In estimating on the tunnel scheme a tunnel 60 ft. wide at the spring of arch, by 30 ft. in height at the centre, has been assumed, any smaller size for the purpose being worthy of the opprobrious title of rathole, bestowed upon such by Mr. Richard Deeves in his communication to the *New York Times* of Jan. 11 of this year.

The estimate follows Mr. Deeves' figures with one important difference. Mr. Deeves has apparently estimated the tunnel excavation at $7 per yard. As the Aqueduct tunnel cost $6.67 per yard, the larger tunnel would certainly not show a better rate, in spite of the advantage of the larger section, for the reason that the conditions are much more unfavorable. In the first place the drainage conditions are much less favorable, all water having to be hoisted from shafts. The amount of water is likely to be greater at the greater depth with reference to tide water at which the tunnel would be, and with the close proximity of rivers on either hand. Secondly, the excavation from such a tunnel would be the most tedious in its character of any work on record. Every yard of rock must be hoisted up a shaft, loaded upon wagons, and the vast majority of it carried an average of a mile or thereabouts to tide-water, and then scowed to an indefinite distance, to be finally dumped. It will be borne in mind that the quantity of material from the tunnel would be so large as to make disposal on the island in its present conditions perfectly impracticable, unless with such haul as to be more expensive than the other plan.

On the other hand, Mr. Deeves allows only $638,000 per mile for brick lining and backing. Such lining could hardly be made safely less than 4 ft. thick for a 60-ft. span, and at 50 cents per cubic foot—a very moderate allowance for this work—this would amount to $1,267,200 per mile, which figure is therefore adopted. Mr. Deeves has allowed rather largely for rolling stock, but has omitted shops. His assumed length is 12 miles, but as it is 13¼ miles in a bee line from the Battery to Kingsbridge, this distance has been substituted for his. With these alterations, and an allowance for the general expenses of such an enterprise, and interest on the money invested while still unproductive, the account stands as given below.

No allowance has been made for freight stations in the tunnel or bridge scheme, the conditions being somewhat unfavorable for getting the necessary side track room without interfering with the streets.

In the case of the masonry viaduct, by connecting the loops between two quarter-mile stations by extra tracks on an additional lot width on each side, ample switching room could be had overhead. The buildings below, connected by car lifts with the tracks above, would afford ample facilities for unloading and storage, wagons being driven in on the ground floor and loaded and unloaded by suitable shoots and lifts.

CONSTRUCTION COST.

The line is from the Battery to Kingsbridge, with loop to ferries, and the estimate is based on spans of 240 ft., with piers 160 ft. from street to upper chord.

Cost per span with tower	$97,160	
Cost " of foundations	4,240	
Total cost per 260 ft. block	$101,400	
Cost per mile.		
20.2 blocks of structure at $101,400	$2,048,280	
4 stations, lifts and platforms, including land, at $120,000	480,000	
Land damages, 20 blocks, at $20,000	400,000	
Rails, ties and fastenings	30,000	
14.6 miles bridge at	$2,958,280	$43,190,889
* 0.65 " trestle at $678,000		440,700
* 0.64 " tunnel at $3,198,000		2,046,720
15.89 "		$45,678,309
Rolling stock		$5,600,000
Shops, block system, water supply and miscellaneous		1,000,000
		$52,278,309
Legal expenses, interest, superintendence and commissions, 12½ per cent		6,534,789
Total cost of bridge structure		$58,813,089

ESTIMATED COST OF MASONRY STRUCTURE.

The estimate is with right of way bought and fully built upon.

Battery to Ninety-seventh Street, with Loop, per Mile.

5 lots per block. 100 per mile		
Extra for four stations 12 " "		
112 lots at $35,000	$3,920,000	
Cost per lot of 6 story fire-proof building at 27c. per cu. ft., $37,857 112 at $37,857	4,240,000	$8,160,000
Extra for supports and arching of railroad	$1,060,000	
4 stations per mile at $30,000	120,000	
Permanent way complete	30,000	1,210,000
		$9,370,000 per mile.

