Design of State Trunk Line No. 92-1

A Thesis Submitted to

The Faculty of

MICHIGAN AGRICULTURAL COLLEGE

By

L.L.Bateman

B.W.Bellinger

W.E.DeYoung

A.M.Hopperstead

L.H.Jones

C.F.Miller

Candidates for the Degree of

Bachelor of Science

June,1920

BIBLIOGRAPHY

HIGHWAY LEGISLATION, STATE OF MICHIGAN.

INSTRUCTIONS FOR MAKING SURVEYS AND PLANS, MICHIGAN STATE HIGHWAY DEPARTMENT.

INSTRUCTIONS FOR SLOPE STAKING AND COMPUTING VOLUMES, MICHIGAN STATE HIGHWAY DEPARTMENT.

AMERICAN HIGHWAY ENGINEERS' HANDBOOK, ARTHUR BLANCHARD.

RAILWAY CURVES AND EARTHWORKS, C.F.ALLEN.

ELEMENTARY SURVEYING, BREED AND HOSMER.

A TREATISE ON MASONRY CONSTRUCTION, I.O.BAKER.

ENGINEERING GEOLOGY, H.RIES AND T.L.WATSON.

TEXTBOOK ON PRACTICAL ASTRONOMY, GEORGE L.HOSMER.

EARTHWORK HAUL AND OVERHAUL, J.C.L.FISH.

HIGHWAY ENGINEERS' HANDBOOK, W.G.HARGER AND E.A.BONNEY.

CONCRETE ENGINEERS' HANDBOOK, HOOL AND JOHNSON.

CIVIL ENGINEERS' HANDBOOK, MERRIMAN.

THESIS OUTLINE

Design of State Trunk Line No.92 - 1.

1.Objects in View.

a.To learn more efficient methods of highway surveying.

b.To investigate the problem of highway location.

c.To study survey party organization.

2.Preliminary Survey.

a.Choice of tangent intersections.

b.Curve determining factors.

c.Tying to established corners.

d.Witnesses.

e.Re-locations.

(1).Topographical survey

(2).Property survey

3.Staking.

a.Curve computations.

b.Chaining and lining.

c.Hubs and markers.

d.Running curves.

4.Benches.

a.Position and frequency.

b.U.S.Geological Survey Bench Marks.

5. Continuous Levels.

a. Cross-sections.

b. Drainage.

c. Grade determining Factors.

d. Checks on Bench Marks.

e. Soundings.

6. Topography Notes.

a. Sketching.

b. Drainage Structures.

c. Soil.

7. Construction Plans.

a. Topography.

b. Profile.

c. Cross-sections.

d. Laying the Grade.

e. Grade Computations.

f. Grade Inspection.

g. Notes.

8. Write-up.

a. Outline, Bibliography, and Introduction.

b. Preliminary Survey and Re-location.

c. Survey Methods.

d. Drainage and Drainage Structures.

e. Plans.

f. Notes, Blue-prints, Photographs, etc.

INTRODUCTION

The highway selected for this thesis is known as State Trunk Line 92 - 1, and is divided into section A and section B. Section A is a continuation of South Main Street in Chelsea, Michigan, and runs in a southerly direction until it intersects the Federal Aid Road 35. Section B is a continuation of North Main Street in Chelsea and runs in a general north-westerly direction, entering Stockbridge from the south on Main Street.

The State Highway Department has been for some time contemplating the improvement of this trunk line, thus with the coöperation of and in conjunction with this department, we were able to make all preliminary surveys necessary before the estimation of the cost and the letting of the contract.

The selection of this thesis was goverened by the desire not only to work out some of the commonly used highway methods viewed in the light of efficiency, but to try and devise better and more economical methods than the commonly accepted ones. In view of the fact that several members of the thesis party were already familiar with the methods employed by the State Highway Department of Michigan, we believed that the benefits derived from such a thesis would be far in excess of those that might be gained from a purely experimental and theoretical one.

Owing to the fact that the road,as already established,did not follow,except in a few instances,the section line,there were many problems continually arrising that would ordinarily have been absent in a highway that followed more nearly straight section lines.

Our analysis of present survey methods on highways lead us to the conclusion that slightly different organizations of survey parties would greatly facilitate the preliminary survey work. We were able to try these changes as the survey progressed to find whether or not our assumptions were justified.

The attempt was made to work out this thesis in a thoroughly practical manner,thereby securing valuable information which would be beneficial to the State Highway Department as well as to ourselves in the future.

The problem of road relocation confronted us in several instances,and necessitated a careful study of the governing conditions as well as close attention to the economy and aesthetics of a new proposed roadway.

This thesis gave us an opportunity to familiarize ourselves with a larger part of the legislation in the State of Michigan pertaining to highways and particularly to that part which directly concerned us in the establishment of the road as proposed. Roads which are built under the direct supervision of the State fall into three classes as devined by State legislation. These are Federal Aid roads,Covert Act roads,and State

Trunk Line roads.

Special legislation has been passed by both the Federal government and the State of Michigan relative to such part of these highways as concerns each, and a clearer comprehension of these acts may be gained from direct quotations from the laws themselves in part.

Those roads that are called by the State Federal Aided Roads are those that the Federal government, acting through power granted the Department of Agriculture, has defined as Post Roads, all of these highways in the State of Michiganform a part of the State Trunk Line System. They become Federal Aided Roads only after the State has improved them in accordance with these specifications required by the Department of Agriculture and after the approval of the road by Federal inspectors. The Federal government, after approval, reimburses the State to the extent 50% of the total cost of the road provided that the cost does not exceed $40,000 per mile. State legislation in the Public Acts of 1917, No.99, Section 3, in regard to Federal Aided Roads, states: "Counties working under the so-called county road system" - a system providing for part of the cost of a road to be borne by the State after its construction either by the State or by the county itself -- "having a valuation per trunk line mile of less than $50,000, shall pay five percent of the cost of Federal Aided roads; counties having a valuation of more than $50,000 per trunk line mile and

more than $75,000 shall pay seven and one-half percent of the cost of Federal Aided roads". Thus a sliding scale continues up to counties having a valuation of more than $500,000 per trunk line mile,and these are required to pay 25% of the cost of Federal Aided roads. The act states further:that "in each case the State pays the remainder of the cost from the State funds approiated for this purpose and from such funds as may be allowed to each project by the Federal government. The cost of the preliminary work,including plans and surveys,shall be paid by the State. ----- The valuation per trunk line mile of any county shall be determined by the dividing of the latest State equalized valuation by its alloted trunk line mileage." Section 5 of the same act continues with the provisions for maintanance of these roads as follows:"Townships,good roads districts, and counties in which Federal Aided roads shall be built are hereby required to levy annually and raise by general taxation their proportion of the cost of maintenance of said Federal Aided roads,which proportion shall be computed on double the basis as that provided for construction in Section 3 of this act. ----- The remaining portion of the cost of maintaining Federal Aided roads shall be paid out of any other State highway fund not otherwise appropriated."

