders of penalties, other than shock and damage of accident, will have a prominent part. Enforcement with an educational rather than a vindictive motive will seek a more nearly complete apprehension of all offenders, rather than severer penalties upon the few who are caught. Engineering directed toward the reduction of accidents must require for the vehicle greater dependability in brakes and other equipment; and for the highway greater uniformity and consistency in the treatment and marking of roadway hazards, in order that the driver may not suddenly encounter a hazard when a warning is reasonably to be expected.

Traffic Reports Prepared for Cities and Towns

As a result of the Survey, individual accident reports were prepared and submitted to the officials of the 281 towns and cities in Massachusetts. These reports deal with the specific accident and traffic problems encountered in each town or city, and include definite recommendations for improvement.

In preparing these reports the communities were first classified into six groups, designated A to F, according to the number of accidents recorded during the years 1930–33. Class F towns were those having from 1 to 5 accidents, class E from 6 to 25 accidents, class D from 26 to 100 accidents, and class C from 100 to 400 accidents. The class B and A cities both had over 400 accidents, but a more comprehensive study was made of the class A towns at the request of the local authorities.

The cities and towns for which the more complete studies were made are as follows: *

Plymouth	Everett	Lynn
Attleboro	Newton	Salem
Medford	Taunton	Fitchburg
Lowell	Gardner	Holyoke
Fall River	Lawrence	Pittsfield

These reports have been bound and published in mimeographed form by the Massachusetts Department of Public Works for distribution to those concerned with the accident and traffic problems of these communities. The reports, however, are of more than local interest, as they illustrate a practical and logical method for attacking the accident problem, which might well be applied to any community.

The subjects dealt with in these reports are briefly as follows:

An analysis of all accidents recorded during the years 1930–33.

Engineering studies of the community as a whole and at specific intersections, with recommendations for improving existing conditions.

An investigation of the parking problems wherever important.

Suggestions for more effective law enforcement.

Suggestions for an educational program for the reduction of accidents.

Suggestions for administering and financing accident prevention activities.

An outline for a scheduled program for the improvement of physical conditions now contributing to accidents.

* A report for Northborough has also been published as a sample of a typical "C" town report; it does not represent as complete a study as those published for the municipalities included in this list.

The material included in these reports may best be illustrated by excerpts and diagrams taken from them. Fig. 9 shows a composite accident summary for 89 cities and towns, each having from 26 to 100 accidents per year. Similar classifications were made for each accident group of towns or cities and for each community within the group. A comparison between individual cities and their group averages serves to bring out the particular type of accident which is peculiar to that town or city. Fig. 10 shows a classification chart for the city of Lowell. The striking feature of this diagram is the large number of pedestrian accidents. Fig. 11 was therefore prepared specifically for this city to show the nature of these pedestrian accidents.

The accident history of each community is also presented in tabular form as illustrated by the Accident Summary Sheet for the city of Lowell, Fig. 12. This chart covers a four-year period, from 1930 to 1933; similar charts have been prepared for each year within this period. The mass of valuable data contained in these summary sheets can only be appreciated by a careful study of them. They not only show the number of accidents which have occurred, but also the nature of the accident, the time of occurrence, and the relative frequency and severity of each kind of accident. In the lower right-hand corner is an approximate valuation of the economic loss due to highway accidents, shown in comparison with the meager expenditures for prevention and control.

In order to size up the accident situation in each city or town, accident spot maps were prepared which show the location of each accident by means of a dot plotted upon the street layout plan of the city or town. Clusters of dots appearing upon these spot maps indicate the places where accident studies are needed. Fig. 13 illustrates a spot map for Northborough, a town of about 2,000 population, having about 60 accidents per year. Fig. 14 shows a spot map for Lowell, a city of about 100,000 population, having about 900 accidents per year. An inspection of these two diagrams shows the marked difference between the accident problems of these two communities. In Northborough the accidents are concentrated along the heavily traveled, high-speed highways, Routes 9 and 20. In Lowell the concentration of accidents is at congested intersections in the business district.

At every intersection where several accidents have occurred, a special study was made of all the factors pertaining to these accidents.

Fig. 15 shows a typical intersection study. The diagram is divided into four parts corresponding to the four stages of the study. Part (*a*) shows a plot of the points of collision, so far as known, for each accident occurring at the intersection during the period under study. The date