Ninety-seventh to 110th Street, Trestle Structure over Fourth Avenue, per Mile.

Iron trestle at $100 per ft	$528,000	
Permanent way	30,000	
Stations	120,000	
		$678,000 per mile.

110th to 170th Streets, per Mile.

Land, 112 lots at $20,000	$2,240,000	
Buildings	4,240,000	$6,480,000
Construction, permanent way and stations		1,210,000
		$7,690,000 per mile.

170th Street to 183d Street, Tunnel and Approaches, per Mile.

Tunnel and lining	$3,000,000	
Permanent way	30,000	
Land damage	48,000	
Stations	120,000	
		$3,198,000 per mile.

*See estimate for masonry viaduct.

183d Street to Kingsbridge, per Mile.

Land, 112 lots at $8,000	$896,000	
Buildings	4,240,000	$5,136,000
Construction, permanent way and stations		1,210,000
		$6,346,000 per mile.

Cost of Total System, Battery to Kingsbridge.

Battery to Ninety-seventh street 8.5 miles, at $9,370,000		$79,615,000
Ninety-seventh street to 110th street 0.65 " 678,000		440,700
110th street to 170th street 3.6 " 7,690,000		27,684,000
170th street to 183d street. 0.64 " 3,198,000		2,046,720
183d street to Kingsbridge 2.5 " 6,346,000		15,865,000
15.89 miles.		$125,681,420
Connection with New York Central		50,000
Two freight stations, with heat and light plant for system		1,680,000
Rolling stock		5,600,000
Shops, block system and miscellaneous		1,000,000
		$134,011,420
Legal expenses, interest superintendence and commissions, 12½ per cent		16,751,428
Total cost of masonry structure		$150,762,848

COST OF DEEP TUNNEL LINE, BATTERY TO KINGSBRIDGE DIRECT.

Excavation, per mile	$2,860,000	
Lining, per mile	1,267,000	
Permanent way, per mile	30,000	
Stations, per mile	120,000	
Land for stations, per mile	420,000	
13¼ miles, at	$4,697,000	$62,235,250
Rolling stock		5,600,000
Shops, block system, and miscellaneous		1,000,000
		68,835,250
Legal expenses, interest, superintendence and commissions, 12½ per cent		8,604,406
Total cost of tunnel scheme		77,439,656

The income derivable from the different schemes is stated below, on the basis of a single five-cent fare from the Battery to Kingsbridge. On this basis any of the schemes is seriously handicapped in comparison with the present elevated system, whose longest five-cent ride is less than 10 miles in length against about 15 on the proposed Battery-Kingsbridge elevated lines. This difficulty would also make it hard to operate through trains from the suburbs into the city without change. If, however, proper authority were conferred to collect extra fares, say, above 155th street, it is probable that some satisfactory ticket-collecting arrangement could be devised without change of cars.

INCOME.

Bridge Structure.—The income account of the bridge scheme may be estimated as follows: If the passenger business be estimated at three-quarters of the present elevated railroad income from the Third and Sixth avenue lines, or, say, equal one-half of the whole income of the Manhattan, it would at present amount to about $2,000,000 net. It seems fair to assume as much as this in spite of somewhat greater operating expense, in view of the section of the city traversed and of the greater length of line, and also in view of the greater agreeability of a line without stairs to climb, freer from noise and with more agreeable outlook. This $2,000,000 would give less than 3½ per cent. on the estimated cost of $58,000,000. If, now, we turn to the possible maximum business of such a road in order to get a figuring basis, assume the trains fully occupied, that is, all seats taken for 14 hours per day. If the trains are one minute apart on each track of the four, and each train of eight cars seats 400, the annual capacity is 365 × 400 × 60 × 4 × 14 = 490,560,000 passengers at 5c. = $24,528,000, or perhaps $12,000,000 net. This would give a return on the capital outlay of 20.7 per cent.

