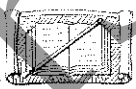
NEW JERSEY STATE HIGHWAY DEPARTMENT

MANUAL FOR CHIEFS OF PARTY —TO— SURVEY AND PLANS DIVISION



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PREFACE

The purpose of this manual is to instruct and guide the men in direct charge of one or more survey parties working in the field or office on highway survey and plan projects. These men are referred to throughout the manual as Chiefs of Party. They have direct responsibility for the instruction and work of the men under their charge, as well as carrying out efficiently the assignments given them. The manual outlines the policy, methods and requirements of the State Highway Department to be adhered to in the proper performance of their duties. It is the intention of the Department to keep this manual up to date with amendments and the addition of new methods and regulations as they become necessary.

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CHAPTER I

PERSONNEL INSTRUCTIONS

A Chief of Party must have, in addition to his technical knowledge, a thorough understanding of all the general policies, instructions, and requirements of the State Highway Department related to his duties or position. First among these is what the Department expects of him in his **general attitude** toward his work, his supervisors, men under his supervision; and toward those with whom he must cooperate.

He is expected to carry out his duties and instructions thoroughly and conscientiously at all times; to be loyal to the Department and advance its interests wherever possible; to be willing to perform duties beyond the regular requirements when such become necessary; to keep his engineering knowledge and technique up to date and continually strive to make himself worthy of advancement.

His attitude toward his **supervisors** is expected to be courteous, receptive, willing, and cooperative. He should not hesitate to offer, at the proper time and place, information or suggestions helpful to the solution of the problems at hand. Where information is needed or where instructions do not seem to apply he should not hesitate to request further information before proceeding. When receiving instructions he must listen attentively and be sure he understands thoroughly. All priuted instructions relative to his work must be read, understood and kept convenient for reference.

Toward the men under his supervision he should be a courteous, helpful and instructive leader, setting an example himself in the compliance with regulations and performance of duties. He should instill in his men the same loyalty and conscientious performance of duty that is expected of him. He should look out for their interests and see that they are treated fairly and without favoritism. He should make sure that they are properly instructed in their duties at all times, giving such instructions decisively, clearly, and making sure that they are understood. He is expected to maintain efficiency; to prevent friction and promote cooperation among the members of his party at all times.

In the course of his duties it will sometimes be necessary for him to confer, work, and cooperate with men from other branches of the Highway Department; from other State Departments; with contractors and their employees; with public officials and with the general public. In his relations with all these, cooperation for the best interests of the State must be kept uppermost in his mind. Always adhering to regulations and instructions, he must tactfully and with good judgment strive to bring about, if possible, the desired results without injuring the good will of those concerned.

Especial care must be taken in relations with the general public. A Chief of Party must realize that all public employees such as he and the men under his supervision are under constant critical scrutiny by many persons. They must therefore take great care at all times not to allow any situations to arise or perform any acts that will create wrong impressions or cast reflection upon the Department.

During the course of the work, it will frequently be necessary to seek information from individual citizens concerning details necessary for a com-

plete survey. Such contacts will call for courtesy, tact, and good judgment. Any attitude tending to create an impression of insistence or arrogance must be avoided.

Men on highway surveys and construction frequently undergo interrogation by private citizens concerning the work being done or proposed. It is therefore necessary for a Chief of Party to prepare himself and the men under his supervision to give suitable answers. Instructions must be obtained from his supervisors concerning the **information to be given** out or withheld. In general, concerning the location or type of any project, it is best to state merely that surveys and studies are being made and that no definite decision has been reached, until the Commissioner makes a definite decision and it is public knowledge. No private citizen shall be given information that is not available to the public at large. Where information is intended to be public knowledge and there is no reason to withhold anything, inquiries should be answered as completely as possible without causing delays, interference with the work, or cost to the State. In all cases the individual making the inquiry should be treated with courtesy and respect, and where the requested information cannot be given, a tactful and explanatory answer should be made. Care must be taken not to make any statements or to give any impressions that will start unfounded rumors. When such rumors are heard they should be corrected wherever possible.