The Covert Highway Act of 1915,under which the so-called Covert Act roads are built,provides a means

by which the owners of property abutting the road may secure its improvement. Section 4 of this act states: "Whenever the owners of more than sixty percent of the lineal frontage of lands fronting or touching upon any highway or portion thereof, desire to improve such highway or portion thereof, they may file application for such improvement to the county road commissioner of the county in which such highway is situated, unless the road to be improved is a part of a trunk line road, if said county has adopted and is operating under provision of Chapter 4 of the general highway law and amendments thereto ----- The eligibility of signers to any application hereby authorized shall be determined by their interest of record in the office of the register of deeds or in the probate court of the county in which such lands are situated, at the time the petition to ----- The State Highway Commissioner." Here an interesting phase of the relations of the State Highway Department to the property owners arose on this particular road concerning the foregoing law. The law does state how the eligibility of the petition signers shall be determined, but it does not state by whom the expense of looking up the records shall be borne. A property owner on the road who was circulating a petition refused to bear this expense, and without authority it was impossible to shift the cost on the county or townships. A conference with the State Highway Commissioner brought to light the willingness of the department to stand this expense.

Roads that are improved under the Covert Act are subject to the regulations provided by the general highway laws of the State,and may include,not only strictly Covert Act,or Assessment District,roads,but State Trunk Lines which will be fully discussed later. The general highway law provides for the part payment of the cost and maintenance of roads,built according to State specifiaations,by the State. In each case the State pays 25% of the cost of construction up to a maximum limit of $75,000 per mile in the case of types F and G. The law however states that:"When such roads form a part of the State Highway System as established under the provisions of Act No.334 of the Public Acts of 1913,as amended, they shall be entitled to State reward of aid amounting to 50% of the cost of such roads up to but not exceeding $15,000 per mile." The road now in question is part of a trunk line road petitioned for under the provisions of the Covert Act.

Trunk lines in the State were designated by Act 334 of the Public Acts of 1913. Division 10 of this act provides for and names the different highways which shall be called State Trunk Lines in the section in which the road is located. Although the road is not mentioned specifically,authority is granted in this act to the State Highway Commissioner to designate it as such. It states:"Provided trunk lines may be necessary to close gaps in important main highways ----- The State Highway Commissioner shall make preliminary surveys and such other investigations as he may deem necessary of one or more routes for State Trunk Line Highways ----- ". This portion of road in question closes a gap between the Trunk Line from Lansing thro Stockbridge to Chelsea where it meets the Federal Aided Road.

The Maintenance Acts of the various roads of the State are so closely interwoven that they should be discussed as a whole rather than by types of roads. The General Highway Law in Chapter 1,Section 12,states: "That whenever a line road or bridge shall have been laid out or established pusuant to previous sections, the officers who refuse or neglect to construct or maintain their designated portion thereof in a manner reasonably safe and fit for public travel,then the State Highway Commissioner shall upon petition of seven freeholders of either township,inspect the merits of the petition,and if said Highway Commissioner decides with the petitioners,he shall direct the officers of said township to which the road or bridge belongs to so construct and maintain such road or bridge,and in devault thereof he shall be authorized to cause said road or bridge to be placed in condition safe and fit for public travel and pay for same out of the highway fund,and render bill for the same to the proper officers of such township or townships,which bill shall be paid on the warrant of such officers and the amount thereof returned to the State Treasurer to be credited to the highway fund". For this maintenance or construction, Section 2-b of the same act gives the State Highway Commissioner the power to condemn for road work such lands as contain gravel,stone,and other material useful in the construction of highways. Section 16 of the same act provides as follows:"A county,good roads districts, or township that shall maintain its roads in accordance with specifications prepared by or approved by the State Highway Commissioner,shall be entitled to an annual maintenance reward equal to six percent of the total State reward previously paid to such county,good roads district of township not counting any roads that may have been accepted for State reward during the current fiscal year:Provided,that no mile of road shall be entitled to more than $100 maintenance reward in one year." Contracts and agreements may be made between counties and the townships containing Trunk Line Roads providing for the maintenance of such roads. The laws provide that in default of such contract the State Highway Commissioner may proceed with the work and collect the cost of such work from these counties or townships.

The exact procedure followed in the case of the State Trunk Line 92-1 in order to secure its improvement was as follows:A petition was circulated under the provisions of the Covert Act,by Mr.Samuel Boyce,a property owner on the road. In as much as the road was part of a State Trunk Line,the petition was transmitted to the State Highway Commissioner along with evidence of the eligibility of the signers as provided for in the same act. The petition was approved by the State Highway Commissioner and the survey instructions given to the Engineer of Surveys of the State Highway Department. Although the petition has been favorably acted upon and a survey made in accordance with the legislation provided for it,there is no clause in the law which will cause the State Highway Department to authorize construction at once,thus the actual improvement of the road must wait the convenience of the State Highway Department.

At the beginning of the work,an agreement was entered between the State Highway Department and the thesis party by which the field expenses were to be met by the Highway Department. These expenses,including a truck for transportation and such unskilled labor as it was necessary to employ in the field together with the customary board and lodging afforded a very economical means for the State to have a survey made. The arrangement was satisfactorilycarried out as far as each party was concerned.