Masonry Structure.—In the case of the masonry structure the income would be made up of: 1st. Rents of buildings; 2d. Passenger income; 3d. Freight income, and 4th. Rental of conduit space (disregarding in all cases income from carriage of mails and express matter). Referring to the estimate we have:

Building investment.

Battery to 97th street, 8.5 miles @ 8,160,000 =	69,360,000
110th street to 170th street, 3.6 miles. @ 6,480,000 =	23,328,000
183d street to Kingsbridge, 2.5 miles @ 5,136,000 =	12,840,000
	105,528,000
Income from this at 4 per cent., to take a conservative figure, is	4,221,120

2d. The passenger income would be same as from the bridge structure.

3d. The freight business practicable seems exceedingly difficult to guess at; 400 cars per day with a rate of 15 cents per ton, including terminal charges, a low rate for the character of freight to be expected, namely, jobbing goods, would be as little as would make it pay to make the estimated outlay for freight stations. This would give a net return of, say, $120,000, after deducting 50 per cent. for expenses.

4th. Allow for rental of conduits, 16 miles at 4,000, $64,000, we then have:

Income Account.	
Building rental	$4,221,120
Passenger income	2,000,000
Freight "	120,000
Conduit rental	64,000
Total	$6,405,120

or 4.3 per cent. on $150,000,000.

The maximum in this case figures out as follows, the freight income and conduit rental being pure guess work, but kept low enough to be apparently quite safe:

Building rental as before	$4,221,120
Passenger income	12,000,000
Freight "	300,000
Conduit rental	100,000
	$16,621,120

or 11 per cent. on the capital invested.

Tunnel.—On the tunnel scheme, if the same passenger income be assumed, we have minimum and maximum returns of 2.6 per cent. and 15.6 per cent. The prospect of even the smaller figure being realized at once seems small in view of the unattractive character of the method of transit.

So many estimates of a general character have been given on the cost of a tunnel system under New York, showing a much smaller cost than the above, that it seems necessary to call attention again to the fact, that, so far as known to the writer, none of these except that of Mr. Deeves, above referred to, have gone into any detail that could be analyzed.

It seems to have been assumed that the driving of a tunnel under New York was one of the simplest and most inexpensive things in the way of tunneling that could be found. The facts as pointed out above are these: The tunnel would have to be driven through a rock generally hard, and almost always treacherous. The use of a shield in view of the blasting required would be impracticable. The quantity of water to be expected would be enormous, judging by the results of wells in different parts of the city. The cost of handling the material, as pointed out above, would exceed that of any known tunnel, so far as can be judged in advance.

An iron lining would be impracticable for a four track tunnel on account of the expense for so great a span with probable irregular and uncertain loading. If four small tunnels were driven the expense of driving them would be enormously increased. The flanges of the iron lining add to the noise inseparable from a tunnel with any known rolling stock and permanent way, except possibly the "glissade" track exhibited at the last Paris exhibition.

The result of this investigation is to confirm the conclusion reached by the very original and entirely different method of Mr. Cooper in your recent issue, that the franchise for building a rapid transit railroad in New York (other than by an elevated structure in a street), in competition with the present elevated system, is one requiring subsidy and not one for which capitalists will pay money or which they will undertake without assistance.

The most feasible method would seem to be by guarantee, on the part of the city, of a limited interest on the investment, viz., that it would make up any shortage below the rate fixed upon, with release of the property from taxation for a limited period. The commission having determined the most practicable route and method, might ask the legislature for power to make such an arrangement with the party who would bid for the franchise at the shortest term of tax release.

April 6, 1891.

Block Signaling.*

[Mr. Paine's paper dealt with many things with which our readers are already familiar; therefore we reproduce but a small part of it. It will probably be published in full by the club.]