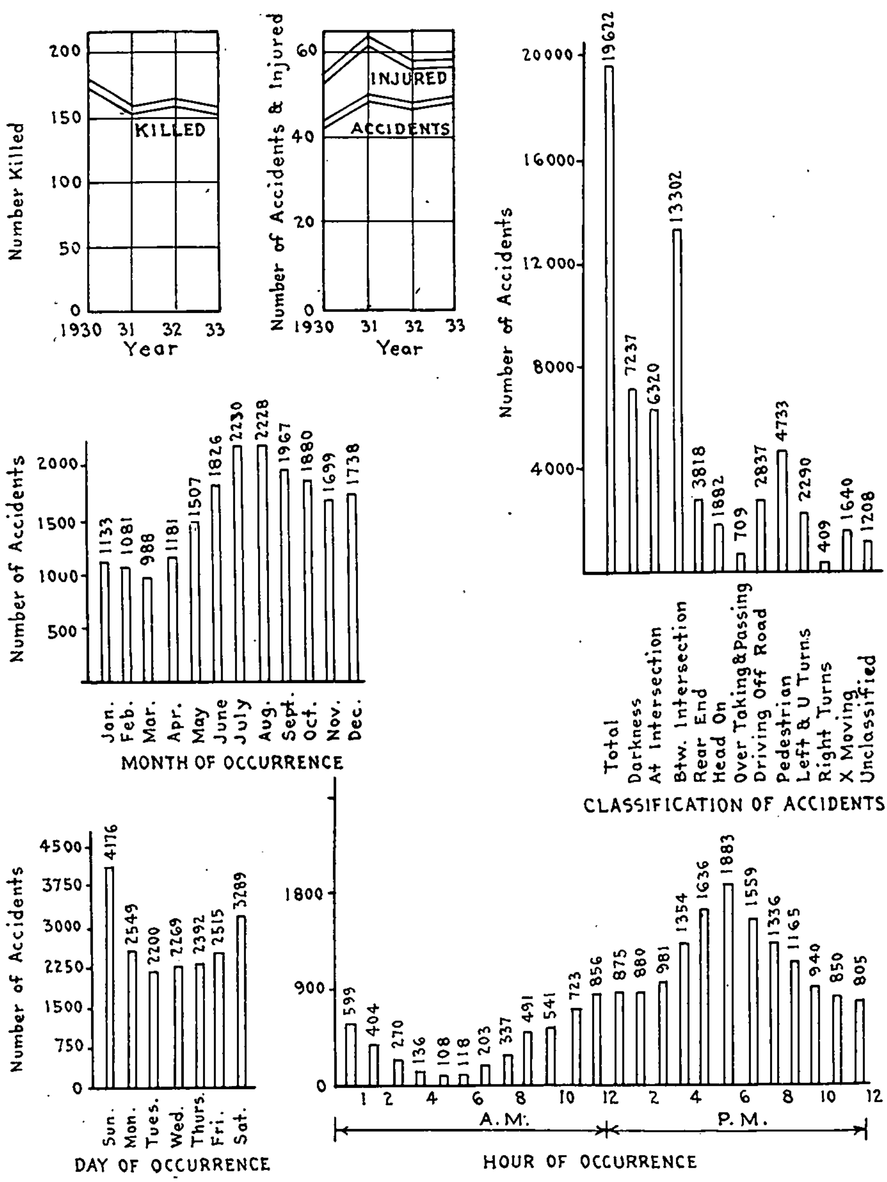


FIG. 9. — FOUR-YEAR (1930–1933 INCLUSIVE) SUMMARY OF 89 CITIES AND TOWNS, EACH HAVING FROM 26 TO 100 ACCIDENTS PER YEAR

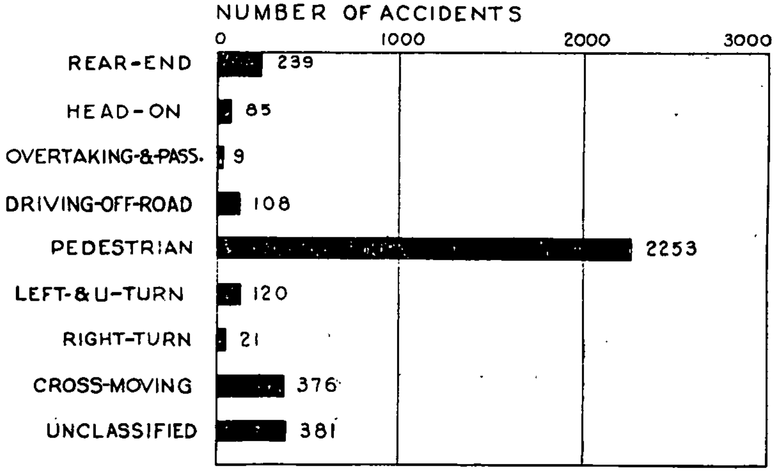


FIG. 10. — CLASSIFICATION OF ACCIDENTS, 1930–1933, FOR THE CITY OF LOWELL, MASSACHUSETTS

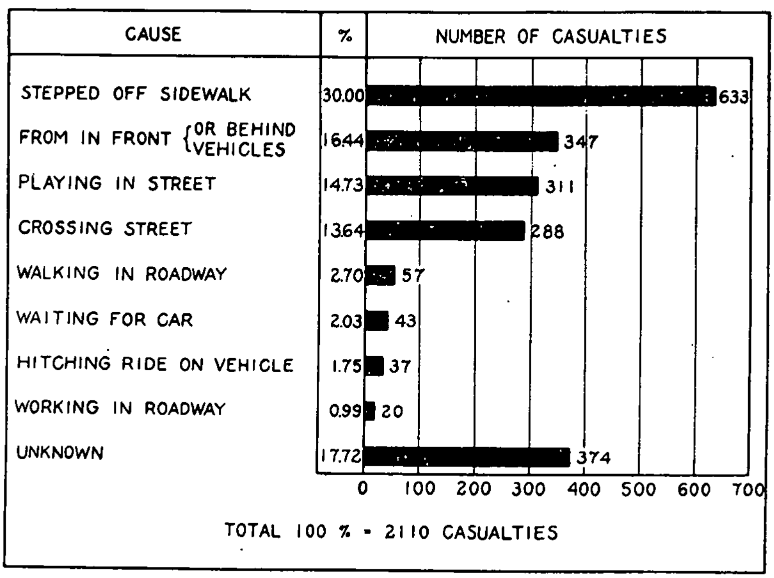


FIG. 11. — CAUSES OF PEDESTRIAN CASUALTIES, 1930–1933, FOR THE CITY OF LOWELL, MASSACHUSETTS

LEGEND
- Car in motion
- Car parked at side of Rd.
- Car stopped in R'dway
- Fixed object
- Pedestrian in R'dway
- Person other than Ped in R'dway (bicycle rider etc.)
- Car overturning

ACCIDENT SUMMARY

MILES OF HIGHWAY 232.0 LOWELL - 206 YEAR 1930-1933
ESTIMATED YEARLY VOLUME ____ VEHICLES ROUTE ____
MILLION VEH. MILES ____ SECTION ____

TYPE	CODE NO.		A AT INTERSECTIONS ACC.	VEH.	INJ.	KILLED	DARK	B BETWEEN INTERSECTIONS ACC.	VEH	INJ.	KILLED	DARK	TOTALS ACC.	VEH.	INJ	KILLED	DARK
REAR END	1		44	91	56		15	136	271	149		46	180	362	205		61
	2		9	19	7		4	26	50	21		17	36	69	23		21
	3		9	18	13		4	16	32	24		2	24	50	37		6
		TOTAL	62	128	76		23	177	353	194		66	239	481	272		88
HEAD ON	10		22	44	33		8	26	55	35		18	48	99	68		26
	11		19	20	18	3	10	18	20	27		10	37	40	45	3	20
		TOTAL	41	64	51	3	18	44	75	62		28	85	139	113	3	46
OVERTAKING & PASSING	20							4	8	5		4	4	8	5		4
	21		1	2	1		1	1	2	3		1	2	4	4		2
	22							1	3	1			1	3	1		
	23							2	4	3		2	2	4	3		2
		TOTAL	1	2	1		1	8	17	12		7	9	19	13		8
DRIVING OFF R'DWAY	30		2	3	1		1						2	3	1		1
	31		19	21	32	1	10	59	57	65	2	31	78	78	97	3	41
	32		13	14	16	1	6	15	17	20	1	2	28	31	36	2	8
		TOTAL	34	38	49	2	17	74	74	85	3	33	108	112	134	5	50
PEDESTRIAN	40		708	691	645	9	266	959	975	878	26	267	1667	1666	1523	35	533
	41		84	91	70	2	22	63	63	63	1	10	147	153	133	3	32
	42		74	70	72	1	26	189	192	176	6	54	263	262	248	7	79
	43	UNCLASSIFIED	52	53	45		21	124	125	116		30	176	178	161		51
		TOTAL	918	905	832	12	334	1335	1360	1233	33	361	2253	2216	2066	45	695
LEFT & U TURNS	50		35	69	53	1	13	9	20	10		4	44	89	63	1	17
	51		8	16	8		1	8	17	8		4	16	33	16		5
	52		27	55	35		5	1	2	1			28	57	36		5
	53		28	52	33		12	4	8	4		1	32	60	37		13
		TOTAL	98	192	129	1	31	22	47	23		9	120	239	152	1	40
RT. TURN	60		13	25	14		6	2	4	1			15	29	15		6
	61		5	11	11			1	2	6		1	6	13	17		1
		TOTAL	18	36	25		6	3	6	7		1	21	42	32		6
X MOV.	70		373	746	448	3	108	3	8	5		2	376	754	453	3	110
UNCL.	80		188	336	166		64	193	312	170		56	381	648	336		120
ACCIDENTS			1733					1859					3592				
VEHICLES				2447					2252					4699			
INJURED					1777					1791					3568		
KILLED						21					36					57	
DARKNESS							601					562					1163