It is often necessary to **enter upon private property** for the purpose of making surveys. Where such property is occupied; has special value; is a cultivated or enclosed estate; or is of such nature that trespassing thereon is unusual or objectionable, contact with the owner or caretaker should be made and permission requested. At the same time, the nature and reason for the

survey should be explained in a courteous and tactful manner, stating that care will be taken not to cause any unnecessary damage to the property. If permission is refused, it should then be explained that the State can take legal steps to prevent interference with necessary survey duties, but that the State is reluctant to do this and would rather have the voluntary cooperation of the owner. That part of the law outlined in Section 7, Chapter II, should be shown to the owner when he doubts the legality of entrance to his property. When he remains adamant in his refusal the Chief of Party must then take up the matter with his supervisors and the necessary legal steps will be taken if entering the property is essential to the survey. Often, however, such property can be avoided, by triangulation offset lines, or other similar methods, which althougb requiring more field work will save time in the end.

When working on private property, the Chief of Party must instruct his men to be particularly careful to avoid any **property damage,** such as unnecessary cutting of trees, breaking fences, tramping down crops, flowers and shrubs; failing to close gates, blocking driveways, or other unnecessary actions that will annoy owners or cause damage.

The normal required **working hours** of men in the field or field offices are from 8 A.M. to 5 P.M. with one hour for lunch. This means arriving at the field office or at the work to which they are assigned at 8 A.M. and leaving such work at 5 P.M. Any modification of the normal working hours shall be made only with the approval of immediate supervisors or by Departmental orders. It is the duty of the Chief of Party to make sure that punctuality and attendance on the work are strictly adhered to. He can best do this by setting the proper example himself and requiring the men under his supervision to follow it.

CHAPTER II

EQUIPMENT

A Chief of Party has in his charge equipment necessary for the carrying out of his work. This equipment is the property of the State but should receive the same care that one would give to his own personal property. The men using this equipment should be instructed and made to feel the necessity of giving it careful use and proper care.

During times when no field work is possible or necessary, members of the party who are not needed for office work should be given the task of cleaning, repairing and adjusting equipment. A supply of necessary repair materials should always be on hand, such as tape mending outfits, paint and brushes for rods, rags, oil and rust removers, screw drivers, chisels, hammers, screws and such equipment needed for ordinary repairs.

Of special importance is the care of the transits and levels assigned to a survey party. The Chief of Party shall be responsible for keeping these instruments in good working condition. They must be boxed carefully each time they are used, making sure they are not loose and will carry without jar or injury. They must be carefully handled in being placed in and out of cars and so placed in the car as to receive the minimum amount of jar. They must be guarded from injury from traffic and should never be allowed to remain unguarded in any position of doubtful safety.

The instruments must be checked at frequent intervals for the necessary accuracy. When adjustments become necessary they should be made by experienced men and only those adjustments that can be made safely without injury to the instrument should be attempted. All such adjustments should be reported to the district office. When other adjustments are needed or when

the instrument has been injured it should be turned in to the district office for replacement and the instrument sent to a repair shop. They shall be cleaned and oiled when necessary.

The Chief of Party must observe the handling of these instruments by the instrument man and make sure that he is giving them the care that sensitive and delicate instruments require.

Having on hand the proper equipment and materials is an item that requires the constant attention of a Chief of Party. He must anticipate and estimate the needs of his party for the work to be done. Such equipment as instruments, rods, tapes, axes, sledges, brush hooks, sight poles, tapes, note books, tables, etc., must be checked often; materials such as stakes, spikes, tacks, nails, keel, pencils, must also be kept on hand in sufficient quantities to prevent any time being lost because of their absence.

By far the most important equipment assigned to a survey corps is the **cars** used for their transportation. These cars are under the supervision of the **Equipment Division** and their regulations and instructions must be complied with. Following is an outline of their requirements:

The motorized equipment used by the various divisions of the State Highway Department is furnished and maintained by the Equipment Division. The State is divided into seven (7) Equipment Division Sections, each in charge of an Inspector.