PRELIMINARY SURVEY

In the early days of new settlements, roads were made or rather existing trails were widened . These trails were usually first established according to the line of least resistance and without any regard to section lines, and no consideration was given to future requirements other than the easiest method of conveying goods from one place to another. This is shown by photograph No.1. These existing roads often contain curves that are dangerous to modern traffic, as shown by photographs Nos.2 and 3. Often, the vision is obstructed by high banks on the intrados of the curve and a steep drop on the extrados, as typified in the former, making an exceedingly dangerous situation. In photograph No.3, the existing road follows a reverse curve along which the vision is obstructed by the banks and some timber, allowing only a maximum sight of three hundred feet. This alignment of the old traveled way may be greatly improved by a judicious choosing of tangents to eliminate the general sinuosity of the old line and by flattening out or widening sharp curves.

The existing road, in the main, was already located, and the necessity for the location of a new one did not often arise, and when it did, only in comparatively short stretches of road. The original location in these places may have been fit and proper when the region


No. 1


No. 2.

was new and undeveloped and the means of travel crude, but the increase in the amount and the change in the character of it, justified some considerable changes. In proposing these changes, we made a thorough study of the existing conditions and of the topographical features of the location through which the road is to pass, for in this work of re-location, we consider it most economical to spend considerable time in the intelligent study of the terrain. The importance of the selection of the best route was borne in mind at all times because an error made in this first stage of road making would cause a heavy expense for rectification and until rectified impose a perpetualtax upon the public, for the road as constructed will probably serve for many generations, and as the growing importance of the surrounding country and the location of buildings and the division lines of the land with reference to the road make it increasingly more difficult and expensive to change the location. Economy, forms a true basis for proper location; that is, ultimate economy fulfilling the requirements that the route should be as direct as possible, subject to drainage requirements, as level as possible, and yet achieving the best results at the least present and future expense. The location is not, however, entirely a question of economy, since the location should be made with reference to the convenience and comfort and also to the pleasure of those who use it. Likewise, attention was given to other points, full knowledge of which was obtained in order to enable us to determine the most economical location considering foundation, drainage, aesthetics, the condition and character of cross-roads, the character of existing surfaces, and the availability of materials.

Straightness in a country road is frequently overrated, and efforts to obtain it involve, in many cases, injury to the beauty of the road and to the landscape and still gains no economical advantages. This point is shown in photograph No.4 where a straight line of considerable length could have been obtained but at the sacrifice of the trees, but instead, two deflections were established. In other words, our preliminary survey partook of a nature of a railroad reconnaissance or a study of location in which curvature and distance were the main points considered on account of the numerous deflections in the road. In a less devious road this survey would not have been necessary. In this survey we established PI's (Point of Intersection) having in view that the proposed road should fulfill four requirements:

(1). That the highway should develope to a maximum extent the commercial, agricultural, industrial, and the aesthetic interests of the community.

(2). That other conditions permitting, natural or present


No. 3.


No. 4


No. 5.

foundations should be utilized.

(3). That the amount of cut or fill should be reduced to a minimum.

(4). That long, easy curves should be substituted for sharp ones.

In photograph No.5 a portion of the road is shown where the excellent foundation was the determining factor for the location of the center-line, there being a 30-foot gravel road and with practically no cut nor fill.

In order to reduce the amount of cut or fill to a minimum, the PI of the curve shown in photograph No.6 was so established as to provide a heavy side cut to balance the heavy side fill. The fill was necessary so that a longer curve could be used instead of the present sharp one. As the grade leading to the curve is of the maximum percentage, and the present surface will make a good foundation for the future road, this method of providing the necessary earth was used rather than the cutting down of the present grade. This same method was duplicated at the locations shown in photographs Nos.2 and 7.

On order to preserve the aesthetic side of the present road in addition to what has already been mentioned, the PI of that portion shown in photograph No.8 was established so that the trees will not be affected.

The PI's of the road shown on photographs Nos.2,3 and 7 were set with a further view, that of precautionary


No. 6.

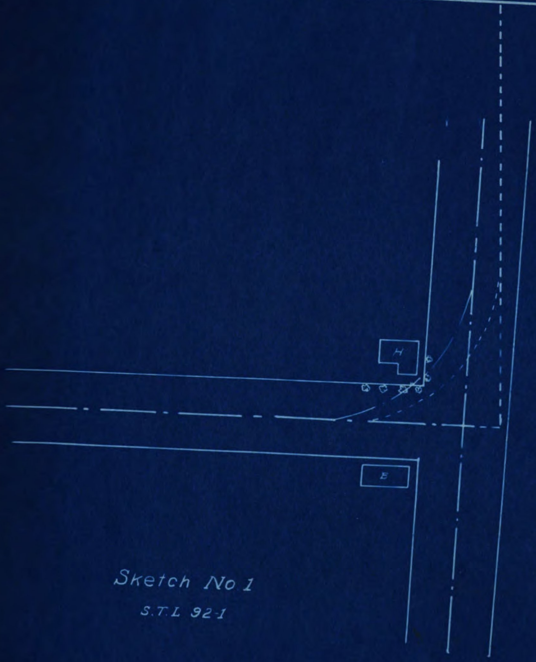

No. 7.

measures. Two of these curve locations have been discussed previously but the third includes a branch road which leaves the present road on the curve,and we decided that,if for no other reason,than that of a safety measure,this establishment was justified. In addition to this it also reduced the cuts and filld at this point by providing the earth necessary to get a good grade.

In the determination of the proper curve,the deflection angle and the length of the most suitable external were,in the main,the determining factors of the curves,except at the right-angled curves where the radius was the other prime factor. The State Highway Department has placed as a minimum a radius of 100 feet for right-angled curves but in the location of photograph No.9 this would not serve since there is improved property on the inside of the curve which would be damaged to some extent by a radius of 100 feet. Searles, in his handbook on Highway Engineering,suggests a method as shown in sketch No.1 but as this curve was at a road inter-section the adoptiong of this method would mean the placing of a kink unnecessarily in what is now a fairly straight road and also the acquiring of property. We deemed it advisable to adopt the shorter radius of 66 feet.


No. 8.


No. 9.