ACCIDENTS BY MONTHS

January	211	May	304	September	368
February	192	June	315	October	369
March	207	July	302	November	321
April	254	August	390	December	365
No Date	4			Total	3592

PERCENTAGES

CLASSIFICATION TYPE	CODE NO.	ACCIDENTS NO.	% OF TOTAL	VEHICLES NO.	% OF TOTAL	INJURED NO.	% OF TOTAL	KILLED NO.	% OF TOTAL	DARKNESS NO.	% OF TOTAL
REAR END	1-3	239	7	481	10	270	8			88	37
HEAD ON	10-11	85	2	139	3	113	3	3	5	46	54
OVERTAKING & PASSING	20-23	9		19		13				8	89
DRIVING OFF ROAD	30-32	108	3	112	2	134	4	5	9	50	46
PEDESTRIAN	40-43	2253	63	2216	48	2066	58	45	79	695	31
LEFT & U TURNS	50-53	120	3	239	5	152	4	1	2	40	33
RT. TURNS	60-61	21	1	42	1	32	1			6	29
X MOV.	70	376	10	754	16	453	13	3	5	110	29
UNCL.	80	381	11	648	14	336	9			120	31
TOTAL		3592		4699		3568		57		1163	
AT INTER.	A	1733	48	2447	52	1777	49	21	37	601	17
BETWEEN INTER.	B	1859	52	2252	48	1791	51	36	63	562	16

SEVERITY

TOTAL	NUMBER	PER MILE	PER MILLION VEHICLE MILES	PER ACCIDENT
ACCIDENTS	3592	15.49	9.45	
VEHICLES	4699			1.31
INJURED	3568	15.38	9.39	.99
KILLED	57	.25	.15	.02
INJ. & KILLED	3625	15.63	9.54	1.01

ECONOMIC LOSS

ASSUMED AVERAGE VALUES

PREVENTION & CONTROL PER ACCIDENT	$ 35.00
DAMAGE PER VEHICLE INVOLVED	$ 30.00
MEDICAL CARE & TIME LOST PER INJURY	$ 175.00
COST TO COMMUNITY PER FATALITY	$ 5000.00

LOSS TOTALS

	NUMBER	AT	COST
ACCIDENTS	3592	$ 35.00	$ 125720.
VEHICLES	4699	$ 30.00	140970.
INJURED	3568	$ 175.00	624400.
KILLED	57	$ 5000.00	285000.
		TOTAL	$ 1176090.

LOSS RATES

$$\frac{\text{TOTAL COST}}{\text{MILES OF HIGHWAY}} = \frac{\$\ 1176090.}{232.0} = \$\ 5069. \text{ PER MILE}$$

$$\frac{\text{TOTAL COST}}{\text{MILLION VEHICLE MILES}} = \frac{\$\ 1176090.}{380.0} = \underline{\quad\quad} \text{ PER M.V.M.}$$

FIG. 12. — ACCIDENT SUMMARY SHEET, 1930–1933, FOR THE CITY OF LOWELL, MASSACHUSETTS

of the accident is also recorded, and, in brackets, the number of persons killed or injured. Part (*b*) shows the results of a 12-hour traffic count at the intersection. The width of the bands, plotted to a scale of vehicles, shows at a glance the relative traffic importance of the two streets and

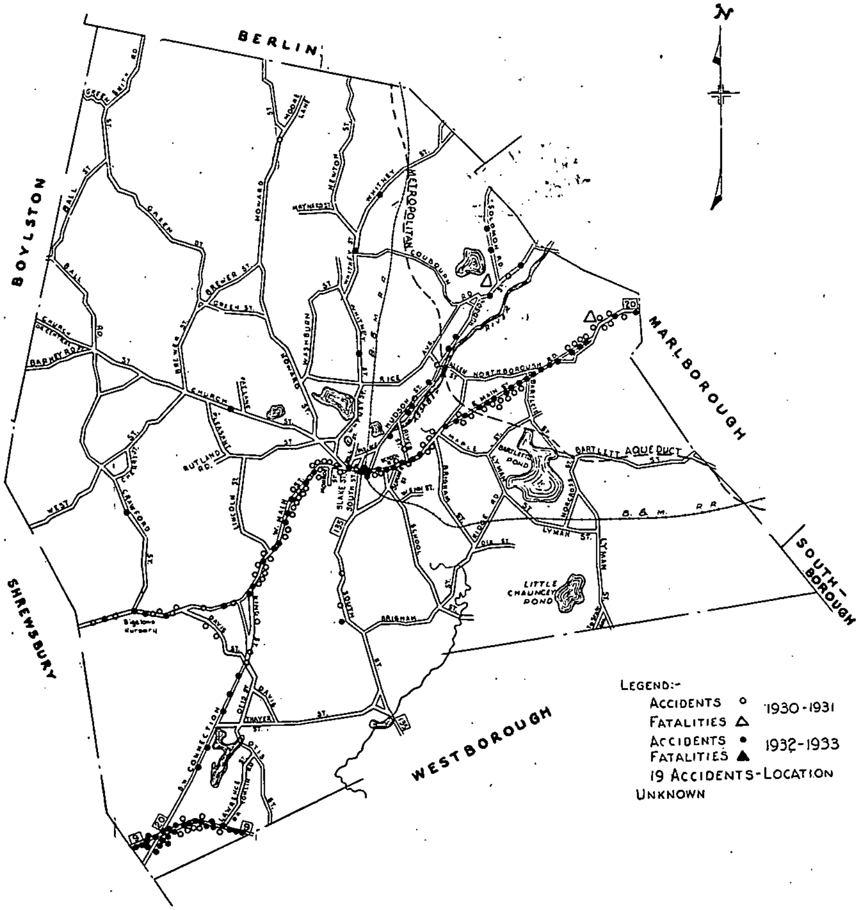


FIG. 13. — SPOT MAP OF NORTHBOROUGH, MASSACHUSETTS

the relative importance of the turning movements. In the same plot is a speed diagram showing the average speeds recorded for vehicles passing through the intersection. Part (*c*) shows the existing conditions at the intersection, emphasizing those features which may contribute to accidents. Part (*d*) indicates the recommended changes which should