Permissive blocking does not strike me as being blocking at all. Its success depends on the combined action of two persons who must both obey their rules promptly and correctly. In order that the system may prove a success, the flagman must run back a long distance as soon as the train slackens speed, no matter what the weather may be, no matter how tired or sleepy or lazy he may be, and the engineman must be on the lookout for the flag at every moment. He must not be attending to any of the multifarious duties devolving on him, but must give his whole attention to the track in front of him, so far as his eyes are concerned. The engineman must, first and foremost, make his schedule time, or, if late, something more than schedule time; he must also run carefully under the permissive signal.

Does any one doubt what the result will be? He always has and always will argue when placed in a similar position, either that the train against which he has been cautioned has got out of the way or else that the flagman of that train has been sent out to protect it. On the other hand, the flagman, knowing that he has the protection of the signal behind him, reasons that the engineman of the following train has been cautioned against the train in advance and that he is running carefully under a green signal. Then the inevitable happens. The engineman is in a hurry, the flagman is either tired or careless or lazy, and there is a collision with the usual results, which your are all familiar with, in the way of wrecked cars, and burned, mutilated and suffering human beings. In view of the above facts, I suggest in all sincerity that the term "permissive blocking" be abandoned, to be replaced by the more appropriate expression "pernicious blocking." . . .

At the present time the question of night signals is agitating the minds of railroad officials in general, and signal engineers in particular, and very justly so, for our present standard, or rather want of standard, is most unsatisfactory in every way.

There are many different arrangements of the lights for indicating the positions of signals at night. The most common plan is a green light for caution, a red light for danger and a white light for safety. This plan, although advantageous for its simplicity, may well become, from the breaking of a red or green glass, a source of the greatest danger. I know of several well-authenticated instances where this has occurred. The signal engineer of a well-known road told me not long ago of a case in his knowledge where a serious collision through this cause was averted only by the presence of mind of the engineman, who brought his train to a stop in the face of a white signal, because he knew or suspected that the signal was wrong. The multiplication of lights is a common resource for avoiding the before-mentioned danger, and is practised on many roads. It, however, has many disadvantages, the principal ones being excessive cost of manufacture and maintenance, and the possible confusion of having so many lights. The ideal semaphore would, without reference to color, show at night a brilliantly illuminated arm of approximately the same size and shape as the arm appears by daylight. A very close approach has been made to this semaphore, which, how-

* A paper read by Mr. G. H. Paine, Signal Engineer, before the New York Railroad Club, April 16, 1891.

ever, is susceptible of some improvement. In my own opinion a slight increase in the intensity of the beam of light, together with the decrease in the cost, which would follow the manufacture of it in large quantities will make it a very desirable adjunct to any block or interlocking system.

There are very few railroads east of the Mississippi, north of the Ohio and south of a line at about the average latitude of the St. Lawrence River which could not very easily and with little additional expense establish block signals at their regular stations, maintaining a nearly constant distance between them of five or six miles; I refer now to a single-track. I believe I am not wrong in assuming that on ordinary railroads trains will average a speed of twenty miles an hour. At this speed and with block stations five miles apart an apparent traffic of 96 trains in 24 hours is accommodated—on the assumption, however, that there shall be no breakdowns, no stops, a constant speed of 20 miles per hour, and a passing siding at each block station. These conditions are of course impossible; for there will be breakdowns, must be stops for passengers, freight and so forth; but by taking one-half of 96—that is, 48—we are, I think, quite within the bounds of probability, and at the same time make quite a respectable showing for a perfectly safe train movement on a single-track road. Examine this proposition carefully, and you will see that with 24 trains each way a day, moving at the rate of 20 miles per hour, with block stations 5 miles apart, there will be a distance of 20 miles between each two trains moving in the same direction. Please do not understand me as saying that under ordinary circumstances there must be a space of 20 miles between each two trains—for it is not so. They may be any distance apart, so that it is not less than 5 miles.

Again, suppose the block stations are only four miles apart, while the trains run at the same speed as before. The apparent traffic would then be equal to 120 trains a day. Taking one-half of this as possible, we should have an actual traffic of 60, that is, 30 trains each way a day, with an interval of 16 miles between each two trains moving in the same direction.