Sketch No 1

S.T.L 92-1

Whenever it is possible, the center-line of the road should coincide with section lines but we found a condition where this situation could not be obtained. From sta.714 to sta.752 we found an excellent road-bed of good grade, well-centered on a large culvert in good condition but the center-line of this road was not on the section line but varying at one end 10 feet and at the quarter corner 2.5 feet. We could have used the section line as the determining factor but by so doing, property would have to be purchased, a new culvert built or the present one lengthened, and dirt borrowed to make the necessary fills as a part of this line was in the village of Stockbridge and sufficient cut could not be obtained. Further, by following the section line, the new center-line would not have bisected the distance between present gutters. In view of these facts, the new center-line was made to coincide with the center-line of the road as it now lies rather than with the section line.

RE-LOCATIONS

Among the fundamental rules which govern the design of a well planned highway is the principle that a road should be as direct as the topography and ruling grades will permit,though not so much so as to produce a monotony of alignment. In the improvement of present locations such as we are chiefly concerned with in Michigan, this amounts to the problem of securing minimum curves and grades on a possible new location with a consequent shortening of distance. All of this must be obtained at a reasonable expense for,after all,the problem of highway re-location is one of economy. From the standpoint of desirability there are many considerations such as a suitable foundation,ruling grades,limiting curves,grade crossing elimination,property values,detouring distance, aesthetic features,and drainage possibilities. Due to the importance of the subject,the Highway Department has recently created the position of re-location engineer and adopted the policy of thoroughly investigating every possible opportunity for the improvement of our highways system along this line. In the survey of S.T.L. 92 - 1, we have studied the subject from every possible angle, realizing that the project as designed will be a permanent fixture and that,if a re-location is ever to be attempted, it must be done now.

The first chance for re-location occurs near station 85. At this point the old road curves to the right, as shown in photograph No.10, down a rather steep hill and then reverses to the left across a low gully about 400 feet wide, rising at an 8% grade to its former elevation. The steep grade of the present line and a hidden view caused by the reverse curve are the worst features. By prolonging the center-line as brought up to this point directly over the knoll as pictured in photographs Nos.11 and 12, on the left of the old road and running in an easy curve to meet a tangent on the old center-line beyond the present reversal, the situation is entirely relieved. Although the grade as laid calls for a maximum cut of nine feet, the distance is short and gravel will surely be found a short distance below the surface. This cut will do away with the knoll which has been obstructing the view and still keep a good intersection with the right fork, the whole yardage being used in the fill at the fork of the hill. The new grade will be only 2½% which is much lower than could have been possible using the old center-line, without filling the road to the right for some distance. As for expense due to yardage, it will be comparatively small due to the short haul and ease of excavation. Probably about 3/4's of an acre of land will have to be purchased, but the owner is willing to sell reasonably because of the increased value the improved highway will give to his farm.


No. 10.


No. 11.


No. 12.

The 8% grade at sta.95 is reduced to 5% by making use of a mound of earth at the left of the road, shown in photograph No.13, which offers one of the best opportunities for cheap excavation on the whole project. This mound obstructs the view on the curve which is another reason for its removal and use as a fill.

At sta.297, the present center-line curves to the left and follows the path a the upper half of a letter S before straightening out as illustrated in photograph No.14. From all appearances, the reason for this peculiar location was to provide a shorter cross-over on the intervening bog. At the present time, the soundings taken indicate that a direct line of crossing is as good as the old line. In either case, there is a distance of approximately 150 feet which has a doubtful foundation but with the new alignment there will be about 200 feet less road to build. As for a foundation for the drainage structure required, one place is as good as the other. The expense involved in securing the necessary property, about an acre, will be partly balanced by the shorter distance necessary to build.

By far the most irregular phased re-location on the whole project extends forward from sta.327. Apparently all the rules of economic and aesthetic aliggment are sacrificed for the consideration of


NO. 13


NO. 14

directness. At the very beginning, a twelve hundred foot radius curve puts a new center-line directly through a row of trees on the left of the present road-bed as shown in photographs Nos. 15 and 16. However, an analysis of the situation shows that a curve of shorter radius involves the purchase of property on the left and the destruction of part of a young orchard. A curve of larger radius is entirely out of the question because of the deep gully at the point of tangency as shown in picture No. 17, and the consequent necessity for keeping the center-line as far to the left as possible. A small deflection at sta. 338 + 83.1 was put in for the same reason. In addition, the trees involved are small, second-growth oak of little value as timber and worthless as road-side ornaments.

The gully mentioned before at sta. 335 is not such a formidable obstacle to economic location as a glance at the map might make it appear. A side fill of at least twenty feet will be required besides some provision for under-drainage. Hoever the soil is gravel and from sta. 336 to sta. 338 is an excellent opportunity to get all the fill required. If rip-rap seems necessary to prevent side washing it can be procured in the shape of field stones found less than 200 feet away on the hillside.


No. 15.


No. 17


No. 16.

One of the intended re-locations on the project did not materialize. In the preliminary survey a straight line was made from the deflection at sta.620 to sta.643 and a topographical map of the whole area was made. This alignment did away with two natural deflections in the present road-bed but meant the purchase of two strips of land,one on each side of the road,and the moving of approximately a mile of wire fence. For these reasons,it was deemed advisable to attempt a direct alignment,and the project was abandoned.

This practice of preserving the natural deflections extended back to sta.616 where the maximum deflection allowable without running in a curve was used to avoid buying property on the left. The only place in the whole intended re-location where the line was not held to the old road-bed was on a curve starting at sta.618 + 80.6 as shown in photograph No.18. Keeping to the left at this place for approximately 300 feet not only eliminates one deflection point and makes an easier curve possible,but prevents the possibility of overflow from the bog on the right in time of high water.

These four specific cases are the only available opportunities for re-location in the design of S.T.L. 92 - 1,but with the exception of grade-crossing elimination,they involve in some manner every argument for new alignments. We have tried to minimize the expense


No. 18.


No. 19.

in every way possible, consistent with good engineering, and the results obtainable far off-set the difficulties to be overcome. If, by our efforts along this line, we succeeded in making this highway safer, easier and more comfortable to travel on, we will feel that our energies have not been misdirected.

SURVEY METHODS

The topic of survey methods may be considered under the different party organizations necessary for the laying out of a highway,namely:the traverse survey party,the staking party,the bench level party,the continuous level party,and the topography party. These will be discussed in order as applying to the particular road we surveyed.