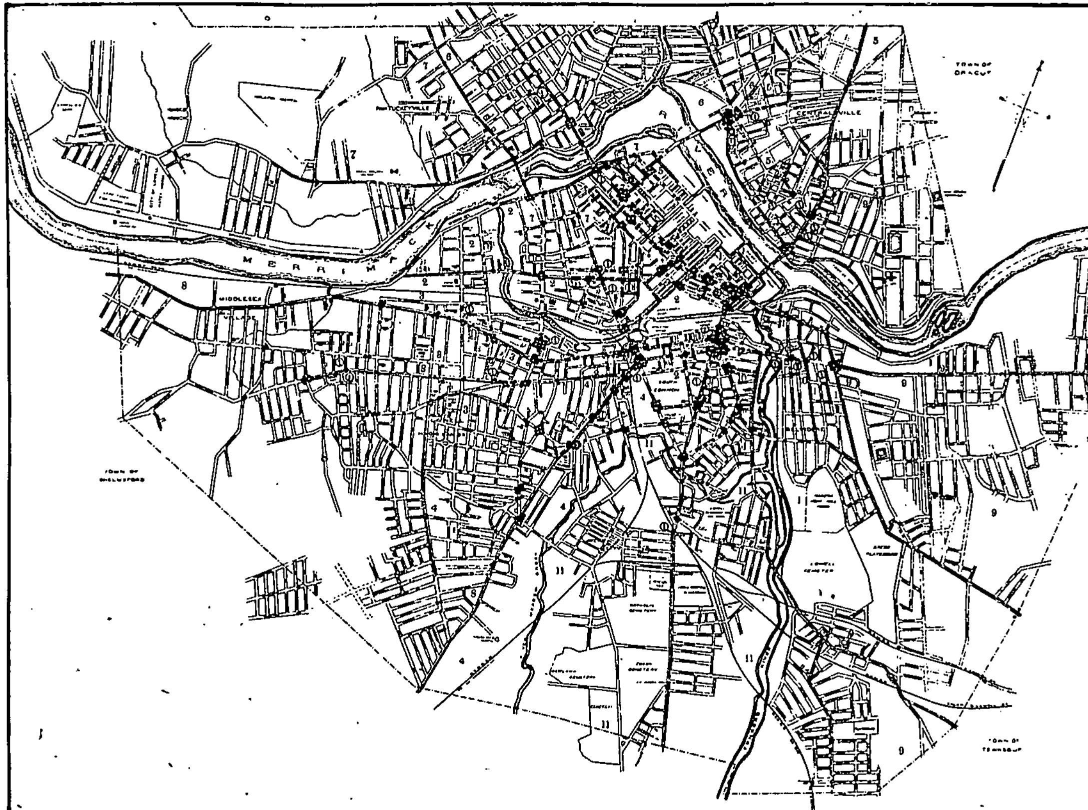


FIG. 14. — ACCIDENT MAP OF THE CITY OF LOWELL, MASSACHUSETTS

Dots show the locations of all accidents occurring during the period 1932–1933

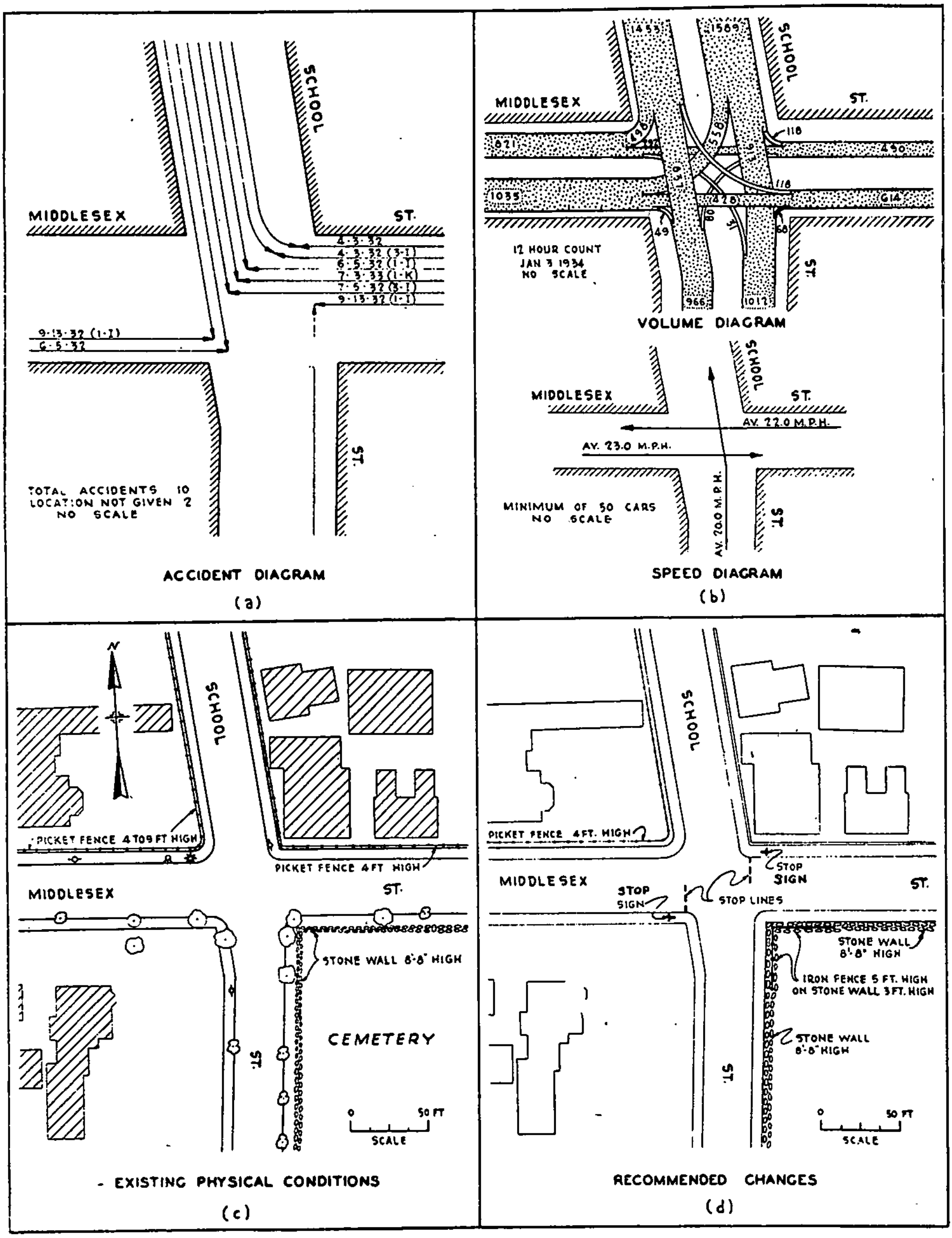


FIG. 15. — INTERSECTION STUDY AT SCHOOL AND MIDDLESEX STREETS, LOWELL, MASSACHUSETTS

be made to lessen the accident hazard at this intersection. In this case the recommendations include the erection of stop signs on the lighter traveled road, the painting of stop lines on this road, and the remodeling of the stone wall around the cemetery so that the view will not be obstructed.

The recommendations resulting from intersection studies of this nature vary according to the importance of the place and the seriousness of the accident record. In some cases improvement may be gained by merely painting lane lines or cross walks on the pavement; at other locations traffic signals are advisable; at still other places traffic circles are desirable; and in a few cases grade separations are recommended.

Each report is concluded with a plan for carrying out the recommendations made therein. The work to be done is scheduled in the order of its urgency or feasibility, and the program spread over a period of three to five years in order not to incur too great expense in any one year.