Upon the acquisition of a piece of equipment the operator's first responsibility is to ascertain what section he is located in, and to contact that garage for all necessary service. It is the duty of every operator of Highway Equipment to notify the **section inspector** immediately if trouble develops in the equipment.

The Equipment Division has mechanics on the road constantly to make minor repairs, grease this

equipment, and to see that it is kept in proper condition. The equipment is not to be operated if it is in an **unsafe condition,** with bad brakes, faulty steering, poor tires, etc., unless the Department inspector grants that permission. It should then be operated cautiously until such repairs as are necessary can be made. The survey field offices must be notified of all defective equipment in sufficient time to have repairs or replacements arranged for.

It is the **operator's responsibility** to see that the equipment is properly taken care of and not abused. He must see that the gasoline, oil, water, and tires are properly checked. The air pressure in the tires should be checked twice a week and any defects reported immediately. The gas and oil should be obtained whenever possible from departmental tanks. All operators' reports together with gas and oil receipts must be sent in promptly at the end of each week.

Where cars are driven by **more than one driver** the Chief of Party must see that the proper cooperation is arranged and that no omissions occur due to misunderstandings.

Vehicles should not be overloaded at any time. Over-loading is detrimental to tire life and the mechanical parts of the equipment.

All State **Motor Vehicle Laws** are to be observed at all times, especially that pertaining to the maximum speed. No one but a licensed operator is to operate any equipment at any time.

CHAPTER III

DRIVING

The Chief of Party shall be responsible for the **proper instruction** of the operators of the motor vehicles assigned to him or working under his supervision. He must make sure that these operators read or have read to them the following **instructions:**

Operators of Department Vehicles shall always comply with prevailing speed laws and traffic regulations, shall always exercise tbe utmost care to avoid accidents in driving or parking, and shall always be courteous to and considerate of the rights of other motorists and pedestrians.

Supplemental to our efforts to build safer and more useful highways, it is one of the duties of all operators of Department Vehicles to set an **example** to other motorists in the proper use of motor vehicles and of the roadway. It is evident that if those who are engaged in the building of roads violate traffic regulations and misuse the products of their efforts the general public hardly can be expected to do otherwise. By the safe, courteous, considerate, and sensible operation of Department Vehicles they will help greatly to induce a favorable attitude on the part of the pnblic toward themselves, their fellow-employees, and the Department as a whole. It should always be borne in mind that, as State employees, their welfare, as well as the welfare of tbe Department, is greatly dependent upon **public opinion** and that it is one of their duties to foster favorable opinion by strict compliance with all speed laws and traffic regulations even though at times this may prove to be irksome or inconvenient to themselves and apparently a waste of time.

In addition, it is essential that Department vehicles be operated at reasonable **speeds** in order to

prolong their useful life and to keep the cost of maintenance as low as possible.

The operation of motor vehicles at high rates of speed is a very dangerous and costly practice and, in the case of Department-owned Vehicles, cannot help but incur an unfavorable public reaction.

Finally, it should be borne in mind that the operators of Department vehicles enjoy **no special driving privileges,** that in the eyes of the law they are just plain motorists and are as susceptible to prosecution by failure to comply with traffic regulations as anyone else.

CHAPTER IV

SAFETY IN WORKING

The Chief of Party is responsible for the safety of the men in his charge. He must make certain that the men under his charge have obtained and read a copy of **"The Safety Manual of the State Highway Department"**. When obliged to work in dangerous locations, such as on travelled roadways, he shall formulate an opinion as to the **dangers involved,** and see that all reasonable precautionary measures such as flagmen, warning signs, barricades, or other means, are employed to safeguard both the men in his charge and the travelling public. He shall issue such instructions to his men as are appropriate to prevent their being injured or contributing to an accident. He shall, under no circumstances, issue instructions to anyone to work under daugerous conditions without providing all reasonable means to prevent accidents.