Three men were found to be needed in the traverse survey party,the chief of party,an instrument man,and a flag man. The remainder of the road party was sent forward on the proposed road to locate all section and quarter corners possible. These corners were to be used as instrument points when possible and when this was not practical,the corner was tied in to the survey. The intersection points on the road were chosen by the chief of party with due consideration to the location as covered in the discussion relative to preliminary survey. Magnetic readings on both tangents were taken as checks on the plate deflections. The points of deflections were marked by 1½ feet of 3/4's inch gas pipe. driven into the ground and tied in by three witnesses. Care was taken to chose the witness points outside of where construction work will take place. When it was necessary to establish the PI so as to bring the center-line of the proposed road on some important cut or fill or between sidewalks and curves,the string method was used.

Staking parties were tried consisting both of four and six men. In the four man party, the chief of party located intersection points while the stake drivers chained. The six man party consisted of the chief of party as head chainman, an instrument man, two stake drivers, a rear chainman, and a stake marker who also held the cross chain for the stake drivers. The six man party was found to be the more economical arrangement because in the four man party the road is covered twice, once during the chaining and later when the stakes are set. In the six man party, the chainmen can chain to the instrument, establish the PC of the curve and together with the instrument man, run the curve before the staking party catches up. Thus the staking party, of necessity the slower moving portion of the party, will not be held up. General highway practice, at the present time, requires stations to be set every hundred feet, stakes one inch square and eight inches long being used for hubs and set twenty-five feet from the center-line on each side of the road. Back of these are set markers 7/8" x $3\frac{1}{2}$" and 2' long. The stations are marked consequtively on these markers. The chain gang tapes ahead setting spikes firmly at each station on the center-line, and the staking party follows. The curves can be computed from the traverse notes except the chord deflections which are arranged as soon as the point of intersection is stationed. Eight degree curves or less can be stationed with one hundred foot sub-chords;between eight and sixteen degrees,fifty foot;between sixteen and twenty-four degrees,twenty-five foot;and anything greater than a twenty-four degree curve requires a ten-foot sub-chord. These divisions have been arbitrarily set but these lengths of chords approximate the circle sufficiently. Care should be taken in staking curves to set all stakes on their respective radii. Hubs and markers may be set less than or greater than twenty-five feet from the center-line incase of obstruction,but in this case the distance out from the center-line should be plainly marked on the back of the marker.

Benches are placed in highway work about one thousand feet apart. Spikes in the roots of trees are the most feasible but care should be taken that limbs do not hinder the shots to or from the bench,and they should be kept well out of any construction. The trees should be blazed or otherwise marked to insure an easy pickup. United States Geological and Geodetic bench marks were checked on whereverencountered. Bench marks were ordinarily established with a two or three man survey party consisting of the instrument man,who also kept the notes,and one or two rodmen. If a fourth man was added,he kept the notes. We tried a five man party using two instruments and obtained splendid results. The instruments alternated, both being kept in good adjustment, and a check within 1/10 of one foot on U.S.G.S. benches was obtained. This arramgement is an unusual practice but considering it from an economy of time standpoint three men can run four miles in a 10 hour day while five men average 8 miles per day.

Cross-sections or continuous levels were taken at every station with intermediate shots where the contour of the ground prevented the station shots from giving the true volumes. Shots outside of the hubs were taken where cuts or fills would overreach. Soundings were taken in water or in spots of questionable foundation such as shown in photographs Nos.14 and 29. A party of two to five men was used at different times when taking these cross-sections. Here, as during the establishment of benches, we found that the larger party was very economical. Instruments were alternated as before and each instrument took the cross-sections within two hu ndred feet each way and the turning point while the second instrument was being moved and set up. A two man party can average two miles per day with usual going, a three man party three miles per day, while the five man party can run easily a mile an hour. Thus it is readily seen that this arrangement is very economical. Elevations at tops and bottoms of all culverts and drains at both ends were determined. A line of levels was run along the ditches to culverts at both the inlet and outlet ends. Where bridges occur, elevations were taken of the bridge seats, bridge floors, tops of parapet walls, highwater marks, points that determine the stream-bed at the bridge, and points along the banks of the stream, both above and below the bridge. Elevations of manhole covers and gate boxes were also taken.

The topography adjacent to the road and of importance in the design of it, was taken by perpendicular off-sets from the center-line. The perpendicular distance can be estimated while the plus station is paced off. In re-location work the stadia method was used to advantage, as there was much contour work to be done. A one man topography party was found to be the most economical although three men are needed on re-location work. These are an instrument man, a rodman, and a mapper. In order to clarify some situations, photographs were taken.

In conclusion it can be said that the six man party with a motor truck for transportation is very economical. Of these six which includes the chief of party, two should be instrument men, and the other three should have a general knowledge of rodding, flagging, and staking. The cost of such a party in the field would be approximately fifty dollars a day, and in an average location they would turn in a mile a day. We completed fourteen

and one-half miles in twenty working days in one of the worst locations in Michigan. The arrangement of the party works out as follows: three one the traverse survey while the remainder locates section corners and runs benches, if time is available. After the traverse survey is completed, the staking party is formed. The five man bench level party should complete the benches next and then takes a cross section while the chief of party takes a topography. In this arrangement, the transpotation is used to the best advantage.

DRAINAGE AND DRAINAGE STRUCTURES.

Drainage, as applied in highway construction, has been defined as "the interception and removal of water from, upon or under the roadway". In the construction of any type of road, the securing of proper drainage is an important factor, since water is one of the most destructive agents encountered in the construction and maintenance of highways. Drainage may properly be considered under two main heads, namely; Sub-drainage and Surface drainage.

The necessity of sub-drainage is effected by the kind of soil, the location of the road, and the climatic conditions. On S.T.L. 92 - 1, the prevailing soils on which the road will be laid are sand, sandy loam, and gravel loam, all of which are suffieiently porous to carry away the water which percolates under the road-bed. This fact obviates the necessity for sub-drainage on the project and makes the subject one of minor importance in this thesis. We find that it is the practice of the Michigan State Highway Department to avoid the use of sub-drainage except under extreme conditions and in such instances the so-called French drain is given preference over other types.