Much space in the reports is devoted to matters of law enforcement and administration. As these are not strictly engineering matters no further discussion will be made of them here. The necessity for more concerted effort for accident prevention and control cannot be denied. Fig. 16, taken from the Lowell report, shows a comparison between monetary accident losses and prevention expenditures for twelve Massachusetts cities. The economic losses computed in this figure are based on the assumptions stated on the summary sheet, Fig. 12. For every city the loss sustained shows an increase for 1933 over 1932, whereas all but two cities show a curtailment in accident prevention expenditures. Surely greater expenditures are justified to reduce the accident toll. A sum of money is but a paltry substitute for human life or injury. A life once lost or a body maimed cannot be reclaimed at any price.

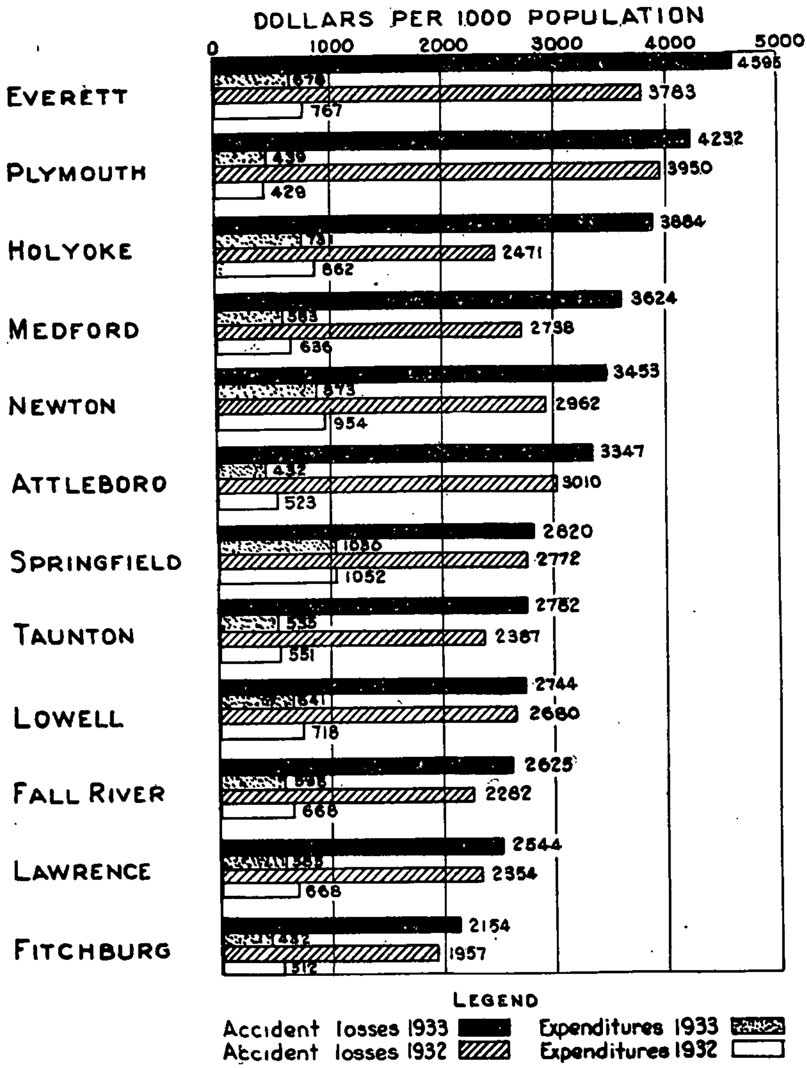


FIG. 16. — MONETARY ACCIDENT LOSSES AND PREVENTION EXPENDITURES FOR TWELVE MASSACHUSETTS CITIES, YEARS 1932–1933

Appendix

QUESTIONNAIRE SENT TO MOTORISTS AND ANALYSIS OF REPLIES RECEIVED

Question 1. Do you believe it advisable to re-examine operators at stated intervals?

		Per Cent
"Yes"	6,084	51
"No"	5,964	49
No statement	79	–

Comments:
"Re-examine on suspension of license."
"Present examination should be more extensive and thorough."
"Would develop into another racket to get money from motorists."

1A. How often?

		Per Cent
Re-examination every 5 years	2,181	40
Re-examination every year	927	17
Re-examination every 2 years	843	15
Re-examination every 3 years	810	15
Re-examination after every accident	465	8
Re-examination every 10 years	259	5

Question 2. Do you believe applicants should be required to present a certificate from some recognized or state-operated training school?

		Per Cent
"Yes"	1,840	15
"No"	10,135	85
No statement	152	–

Comments:
"Yes, because they would be more thoroughly trained."
"Subject to abuse."
"Too expensive."

Question 3. At what age do you think applicants are sufficiently mature to represent a good safety risk?

		Per Cent
16 years	2,006	17
17 years	275	2
18 years	5,272	53
19 years	160	1
20 years	813	7
21 years and older	2,413	20
No statement	188	–

Comments:
"Depends on the individual."
"Not a question of age but of driving ability."
"Depends on sight and strength."

Question 4. Do you believe that a reduction in insurance premiums for good drivers and an increase in premiums for careless drivers would help to prevent accidents?

		Per Cent
"Yes"	10,291	86
"No"	1,616	14
No statement	220	–

Comments:

"Yes, but would be impossible to administer fairly."

"It would lead to graft."

"Plan would be too difficult to apply in practice."

"Believe in a flat rate of insurance for every one regardless of where he lives."

Question 5. What penalties would you suggest to help cure drivers of their careless habits?

		Per Cent
Suspension of license for varying periods	5,817	49
Fines in varying amounts	1,605	13
Enforcement of present laws	1,145	10
Revocation of license for continual carelessness	850	7
Higher insurance charges for carelessness	689	6
Jail sentences	548	5
Stop police from fixing cases	503	4
Suspension of registration plates	279	2
Suspension of second offenders	266	2
Written warning from Registry	245	2

Question 6. Do you believe that some system of merits for good drivers and demerits for careless drivers would help to reduce accidents?

		Per Cent
"Yes"	7,175	62
"No"	4,515	38
No statement	437	–

6A. What do you suggest?

Suggested Merits for Good Drivers

Reduction in insurance premiums	1,665
Some insignia on car	909
Driving qualifications on license	302
Basing merits on yearly record	176
Pins for drivers without accidents for one year	151
Certificate of good driving from Registry	145

Suggested Demerits for Careless Drivers

Increase in insurance premiums	1,151
Suspension of license	512
Some insignia on car	472
Accident record on back of license	463
Base demerits on yearly record	183
Increase license fee	150

Question 7. Is the present method of inspecting cars and equipment adequate?

		Per Cent
"Yes"	7,655	64
"No"	4,269	36
No statement	203	–

7A. If not, why?

Not thorough enough	1,783
Not often enough	1,307
Examination should be made by state officials	714
Too lenient	372
Present system corrupt	371
Garage men give stickers to friends without inspection	231
Stickers sold without examination	194
More supervision by Registry	171

Question 8. Should there be inspection of the following parts of an automobile which are not now required by law?