There seems to me nothing impossible in this arrangement, and, while my figures are necessarily of an empirical character, they prove how perfectly possible and positive a block system may be.

The number of trains which may be run on any piece of road every 24 hours is determined through the combination of so many different conditions, besides the length of blocks, that no rule can be depended upon. What I wish to insist on is the fact that absolute blocking is just as necessary and quite as possible on small roads with a light traffic as on roads with a heavy train service. Many things tend to increase the capacity of a piece of track—frequent and overlapping passing sidings, isolated pieces of double track, etc.; and as the capacity of a railroad naturally grows with the demand made upon it, so must the block system.

The method I have been describing is of the most elementary character. It requires nothing but the telegraph operator, who would be needed at almost every station even if there were no block system, and a two-arm semaphore post connected with the telegraph office by a piece of wire or chain.

With blocks averaging five miles in length, the first cost of materials necessary would not, I believe, much exceed fifteen dollars per mile. The increased cost of operation would vary greatly over and above certain fixed charges, such as oil and waste for the signal lamps; it might easily be very little, and could not be very much. The most important item would be the additional operators required over and above those necessary for the ordinary work of the road. This would depend greatly on the ingenuity and care used in the locating of the block stations. . . .

[Mr. Paine here described the Hall, the Union and the Westinghouse electro-pneumatic systems.]

I am not in a position to know what the exact cost of maintenance is of the electro-pneumatic. I have been told, however, by persons using the system that the signals should be properly maintained at an expense of about $90 per block per year. This would include the fuel, oil and waste necessary for operating the compressors and filling and cleaning the lamps, as well as the pay of all men employed in inspecting, operating and maintaining the system.

Although the cost of a plant of this character is large at the start, the cost of maintenance is so slight in comparison with the cost of maintenance of a mechanical system that its advantage will be seen at once. On a certain railroad the system of pneumatic-automatic signals has been put in, embracing a section of road seven miles long, four main tracks, with the block signals about half a mile apart. A mechanical system of the same length, with the block stations the same distance apart, would have cost to erect less than half as much as did the automatic pneumatic. The cost of operating the mechanical system for one year, however, including the pay of operators, 22 of whom would have been required, would have been equal to about three times the sum which it has cost to maintain and operate the automatic, and in four years from the date that the automatic system was put in service this saving will have much more than paid for it, without at all taking into consideration the entire immunity from collisions which has been procured. This proportionate gain increases rapidly as the length of road protected is increased.

To give another illustration, all the elements of cost of a 14-mile section of double-track road, with the blocks varying from 1,500 ft. to 2,650 ft. in length, have been estimated. To erect a mechanical system of the same size would have cost somewhat less than one-third as much. To maintain and operate the mechanical it would have cost four times as much as would the pneumatic, and the net yearly gain in favor of the pneumatic would have paid for it in the amazingly short time of two years. . . .

Some Railroad Crossings at Chicago.

With the large number of eastern and western systems of railroads obtaining an entrance, one after the other, into the heart of the city of Chicago, there have been established many complicated systems of tracks, not only for main-line but for yard purposes. Each road, as it procures a right of way into one or the other of the half-dozen great passenger stations, is obliged at times not only to use the tracks of existing lines, but to cross and recross many opposing lines. The Alton and Burlington roads use the Ft. Wayne tracks, the former north of Grove street and the latter north of Sixteenth street, the Chicago, St. Paul & Kansas City uses the Wisconsin Central or Chicago & Northern Pacific tracks for quite a distance out; the St. Charles Air Line is used by and jointly owned by the Northwestern, Burlington, Illinois Central and Michigan Central for transfer from the west side of the river over to the lake shore. The Chicago, Madison & Northern, which is a proprietary line of the Illinois Central, will use these tracks east of the Air Line crossing, and the Western Indiana brings into the Polk street station some half a dozen or more lines. So that now, besides being extremely hard to pick out any good way of getting in at all, when that way is found it proves to be enormously expensive. Notwithstanding the fact that there are several of these passenger stations it is rapidly becoming a problem in some cases how to handle the trains at certain hours of the day. When the handling of a heavy suburban service and the departure of through trains occur at the same hours of the day on several large roads running into a single station, the question of changing a time card is a rather serious affair.