In order to remove promptly from the surface of the road the water which falls on it and to prevent the water from standing on the surface, the road is crowned. In standard practice in this State a crown of 3/4 of an inch per foot of half width on gravel roads is required. The water which flows from the surface of the road is collected in side ditches or gutters whence it follows a longitudinal grade to the outlet, which may be a natural waterway, culvert, or catchbasin. The cross-section used on S.T.I. 923- 1 include four standard ditch shapes. The depths are 18 inches, 24 inches, 30 inches, and 36 inches respectively from the finished surface of the road. The 18 inch ditch is V-shaped and the others are trapezoidal. The slope on either side of the ditches is $1\frac{1}{2}:1$.

The length of side ditches should not be greater than is necessary to carry the water to the nearest natural outlet, since, if the amount of water becomes too great the capacity of the ditch will be exceeded and scouring will result. On our project, the topography is such that no difficulty will be experienced in this respect. Most of the grades are short and where long grades are encountered we found waste land or a natural waterway into which the water could be diverted.

The grade of the side ditches is an important consideration. If the grade be too low, the water will pond and sedimentation will clog the ditch. If, on the other hand, the grade be excessive, the bottom of the ditch is almost sure to scour. The practicable limits for ditch grades are considered by the writers to be 0.1% and 6%. On S.T.L. 92 - 1, we found no case where a ditch grade of greater than 0.1% could not be obtained and no instance where the grade will exceed 6% as the ditch grade on the completed road will parallel the center-line grade in all cases.

The disposal of surface water on this project is a comparatively simple problem. At many of the low points in the grade natural waterways offer efficient outlets and at other points the road is bordered by swamps or other unserviceable land onto which the water can be discharged without damage.

Drainage Structures.

Under this head will be considered the various drainage structures now existing on the road, their adaptibility to future use, and the reasons for retaining, modifying, or replacing them.

Driveway culverts are the first of the drainage structures to claim our attention. All of these on our road are of vitrified tile with the exception of two cast iron pipe culverts at stations 2 + 25 and 2 + 66. The minimum size of vitrified tile allowable for driveway culverts is 6 inches in diameter and the minimum length required is 18 feet. Where the existing culverts are of sufficient size and length to meet the above requirements,we reccommend that they be left in place and that concrete headwalls be built to protect their openings. We reccommend that those which fail to meet the specifications be removed and new ones installed.

Catch-basins are not to be disturbed in any instance since the proposed grades within the village limits conform so closely to the present grades that no material change in the elevation of any part of the road will be necessary.

The factors which affect the adaptibility to further use of culverts and bridges are their length relative to the fill on the new road,their capacity,and their state of preservation. The relative costs of repairing a structure and of replacing it with a new one must also be considered when making reccommendations for drainage structures.

At station 17 + 80 occurs a steel and concrete jack arch bridge of 19.5 feet span and with a width of floor equal to 20 feet. The bridge is unique in that it is placed on a curve which is nearly a right angle. Its location is shown by photograph No.20. The bridge is in good condition with the exception of bad cracks in the wingwalls as shown in photograph No.21. Its removal is necessary because it is on a curve,


No. 20.


No. 21.

too narrow for safety,and of insufficient waterway. We reccommend the diversion of the drainage ditch from its present channel so as to make it cross the road at sta.19 + 50,thence following the north side of the road to a junction with the present channel at a point about 100 feet below the present bridge. A reference to Sheet No.4 of the plans will show how this diversion could be easily accomplished. The location of the proposed bridge is shown by the arrow in photograph No.20. We reccommend for the new structure a 28 foot span T - beam bridge with 10-foot abutments according to standard plan B-1-A-5,shown herewith.

We find another jack arch bridge at sta.70 + 60 which is in good condition except for slight construction cracks in the wingwalls. It is,however,too narrow for use on the new road,the width of floor being only 16 feet. It is also of insuffieient waterway capacity, having an opening between the abutments of but 8 feet. Photograph No.22 shows the present structure. We reccommend the removal of this bridge and its replacement by a 20 foot span T-beam bridge with abutments 10 feet high according to standard plan B-1-A-5, refered to above.

At sta.89 + 50 water is carried across the present road by 35 feet of 18 inch vitrified tile. An open


No. 22.


No. 23.

ditch carries the water from this point across a swampy spot in the forks of the road and another 18 inch tile carries it across the north fork of the road. The ditch and outlet of the former culvert are shown in photograph No.23. A large area is drained by the ditch leading to this culvert and we find from indications and reports that, in time of high water, the capacity of the culvert is inadequate. Therefore we recommend its removal and replacement by a concrete box culvert of 3-foot span and 3-foot depth according to standard plan E-2-C-13.

At sta.156 the drainage ditch is spanned by a 3-foot concrete arch culvert, two views of which are shown in photographs Nos.24 and 25. There is a deep fill at this point and the road has been improved with a 12-foot course of gravel. Evidently, when the fill was made, headwalls were found necessary to retain it and the north headwall was built at the edge of the fill instead of at the end of the culvert. The result is that the end of the culvert now extends about 10 feet beyond the headwall and its opening is protected only by a few loose rocks piled around it. As the present culvert, with a 3-foot opening appears to be large enough to handle the flow, we recommend the placing at this point of a concrete culvert of 3-foot span and 3-foot depth according to standard plan E-2-C-13.


No. 24


No. 25.

The concrete arch culvert at sta.214 is in poor condition as shown by photograph No.26. It is also set at an angle with the center-line of the road and is too short. We recommend that it be replaced by a culvert similar to the one specified at sta.156.

A special drainage problem is found at station 321, where the road makes a sharp turn at the foot of a long, steep hill. It is necessary for a large volume of water to cross the road at this point. It is handled at present by two circular concrete culverts, one at sta.320 + 20 of 12 inches diameter and one at sta.321 + 30 of 18 inches diameter. Photograph No.27 is taken from the hill to the south of the road and shows the culvert at sta.321 + 30, its ends being marked by arrows. We consider it advisable to replace these two structures by one culvert at sta.320 + 80 and recommend a thirty inch circular culvert with concrete headwalls according to standard plan E-2-C-10.

At sta.416 there is a 3-foot span concrete arch culvert with masonry wingwalls, a view of which is shown in photograph No.28. The culvert is in good condition and of ample size to handle the amount of water flowing through it. Although only 22 feet in length, we consider that the added expense of replacing it would not be justified by the advantage derived from the gain in length.