		Per Cent
Tires:		
"Yes"	6,120	53
"No"	5,442	47
No statement	565	–
Rear-vision mirror:		
"Yes"	8,607	74
"No"	2 948	26
No statement	572	–
Visibility through windshield:		
"Yes"	9,267	80
"No"	2 263	20
No statement	597	–
Bumpers:		
"Yes"	5,431	48
"No"	5,883	52
No statement	813	–
Stop light:		
"Yes"	9,786	84
"No"	1,850	16
No statement	491	–
Anything else?		
"Steering gear"	1,105	
"Horn"	95	
"Mechanical condition"	85	
"Wheels"	83	
"Front system"	25	
"Bumper height standardized"	21	

Comments:

"Any person operating a car with old or worn tires should drive accordingly."

"Rear window should be free from any obstruction which would tend to block the view."

"Stop light for the lazy driver who does not give hand signals when slowing down or making a turn."

"Increase insurance premiums for drivers who do not keep their equipment in condition."

Question 9. How often should car inspection take place?

		Per Cent
Every 3 months	1,736	15
Every 4 months	931	8
Every 6 months	6,713	57
Every 12 months	2,329	20
No statement	418	–

Comments:

"Three months for lights, 6 months for brakes, 12 months for other equipment."

"Have motor vehicle inspectors on the road and examine cars without publicity or warning."

"Cars should be inspected on a mileage basis, suggest every 5,000 miles."

"Should be inspected immediately after being involved in an accident."

Question 10. Do you think the responsibilities of pedestrians and motorists on highways are clearly understood: By motorist? By pedestrians?

		Per Cent
By motorists:		
"Yes"	7,159	61
"No"	4,577	39
No statement	391	–
By pedestrians:		
"Yes"	3,820	33
"No"	7,905	67
No statement	402	–

Comments:

With reference to motorists:	
More publicity concerning traffic laws	823
No regard for rights of others	596
Carelessness	429
Negligence	357
Indifference to laws	167
Motorist thinks he has right of way	151
Not alert at all times	124
Take too many chances	118
With reference to pedestrians:	
Careless in crossing streets	1,355
More publicity regarding traffic laws	1,218
Make pedestrians observe traffic lights	777

Comments — *Con.*

With reference to pedestrians — *Con.*

Pedestrians disregard rights of others	504
Jay walkers should be penalized	452
Negligence	378
Pedestrians should assume more responsibilities	374
Pedestrians think motorists should look out for them	351
Pedestrians should face on-coming traffic	288

Question 11. Should schools be required to teach children accident prevention?

		Per Cent
"Yes"	11,204	97
"No"	391	3
No statement	532	–

Comments:

"Schools should be encouraged but not required to teach accident prevention."
"Should be taught to obey traffic lights and cross the street only at crossing."
"Handle through Boy and Girl Scouts' meetings."
"Parents should teach safety."
"Who is to teach the teacher?"

Question 12. How efficient are police officers in directing traffic?

		Per Cent
"Excellent"	3,785	32
"Average"	7,342	61
"Poor"	825	7
No statement	175	–

Comments:

"Efficiency depends entirely on individual officers."
"Excellent as a rule — greatly improved during the past few years."
"City police excellent, suburban police poor."

Question 13. Are police officers' signals to motorists excellent, average, poor?

		Per Cent
"Excellent"	3,314	28
"Average"	7,310	61
"Poor"	1,332	11
No statement	171	–

Comments:

"Not uniform; police should use uniform signals."
"The efficiency of police would increase if they had shorter periods directing traffic."
"Traffic officers should be changed from time to time, as they become stale on the job in the same place."

Question 14. What suggestion do you make for improving traffic handling: By State Police? By Local Police?

With reference to State Police:

More officers	769
Should make slow drivers keep to right	335

With reference to State Police — *Con.*

More strict	303
Should make slow drivers speed up	290
Should increase general speed	290
Should be on the road instead of in ambush	220
More attention to speeders and those cutting out of line	206
More uniform system	171
Better schools for police	123

With reference to Local Police:

More training in handling traffic	779
More officers	609
Better traffic signals	548
Greater attention to duty	506
More strict	392
Lax in enforcing parking rules	255
More courteous	191
More uniform system	140
Officers in congested area	126
Model traffic handling after State Police	118

Question 15. How is traffic at city street intersections best controlled: By traffic officers? By automatic traffic lights?

		Per Cent
By traffic officers	4,129	35
By automatic lights	7,599	65
Combination	185	–
No statement	584	–

Comments:

Favor lights uniformly timed	553
Use of lights or officers depends on locality or conditions	518
Officers should be used at busy intersections	515
Motorist has more respect for officers than for lights	503
Combination automatic lights and officers at busy intersections	461
Officers speed up traffic	457
Lights fair to all traffic	414
Direction by officers more flexible	355
Lights do not make mistakes; officers do	315

Question 16. How is traffic best controlled where side roads meet main highways: By blinker signals? By automatic lights? By stop and enter signs?

		Per Cent
"Blinker signals"	2,063	17
"Automatic lights"	3,775	30
"Stop and enter signs"	6,553	53
"Combination"	406	–
No statement	214	–

Comments:

"Kind of signal depends on conditions and location."

"Monitor-controlled lights are best."

"Stop and enter signs are least expensive and will be just as effective if backed up by police prosecution upon failure to obey."

"Blinker signals where traffic is light. Automatic lights where traffic is heavy."

Question 17. In general, are automatic lights and flashing beacons properly located?

		Per Cent
"Yes"	10,508	89
"No"	1,278	11
No statement	341	–

Comments:

"They should be uniform in structure and location."

"Lights should be in center of intersection."

17A. Do you think there are enough of them?

		Per Cent
"Yes"	6,541	56
"No"	5,076	44
No statement	510	–

Comments:

"Should be more flashing beacons but fewer automatic lights."

"Establish definite right of way at intersections and enforce it."

"Too many lights. Stop and enter signs could take care of many places."

"Too many stop and enter signs, which require a full stop when often there is no need."

"In most cases yes, but none of these should be placed until after a careful traffic study has been made."

Question 18. Do you think there are enough or too many highway signs indicating curves, intersections, school zones, etc.?"

		Per Cent
"Not enough"	5,670	48
"Enough"	5,911	50
"Too many"	188	2
"No statement"	358	–

Comments:

"Enough; but in many cases they are placed too close to the danger spot."

"Entirely too many. Such signs divert drivers' attention from road."

"The disadvantage of too many signs is that there is a tendency to ignore them. Fewer but more important signs better."

18A. Are they properly located?

		Per Cent
"Yes"	10,471	90
"No"	1,155	10
No statement	501	–

Comments:

"On the whole, very good, but their locations should be uniform where possible."

"Too near danger point for fast driving."

18B. Are they properly worded?

		Per Cent
"Yes"	10,800	93
"No"	812	7
No statement	515	–

Comments:

"Should more clearly define danger, such as steep grade, sharp turn, etc."

"They should be more uniform."

"In most cases, yes; sometimes vague."

"A national code would be better."

18C. Do they stand out?

		Per Cent
"Yes"	9,547	82
"No"	2,065	18
No statement	515	–

Comments:

"Not all are good for night driving."

"Signs should be of the reflecting type."

"Signs are not uniform and therefore lose some of their force."

Question 19. Do signs similar to those used in Rhode Island showing permissible speeds on the highway help to prevent accidents?