He shall endeavor to bear constantly in mind that safety in working under dangerous conditions depends largely upon realizing the dangers involved and taking the proper precautions. He should frequently remind his men that the most important rule in working on **traveled highways** is that one should never take it for granted that he is seen by the driver. This applies regardless of whether or not flags, waruing signs, or barricades have been erected, because motorists more frequently than one might suppose run directly into all sorts of warning devices at any time of day or night regardless of how prominent or visible these devices may be. He should endeavor to impress upon his men that when working on traveled roadways they must, in the interests of their own personal safety, endeavor to keep one eye on the work and the other on approaching vehicles and to get well in the clear when it ap-

pears necessary. He should also endeavor to have each of his men size up the situation before starting work and decide in advance upon the safest course of action for each of them to follow in case of emergency so as to avoid the necessity of a split-second decision in which event they might accidentally step into the path of a moving vehicle instead of getting out of the way.

The Chief of Party should not permit any members of his party who are **physically defective,** especially with respect to seeing, hearing, and agility, to participate in work where such defects will endanger them. Great care should be exercised to avoid the contact of steel tapes with railroad tracks, **electric power lines,** wires of any kind, or electrical devices.

Caution must be observed in the handling of axes, knives, brush hooks, and other **sharp instruments.** They must not be carried or wielded carelessly, especially in the proximity of others.

All members of the party should learn to recognize **poison ivy** and poison sumac and realize their susceptibility to these poisons. Those who take them easily should not be allowed to work where they will come in contact with them.

Men should not be expected or allowed to do dangerous or unnecessary climbing.

Heavy lifting by men susceptible to hernia must be avoided.

Salt tablets should be kept on hand and used during days of excessive heat.

Men should not be allowed to acquire excessive sunburn.

The Chief of Party must also see that proper equipment, wearing apparel, etc., is provided for men working in water, swamps, woods, and other difficult places.

He should advise the men as to the proper clothing to wear for the work at hand.

He must make certain that all necessary **safety signs** and equipment are carried by each party and are definitely used.

CHAPTER V

FIRST AID

When an accident or sudden illness occurs to a man at work it shall be the duty of the Chief of Party to see that proper aid and care is given to the victim. He shall make certain that each member of the party has been given and has read the "Safety Manual of the State Highway Department." If a member of the party is trained or experienced in First Aid work, he should be designated to administer proper treatment. Where no such experience is available only common, simple measures for First Aid should be undertaken and where there is any likelihood of the case being serious, medical help should be secured as soon as possible without unnecessary movement of the injured party.

Minor wounds and injuries should be looked after immediately. Cuts and abrasions should be treated and dressed as soon as possible with equipment from the First Aid Kit. Men should not be allowed to continue working and aggravate any wound or injury received.

The supplies in First Aid Kits must be replenished after using. An occasional check should be made to see that sufficient First Aid Kits are on hand and their supplies complete.

CHAPTER VI

REPORTS

One of the duties of a Chief of Party is the making out of reports. These consist of **two kinds,** routine and special. The routine reports are the weekly car reports, made on forms supplied by the Equipment Division, and weekly time reports made for the Assistant District Engineers in charge of the field offices.

A weekly **car report** must be made out for each car each week. The Chief of Party must familiarize bimself with the details and make certain that a report is sent to the Equipment Division promptly for each car assigned to him or working uuder his supervision.

Weekly **time reports** must be handed in to the Field Office each week showing the daily assignments of the men and the distribution of their time, as per instructions received from the Assistant District Engineer.

Some of the most important special reports to be made out are the **accident reports.** These are made on forms supplied by the Department's Bureau of Claims and Compensations for injuries, and by the Equipment Division for motor vehicle accidents.

An accident report must be made out for any accident causing damage to a State car or for any personal or property damage caused by a State owned car.

A report of any **injury** received in the course of the work must be made out, if there is the slightest possibility of any compensation claims being made immediately or in the future. This must be done not only for the protection of the State but for the protection of the employee as well.