No. 26.


No. 27.

We recommend, therefore, that it be retained.

At sta.495 a low portion of the road is bordered on one side by a pond and on the opposite side by a swamp. At present no drainage structure exists at this point. To prevent overflowing of the road at times of high water, we recommend the placing of an equalizer, which should be an 18-inch circular culvert according to standard plan E-2-C-16.

The last drainage structure of importance is a 4-foot span concrete arch culvert at sta.723. A view of it is shown in photograph No.30. As it is in good condition and wide enough to accomodate the traffic, we recommend that it be left in place.

Soundings.

Where the condition of the soil on the line of the new road is such as to make its supporting power an uncertain quantity, it is necessary to atke soundings to determine the depth below the surface of a firm stratum of earth. Bogs, swamps, and quicksands are examples of such conditions. On S.T.L. 92 - 1 we found two instances where soundings were necessary. From sta.299 to sta.302 the road crosses a bog which is described by residents of the locality as bottomless. The present road crosses one edge of the bog and ever since its construction about 40 years ago, it has settled and appreciable amount every year with the exception of the last five years. At sta.495 the road crosses a swamp as shown in photograph No.29 and it was considered advisable to atke soundings at this point.

Soundings were taken by pushing a 1/2 inch gas pipe into the ground until a resistance was encountered which indicated a solid layer of soil. The station and plus of the point and its distance from the center-line were recorded together with the depth to which the pipe was sunk.

The results of the soundings are shown by the following copy of the notes.

Sta.	L.H.	C.L.	R.H.
299 + 20	0.0	3.0	5.5
+ 60	12.0	15.0	15.0
300 + 10	20.0	20.0	22.0
301 + 80	12.0	10.0	10.0
302 + 20	1.0	0.0	0.0
494 + 50	25L/5.0 8L/5.0		15R/6.0 25R/6.0
495 + 00	15L/8.0 5L/7.0		10R/5.0
+ 25	20L/5.0 10L/4.0		10R/4.0 20R/4.0

All elevations from surface of ground at C.L. of road.


No. 28.


No. 29.


No. 30.

PRELIMINARY MAPPING

The data collected in the field furnished the basis from which the plans and maps were drawn. General highway practice and the specifications of the State Highway Department require that certain sets of field notes be taken that will place at the command of the draftsman, all the information that he needs to complete a set of working drawings and plans. These notes which were taken are: alignment, bench levels, continuous levels, and topography notes.

Standard tracing cloth as used by the State Highway Department, consists of a sheet 36" x 22", the lower half of which is cross-sectioned on a scale that will permit the laying of thirty one stations, using a longitudinal scale of 1" = 100'. The verticle scale specified is 1" = 10'. The upper half of the sheet is unruled and on this portion the center-line of the new road was laid using the alignment notes for the necessary data. The topographical features of the road were drawn to scale on each side of the center-line using the data from the topographical field notes. Below, on the cross-section area of the sheet, the center-line and hub line elevations of the road were laid off. As above stated, thirty-one stations were laid off on each sheet, the last station over-lapping the first station on the next sheet in order to orient and connect the plans.

THE DESIGN

The foregoing work finishes the preliminary mapping and constitutes a foundation for the design. In designing the road the requirements of the future road were the chief considerations. The design consists of the following selections:

(1). Type of metal.

(2). Width and shape of section.

(3). Proper drainage system.

(4). The correct grade line and the determination of quantities.

(5). Other details.

The type of metal and width of section were determined by the State Highway Commissioner. He specified a 16-foot gravel surface. The shape of the section was chosen from the standardized designs of the Highway Department. (See Sheet No.2)

The Grade.

In determining the grade for this road, we bore in mind that upon the proper selection of the grade depended the cost of excavation, the appearance, and the riding or hauling qualities of the road.

We recommended no extensive cuts in order to secure a grade lower than the maximum limiting grade of 6% which has already been determined.

We took special care to avoid using short, choppy grades, for they are undesirable since their use spoils the appearance of the road. It was seldom that we could not use a longer and more uniform grade which did not materially change the volume of excavation.

In determining the grade of a road, the most economical grade would be one in which the cuts just balance the fills at every point. This is impossible, but by putting in intermediate grades, we were able to very nearly approach a balance. However, the economy of grading did not govern our design to the extent of our overlooking the reasons of safety, convenience, and appearance, which demanded certain elevations and shapes.

Other features that determined our choice of grades were: the elevations of the pavements and railroad crossings and the grade of the sidewalks at Chelsea, where the road begins, and at Stockbridge, where the road ends, the swamp fill at sta.299 to sta.302, the existing bridges at sta.70 + 60 and sta.723 which are to be maintained, and the excessive cut at sta.86 to sta.89.

Maximum Gradient.

The selection of a maximum gradient depends more on the topography than on the traffic, although we did not overlook traffic. The country through which this road runs is very rolling but by following the valleys we were able to keep the gradient to a maximum of 6% which is within the limits for traffic. Our maximum gradient was determined at sta.152.

Minimum Gradient.

Our minimum gradient was obtained from sta.69 to sta.74 + 50. There we used a level grade. The drainage is taken care of by swamps on both sides of the road which carry the water away.

Intermediate Gradients.

Economical design demanded the use of rolling grades. Traffic does not require long stretches of straight grade. We deemed it unwise to cut, say a 3% grade to a 2% grade, inasmuch as our ruling grade is 6%. However, we did not hesitate to cut as much as was necessary to obtain the required ruling grade. We studied economy on the more level parts.

Laying the Grade.

In the balancing of earthwork we first considered the shrinkage of earth in embankments. The ratios given in the usual handbook are not applicable to this roadwork for they do not take into consideration the sod or other vegetable matter which is not suitable for embankments and must be wasted. From the State Highway Department we obtained the following table which has been compiled from experience.

Light skim work with considerable sod	1.30 to 1.35
Light work without much sod	1.25
Medium work	1.20
heavy work	1.15

The economical grade was found by holding a template over the earth section so that cut balanced fill and marking the elevation of the template on the profile. Through these points an average line was passed which gave the average economica grade.

The profile or theoretical grade is one which passes through the bottom point of the metal. The section is flat for ease of figuring and the earthwork was figured according to this grade. This grade was made to balance exactly in cut and fill for experience has taught that there will be no shortage of material for the shoulders of a gravel road.