For the transfer and shipment of freight, this subject of track facilities is one of very grave importance. The number of freight houses is legion, and they are located in all parts of the city. This is not only true of the roads in general, but with some allowance is true of individual roads. The Northwestern, for instance, has large freight depots in several quarters of the city. The effort to get at their respective depots by each of the roads, it will be readily seen, produces a complicated network of tracks which, as a whole, will give one abundant exercise for his ingenuity for some time.

The worst tangle which we know is the one illustrated here, extending from one-half to one and a half miles south of some of the principal passenger stations. Some time ago there was a move on the part of several of the entering roads to attempt to better the condition of affairs in this section of the city, and Mr. E. L. Corthell undertook to bring about some concerted action among the different companies for overcoming a part of the difficulties existing at these three points. Most of the study has been done at the Stewart avenue crossing, and it is here that the immediate work is to be undertaken.

The tracks east of the Indiana elevator are to be changed by crowding the Western Indiana tracks over, and giving space for a sixth track where now there are but five. From a point where the Santa Fé and Chicago, Madison & Northern cross the Fort Wayne, a double line of slip switches is run across the Alton and into the Western Indiana tracks, enabling the Santa Fé to use their Indiana tracks for their passenger service, the three tracks southeast of the Chicago, Madison & Northern being used for freight only. The work for this portion is now being pushed by the Morden people, who are making 45 crossings and 65 switches with frogs, besides 21 slip switches and all of the cut lengths. Every piece is finished and marked at the shops, and when laid down on the ground the whole needs only to be bolted together. The changes at the Air Line crossing at Sixteenth street were made by this same frog and crossing company a little over two years ago. They put in 125 crossings at that point.

It was proposed to put in a double crossover between the Santa Fe and Chicago, Madison & Northern near Twenty-second street so as to give opportunity for using the two Chicago, Madison & Northern tracks crossing the Western Indiana as a double-track system. This would facilitate the movement of two trains of the same road going in opposite directions, but would not allow two trains of opposite roads to cross the Fort Wayne tracks in opposite directions, as there would be a fouling point both east and west of their north and south tracks. A westbound Chicago, Madison & Northern train would foul an eastbound Santa Fe train at a point east of the Fort Wayne tracks, and an eastbound Chicago, Madison & Northern train would foul a westbound Santa Fe train just west of the Western Indiana tracks. Any such arrangement of crossovers would necessitate moving back the derailing switch so far that it would not be sufficient protection for the main crossing. Thus there are two sides to the question, and, although there are disadvantages in being confined to a single track for a short distance, still it has been thought best by some to put up with this inconvenience rather than adopt the other plan.

The two Alton tracks sandwiched in between the others east of the Ft. Wayne are old freight tracks. It will be noticed also that the two main-line Alton tracks cross each other soon after leaving the Ft. Wayne on account of this latter road running trains on the right-hand track, whereas the Alton uses the left-hand track.

Mr. Corthell's scheme is to erect a pneumatic interlocking tower at each of these three systems of grade crossings, and to erect a power-house at some centrally located point so as to supply power to the three interlocking systems. All three towers are to be connected by a system of electric calls and signals, so that when an outbound Pennsylvania train passes the Sixteenth and Canal street tower it will notify the man at Stewart avenue and Grove street. Likewise when an outbound on the Santa Fé passes the Sixteenth and Clark street tower that tower will notify the Grove street tower. Thus Grove street, knowing that both trains are coming and must cross, can judge which should have the right of way, and set his switches accordingly.

Each tower will have a man in charge who will have complete control over all interlockings at his crossing, the only connection between the several towers being for purposes of notification, as by telephone, bell calls or automatic sight warnings. There will be a superintendent over the whole, whose duty will be to see to the keeping up of all machinery and appliances about the plant.