		Per Cent
"Yes"	8,208	74
"No"	2,917	26
No statement	1,002	–

Comments:

"Yes; if the permissible speed is sensible and not 10 or 15 miles per hour, it might be effective."

"Yes; these signs practically control speed."

"They tend to make one speed-conscious."

"Reasonable but unenforceable."

"No; they merely slow down those who want to obey the law."

Question 20. The law now requires hand or automatic signals indicating turn or stop on state highways where another vehicle is involved.

20A. Is this a reasonable requirement?

		Per Cent
"Yes"	11,465	96
"No"	539	4
No statement	123	–

20B. Should this be extended to cover all roads?

		Per Cent
"Yes"	10,899	92
"No"	953	8
No statement	275	–

20C. Since hand signals are inconvenient in closed cars in cold or rainy weather, should automatic signal equipment be required?

		Per Cent
"Yes"	4,294	36
"No"	7,579	64
No statement	254	–

Comments:

"If not too expensive for all motorists."
"Direction arrow as used on trucks best type."
"A stop light in working order would take care."
"If uniform throughout the country."
"Automatic equipment is not always reliable."
"A window can be easily lowered."
"Inconvenience is less important than safety."
"A hand signal is a conscious motion of the driver and an automatic signal is not."
"Would be just one more automatic device to get out of order."
"No, except on busses, large vans and trucks."

Question 21. Please list below any locations which in your opinion present unnecessary traffic risks, giving reason.

Locations reported as traffic hazards	1,790
Intersections reported as traffic hazards	1,595
Counties where traffic hazards were reported	11
Cities and towns where traffic hazards were reported	113
Persons reporting traffic hazards	5,676
Persons making specific suggestions for improving hazards	2,587

The information regarding these locations has been tabulated, placed on file, and submitted to the cities and towns where they exist.

Of General Interest

INSPECTION TRIP AND OUTING OF BOSTON SOCIETY OF CIVIL ENGINEERS AND SANITARY SECTION, B. S. C. E.

The regular meeting of the Boston Society of Civil Engineers was omitted in June, and in place of the meeting the Society made an inspection trip to the new Salem and Beverly water treatment plant in Beverly, on Saturday afternoon, June 22, 1935. This trip was made jointly with the Sanitary Section of the Society. About seventy members and guests visited the plant.

The plant is located on the shore of Wenham Lake, one of the sources of water supply for the cities of Salem and Beverly, at the end of Arlington Street, Beverly. The pumping station is located near by for pumping water from the lake to the city mains.

This new purification plant is being built under the direction of the Salem and Beverly Water Supply Board, created under the provisions of chapter 700, Acts of 1913, through whose courtesy the Society was privileged to inspect the work. The Board consists of Charles Ross, Esq., of Boston, chairman; Frank P. Morse, city engineer of Salem; and James W. Blackmer, commissioner of public works of Beverly. The design and general supervision of construction was executed by Metcalf & Eddy, consulting engineers. Data regarding the plant were prepared and circulated to members and guests by Mr. Frank L. Flood, from the office of the consulting engineers.

This work is being done as an E. R. A. project, under the jurisdiction of this Board. The plant has a capacity of 9.6 million gallons per day. A low-lift pumping station draws water from the lake. Points of interest were the mixing tanks, coagulation basins, filters and filtered water reservoir. The main building, housing the offices, laboratory and mechanical equipment, is of attractive design adapted to the needs of the plant.

Following the inspection trip the members assembled at Salem Willows for an *Outing* — where bathing in Salem's newly developed salt water basin, tennis, horseshoe pitching and other sports were enjoyed. One of the famous shore dinners at "Ebsens" Restaurant was enjoyed by forty-five members and guests.

The plans for the inspection trip and outing were arranged by the Social Activities Committee, consisting of John H. Harding, chairman, Edward F. Kelley and Joseph A. O'Hearn, with the addition of Frank L. Flood, A. B. Edwards, S. Coburn, J. B. Babcock and E. N. Hutchins.

Boston Society of Civil Engineers Scholarship in Memory of Desmond FitzGerald awarded to Kenneth F. Knowlton, Student at Northeastern University

Kenneth F. Knowlton of Natick, fourth-year student in Civil Engineering in the School of Engineering at Northeastern University, was awarded the Desmond FitzGerald Scholarship of the Boston Society of Civil Engineers on April 24, 1935. The presentation of the Scholarship of $100 was made at a meeting of the students of the school at Jordan Hall, by Prof. John B. Babcock, 3d, of Massachusetts Institute of Technology, President of the Boston Society of Civil Engineers.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

APRIL 17, 1935. — A regular meeting of the Boston Society of Civil Engineers was held this evening at the Engineers' Club, and was called to order by the President, John B. Babcock, 3d. Seventy-five members and guests were present. Fifty-one attended the buffet supper.

The Secretary reported the election of the following new members:

Elected on April 3, 1935:

Grade of Student: Nicola J. Barletta, George J. Begg, Jr., Edward N. Chapin, J. P. Driscoll, Hugh Phillips, Robert C. Sanderson.

Elected on April 17, 1935:

Grade of Student: Kenneth E. Curran, Eric O. Ericsson, Jr., Lincoln S. Estes, John L. Haskell, Ellery H. Hutchins, Lawrence C. Magnant, Fred Merrikin, Charles A. Perkins, William A. Redfield, H. Frank Wagenknecht, Paavo H. Waltonen, Samuel H. Wright.

The President announced that the award of the Boston Society of Civil Engineers scholarship in memory of Desmond FitzGerald, a Past President and Honorary Member of the Society, had been authorized by the Board of Government on January 23, 1935. In accordance with the recommendation of the special committee, the award had been made to Kenneth F. Knowlton, a senior student at Northeastern University. The presentation will be made at a special meeting of students at Northeastern University on April 24, 1935.

The President then introduced Lieut. Col. Stuart C. Godfrey, engineer, 1st Corps Area, who gave an illustrated talk on the "Scope and Accomplishments of the C. C. C. Camps in Massachusetts." Colonel Godfrey discussed the problems of location, construction and administration of the camps in Massachusetts, and described the opportunity afforded thousands of young men throughout New England for healthy employment in work accomplished by the Civilian Conservation Corps.

Mr. Egbert Hans, landscape architect, with the Massachusetts Department of Conservation, gave an illustrated talk on the phases of the work of these camps, which are under the supervision of that Department, the locations of the work undertaken in this State, and the general planning of the work to be done in order to make it of lasting benefit to the people of the State for their use of the forests, natural beauties and recreational opportunities.

Other speakers included Mr. Samuel A. York, Commissioner, Massachusetts Department of Conservation, Mr. Warren H. Manning and Lester B. McFarland.

The meeting adjourned at 9 P.M.

EVERETT N. HUTCHINS, *Secretary.*

MAY 15, 1935. — A regular meeting of the Boston Society of Civil Engineers was held this evening at the Engineers' Club, and was called to order at 7 P.M. by the President, John B. Babcock, 3d. One hundred and thirty-five members and guests were present. Eighty-one persons attended the buffet supper preceding the meeting.

The President announced the death of Alfred E. Burton on May 11, 1935, who had been a member since November 15, 1882.