The grade laying was best accomplished by placing the profile sheets end to end with the stations matching and then stretching a fine thread over the profile. The thread was held in place by pins which were adjusted until the desired grade was obtained. This adjustment was done by eye aided by testing of the proposed cuts and fills on the earth section until we were satisfied that the grade would meet all requirements.

This grade may be called a trial grade. We plotted the elevations of the various points of this grade on the earth sections and the outline of the sections were drawn in with the aid of a template cut to the required section. The enclosed area was then planimetered and the areas plotted as the ordinates of the quantity curve.

Vertical Curves.

Before the sections were plotted, the grade breaks were rounded off by vertical curves. Highway specifications limit the minimum length of these curves at 300 feet except at bridge approaches and railroad crossings where they must often be shorter. We were able to stay above this limitation. This being a gravel road, a 1% change of grade without a curve is not objectionable. The curves used are parabolic. The middle correction was computed by the formula:

$$\frac{G_2 - G_1}{8} \times \frac{L}{100} = r$$

Where G_1 and G_2 are the rates of intersecting grades and L is the length. Intermediate corrections vary as the square of their distance from the nearest curve. All corrections were made to the grade tangent elevations and were plus or minus according as r was plus or minus.

The Quantity Curve.

The quantity curve is a graphical representation of the volume of earthwork in comparison to the center-line depths of cut and fill as shown on the grade profile. It provides an easy graphical check upon balance of earthwork and allows one to rapidly compute the volumes by planimeter for the preliminary estomates.

The quantity curve was laid off in the same manner as the grade profile with the same vertical lines representing the stations. This required a scale of one inch euqls one hundred feet horizontally. The vertical scale is one inch equals one hundred square feet. A convenient horizontal line on the profile sheet was chosen as the base. The ordinates are the areas of the sections in square feet plotted plus for cuts and minus for fills. The ends of the cut and fill sections were carefully worked out to close the figure on the base. The area between the curve and the base represents the volume of cut or fill in cubic feet.

We manipulated the quantity curve in about the following manner: planimetered the areas of the sections above described, accurately and recorded the areas of the sections. Then we plotted the areas to form the quantity curve. We compared the areas of cut against fill. The cut area should exceed the fill area by the amount necessary to make a fill equal to the shoulder fill for the entire number of stations considering both in cut and fill,and providing enough material for the shrinkage of the below-grade fill. The end areas due to the shoulder fill were too small to plot as a fill curve. Where the proper relation (balance) between areas was not obtained,we reconsidered the grade to see if it could be changed to bring this about,being careful not to forget any reason which may have precluded the change of grade necessary to obtain a balance. Where such changes could be made,we inspected the quantity curve to see where and how much these changes were to be made,and change the grade accordingly. This having been done,we re-drew the template sections to the new elevations,re-planimetered the areas,and re-plotted the quantity curve. We then had a balance.

Having thus obtained a balance,we used the earthwork tables furnished by the State Highway Department and computed the volumes from the end areas. These volumes were then recorded together with the end areas on the volume sheets. Adding the 20% fill shrinkage to each figure,we were then ready to compute and draw the mass diagram.

Mass Diagram.

The quantity curve has given us a study and check on volume. The mass diagram (Sheet No.7) is for the purpose of studying the subject of longitudinal haul only and taking no recognition of the cross-haul due

to both cut and fill at the same section. Therefore, the difference is the quantity used in computing the mass ordinate. This ordinate is the algebraic sum of all the quantities (cut is plus, fill is minus) up to any point. It may be positive or negative.

The mass diagram was formed by plotting the stations as abscissa to a scale of 1" = 5 stations and the ordinates to a scale of 1" = 500 cubic yards. Connecting the ordinate points by a series of straight lines gave the mass diagram. This is comprised of a series of loops above and below the zero line whose ascending lines represent cut and whose descending lines represent fill. The loops that convex upward show haul in the direction of the increasing station numbers and the loops that convex downward show haul in the opposite direction, since haul is always from cut to fill. Each loop of this diagram is composed ot two equal parts, cut and fill and volume of these parts is represented by the length of the maximum ordinate which divides them when reckoned from any horizontal line drawn across the loop. The intersection of this line with the loop marks the stations between which so much of the cut and its corresponding fill are located. Similarly the portion of the loop intercepted between two horizontal lines indicated volume of cut on the ascending side and the fill on the descending side and the points of intersection of the horizontal lines and the loop indicate the stations between which such cut or fill occurs.

Where earthwork balanced within free haul limits, the zero line was the only horizontal line needed. Where waste occured, being all cut, it tended to elevate the diagram, while borrow depressed it. This condition required new equalizating lines so drawn that they would provide an economical adjustment.

The shoulder material for fills must be hauled from the cuts and this was automatically taken into consideration in the mass diagram in following the above method of computing volumes and ordinates.

The diagram is now ready to be inspected in comparison with the grade to see that the quantity of haul, borrow, waste, and over-haul were well taken.

Guard Rails.

We recommended the placing of guard rails at every point where the hubs were approximately five feet below the center-line of the road, and that they are to extend in each direction to points where the hubs are but two feet below the center-line.

INDEX TO MAPS IN POCKET.

No.	File No.	Description.
1	G-7-A-5	Title Sheet
2	G-7-A-5	Typical Cross Section
3	G-7-A-5	Plans sta. 0 to 31
4	G-7-A-5	Plans sta. 30 to 61
5	G-7-A-5	Plans sta. 60 to 91
6	G-7-A-5	Plans sta. 90 to 121
7		Mass Diagram
8		Relocation #1
9		Relocation #2
10		Relocation #3
11	B-1-A-5	Concrete Abutments
12	B-11-C-24	20' Reinforced Conc. T Bean Bridge
13	B-11-C-28	28' Reinforced Conc. T Beam Bridge
14	E-2-C-2A	Circular Conc. Culvert for Intersecting roads.
15	E-2-C-10	Headwalls for Circular Culverts
16	E-2-C-13	Concrete Culvert
17	E-2-C-16	Circular Conc. Driveway Culvert
18	E-4-A-32	Guard Rail
19	E-4-A-49	Method of Superelevation