The size of such an undertaking as advocated by Mr. Corthell can be realized when it is considered that the interlocking at Stewart avenue alone would require a tower of nearly two hundred levers; and in order to run these crossings, as may be allowed by the new law, it becomes very essential that the pneumatic systems should work perfectly in every respect; and also, to give the most efficient service, there will be required a quick, clear-headed man in charge at each tower. This is illustrated by the count made at the Air Line crossing about a year and a half ago, when it was found that there passed over this crossing 1,063 engines, 1,202 coaches and 4,825 freight cars in one day, showing that if the blocking of trains is to be reduced to a minimum it is necessary to have the right man at the levers.

The idea of interlocking is strenuously opposed by some of the roads which have had little or no experience with the more improved methods and which think the old style the safest and best; but as the traffic is yearly increasing and already demands heroic treatment it is to be hoped that some such scheme as the above may be carried out. Taking into account the fact that these several nests are already established and that it is out of the question to tear them out and make a fresh deal, it would seem that the proposed plan would meet the requirements of the greatest number with the smallest amount of alteration. Should the interlocking plant be put in at Stewart avenue and Grove street, the improvement of the train service would be so noticeable that we doubt not the roads now objecting to this triangular plan would be glad to swing into line and become as strong advocates of interlocking as any of the others.

This enterprise is being pushed by J. F. Wallace, who has been for so long associated in business with Mr. Corthell, and who at the beginning of this year received the appointment of Engineer of Construction of the Illinois Central Railroad. Very great and, in fact, extraordinary difficulties arise in carrying out the scheme, from the numerous and often conflicting interests of the roads. Even where their interests do not conflict, there is often a mutual distrust which makes any agreement hard to get and harder to keep.

Pipe Culverts on the "Plant" System.

BY W. B. W. HOWE, JR., CHIEF ENGINEER.

There is perhaps no one item in railroad construction and maintenance, which is of more importance in a small way than the proper treatment of the minor streams or drains, which must necessarily be crossed by the roadbed, where perhaps, an area of two or three square feet, is all that is necessary to afford ample passage for the water. To provide for these, not simply in the sense of getting the track over them, but to dispose of them in such a manner that they will require little or no attention from those charged with the maintenance of the track, limits discussion to cases where permanent rather than temporary construction is recognized to be conducive to true economy.

The accompanying plans illustrate in a general way the standard practice of the Plant System, in the use of culvert pipe, which is employed in new construction wherever circumstances will permit, and will eventually replace the small trestles upon the older portions of the system. A short description of the conditions under which culverts of this character are found to be serviceable, and a few notes as to the proper methods to be employed in their construction, may be of interest.

A perfect road bed can best be obtained by preserving uniform bearing for the cross ties at all points. This idea has found expression in the practice of carrying the track ballast even over iron bridges, whose floors are specially designed with that end in view. There are cases it is true, in which this cannot be done, but where possible to adopt such a course, few will question the advantages to be derived from it. The difficulty of maintaining uniform conditions of line and surface, and of securing a smooth and easy-riding track, in the rapid transition from a well-ballasted bed to a rigid bridge floor, and *vice versa*, can only be fully appreciated by those whose duty it is to attain these results.

Where a stream is of sufficient importance to warrant the expenditure of a considerable amount for a masonry arch or iron bridge, the matter is usually placed beyond the everyday care of the section men, but the petty openings are disposed of too frequently in a temporary manner involving constant expenditure for maintenance, absorbing a portion of the time that should be expended upon the track, and destroying that uniformity in the condition of the road bed, to which reference has just been made. The use of culvert pipe offers a comparatively cheap method of providing for such cases, in a permanent and thoroughly satisfactory manner, subject, however, to two limitations, the height of the bank, or the depth at which the pipe can be placed below the track, and the total area of water-way required.

There should always be sufficient earth interposed between the top of the pipe and the cross ties, to afford a good cushion. One and a half diameters of the pipe should be the minimum in good practice, although in special cases, one diameter may answer. There is no