The Secretary reported the names of the following who had been elected to membership on May 15, 1935:

Grade of Member: Edward F. Kelley, Dwight H. Moore, Joseph A. O'Hearn.

The President introduced Prof. George Owen, professor of naval architecture at Massachusetts Institute of Technology, who gave a talk on "Some Engineering Features of the Modern Racing Yachts." Professor Owen's connection with yacht racing for many years made possible the interesting account of developments in racing yachts and the intensive background of experience and research which has been necessary to produce the splendid types of vessels which compete in the races for America's Cup. The talk was illustrated by lantern slides and moving pictures.

The meeting adjourned at 9 P.M.

EVERETT N. HUTCHINS, *Secretary.*

Highway Section

APRIL 24, 1935. — A regular meeting of the Highway Section of the Boston Society of Civil Engineers was held on April 24, 1935, at the Society Rooms, 715 Tremont Temple. The meeting was called to order by the Chairman, George A. Graves, at 7.10 P.M.

The reading of the minutes of the previous meeting was omitted, and the meeting turned over to Col. R. C. Eddy of the Massachusetts Institute of Technology, who outlined the work of the Massachusetts Highway Accident Survey, an E. R. A. project supervised by the Massachusetts Institute of Technology. Colonel Eddy discussed the investigations and findings of the Survey, particularly with reference to driving speeds, reaction-time of drivers, and the effect of highway lighting on pedestrian visibility. The talk was followed by a lively discussion. There were thirty-seven members and guests present. The meeting adjourned at 8.45 P.M.

A. J. BONE, *Clerk.*

Northeastern University Section

MARCH 28, 1935. — The Northeastern University Section of the Boston Society of Civil Engineers held a regular meeting in Room 18H, Huntington Building, on March 28, 1935.

Vice-Chairman J. M. Dearborn called the meeting to order at 7.30 P.M. A committee of three was appointed by the Chair to serve as a nominating committee to nominate men to be elected for the various offices of the Section for the year 1936. These men are to be voted for at the next regular meeting of the Section. The following were appointed on the nominating committee: George F. Hollinshead, 1935; G. Albion Smith, 1936; and E. H. Ziegler, 1937.

Mr. Dearborn then introduced the Speaker of the evening, Mr. Robert Johnson of Weston & Sampson. Mr. Johnson received his B.S. degree from Dartmouth and his M.A. from Harvard. The subject of his talk was "Water Analysis and Purification." Mr. Johnson illustrated the various means of determining the suitability of water for consumption and the methods used to purify water.

There were forty members and guests present at the meeting. The meeting adjourned at 9.30 P.M.

F. H. DUTRA, *Vice-Clerk.*

MAY 23, 1935. — The Northeastern University Section of the Boston Society of Civil Engineers held the final meeting of the year in Room 18H of the Huntington Building. Vice-Chairman J. M. Dearborn called the meeting to order at 7.30 P.M. The Section was honored by Prof. J. B. Babcock, President of the Society, who was present as a guest.

The annual election of officers was held, with the following being elected:

Chairman — J. L. Dallas.
Vice-Chairman — G. A. Smith.
Clerk — F. J. Flynn.
Vice-Clerk — L. S. Perry.
Executive Committee — W. C. Pitts, J. S. Ross, G. L. Cheney.

Vice-Chairman J. M. Dearborn introduced the speakers of the evening: Leslie Meszaros, who spoke on the brass model of the plate girder bridge, and Kenneth F. Knowlton, who explained the work that was done on the wooden models of bridge sections. Both speakers told of the problems encountered in design and construction, explaining at some length how it was necessary in a few instances to resort to methods of trial and error.

David Abernethy presented some excellent entertainment in the magician's art.

There were about fifty members and guests present. The meeting adjourned at 9.30 P.M.

LESTER S. PERRY,
Vice-Clerk (*Division B*).

APPLICATIONS FOR MEMBERSHIP

[July 20, 1935]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

DE SERIO, JAMES NICOLAS, Boston, Mass. (Age 24, b. Vastogirardi, Italy.) July to September, 1929, with New York State Highway Department, Syracuse Division, on maintenance work; September, 1930, to June, 1935, attended Northeastern University, Boston, Mass.; graduated with degree of B.S. in civil engineering "with honor;" chairman Northeastern University Section of Boston Society of Civil Engineers for year 1934–35; awarded the Desmond FitzGerald Scholarship in 1934; October, 1931, to January, 1933, in office of city engineer of Newton, on co-operative work as rodman and transitman doing general engineering work; January to February, 1933, with L. P. Federico, on waterworks construction; May to July, 1933, with Baldwinsville, N. Y., water department, in charge of construction of new supply system; July, 1933, to June, 1935, on co-operative work in office of city engineer, Newton, as rodman and transitman on general engineering work (Civil Service). Now with engineering department of Concrete Steel Company, as draftsman and detailer, making layout and setting plans for steel in reinforced concrete structures. Refers to *H. B. Alvord, C. S. Ell, F. L. Flood, W. P. Morse, A. Q. Robinson.*

TAYLOR, CLARENCE PARKER, Wellesley, Mass. (Age 36, b. Omaha, Nebraska.) In 1927 was graduated from University of California, in mechanical engineering; 1926–27, traffic engineer, Berkeley, California; 1928, Traffic Research Fellow at Harvard University, M.S. degree; 1929, Traffic Research Fellow, Harvard University, postgraduate course; 1929–30, assistant traffic engineer, Massachusetts

Department of Public Works; 1930 to date, traffic engineer, Massachusetts Department of Public Works. Refers to *R. W. Coburn, A. W. Dean, G. H. Delano, G. A. Graves, Albert Haertlein, J. E. Lawrence.*

ADDITIONS

Member

William F. Cummings, North Station, Boston, Mass.

Gail P. Edwards, 393 Broadway, Cambridge, Mass.

Edward F. Kelley, 30 Cleveland Street, Arlington, Mass.

Joseph A. C. Komich, 622 Golf Terrace, Union, N. J.

Dwight H. Moore, Huntington, Mass.

Joseph A. O'Hearn, 11 Woodbridge Street, Cambridge, Mass.

Junior

Henry A. Phillips, 160 Western Avenue, Braintree, Mass.

Students

Charles W. Bowen, 280 Washington Street, Gloucester, Mass.

Edwin N. Chapin, 165 Chicopee Street, Chicopee, Mass.

Kenneth E. Curran, Woodland Farm, Littleton, N. H.

Lincoln S. Estes, Windsor, Mass.

Lawrence C. Magnant, 216 Newbury Avenue, North Quincy, Mass.

Frederick P. Moran, 102 Bridge Street, Newton, Mass.

William A. Redfield, R. D. No. 1, Middletown, N. Y.

H. Frank Wagenknecht, Rockville, Conn.

Paavo H. Waltonen, 29 Gay Avenue, Walpole, Mass.

DEATHS

Nathan S. Brock . .	July 11, 1935
Alfred E. Burton . .	May 11, 1935
John E. Palmer . . .	May 19, 1935
Frank C. Shepherd .	Aug. 6, 1935

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BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

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