These reports must be made out immediately while all details are fresh in mind. In case of

serious accidents or injuries the Field Offices and the Equipment Division or Bureau of Claims and Compensation should be contacted by telephone as soon as possible.

The Chief of Party must secure the necessary accident report blanks, keep them on hand, and thoroughly familiarize himself with all their details and requirements.

Occasionally it will be necessary for a Chief of Party to give reports on complaints, drainage conditions, and other special incidents and construction features. Such reports should stress the main purpose of the report and supply all the information relative to that purpose. The report should be clear, concise, and exact. No information should be given, the authenticity of which has not been carefully checked. All data and figures contained must also have been checked for accuracy.

Where possible a Chief of Party should keep a copy of all reports submitted by him.

All reports must be submitted at the required time.

CHAPTER I

NOTE BOOKS AND NOTE KEEPING

Good note keeping is one of the most essential duties of surveying. The note keeper must always bear in mind that his notes are to be a permanent record; that they must be easy to interpret even by those not familiar with the work a long time after they are made. Therefore, all notes shall be accurate, legible, neat and systematically arranged.

Standard note books furnished by the Department shall be used. The outside cover shall be stamped or lettered in the manner shown in the Illustration in Part Two, Section 3-C.

The title on the cover should, in all cases, be comprehensive enough to readily identify the job and its location.

When beginning the notes, the first few pages should be left vacant for the insertion of **the index.** This index should begin as soon as the nature and extent of the work is known. It must be kept up to date along with the work, as far as possible, and completed as soon as the note book is filled. The index shall show a general outline of the notes contained in that book. This outline shall be comprehensive enough to make it easy to find any particular part of the work without unnecessary trouble. Each book must be indexed.

All indexes should refer to pages of the note book which shall be numbered consecutively beginning at the front. The stations of the survey should be placed in the index and should refer to page numbers in the note book wherever possible. For cross-sections and topography, or other notes that are continuously the same type, groups of not over ten stations in the index should be referred to the corresponding group of page numbers.

When **beginning each day's notes,** the names and titles of each member of the party, the license number of each car used, the date, temperature, condition of the weather or any other circumstance that might affect the work or personnel, shall be entered.

Highway Survey notes in general may be divided into the following classifications: reconnaissance and preliminary survey notes; notes for topography and right of way data; bench mark, cross-section and profile notes; notes for construction layout; as-built survey notes; and notes for special surveys.

Reconnaissance and **Preliminary Survey notes** are usually so diversified that standardization is difficult. In general, they consist of notes of rough topographical surveys by Stadia, or other rough methods of location; cross-sections by hand level or regular level for contour maps; profiles of roads, streets, streams, railroads, etc.; types and valuation of buildings and other property and special and essential features bearing upon the location of a highway. Therefore, due to this diversity, some thought must be given to the general arrangement of these notes beforehand. An estimate of the amount of space to be used should be made where possible. Where such notes will not be extensive, alignment and topography notes may follow in the same book.

Alignment notes shall show clearly all necessary data for running out and reproducing the center line or survey base lines of the highway and its component parts. The point of beginning shall be shown clearly tied in with former surveys or existing lines. The correct station location, and clear, permanent and complete ties must be shown to all points on line necessary for instrument set ups. All P.C.'s, P.I.'s and P.T.'s shall be shown including methods of computation for es-

tablishing the curve and station location of instrument set ups. Special cases, such as offset lines and triangulation around obstacles, shall be clearly shown by sketches, with methods used, and all necessary field data for computations. The bearings and length of all tangents shall be shown, together with all field data for sun shots, polaris computations, or ties to New Jersey Plane Coordinate System Monuments. Where equations in the line occur, they must be definitely labeled and the back and forward stations clearly shown, with the differential in length given showing the line to be longer or shorter than indicated by the stationing. After the alignment notes have been completed the index must be checked to make sure that it shows clearly the location of the important features, such as curves, equations and special problems.

Notes for **Topography and Right of Way Data** require careful planning and considerable thought beforehand. They are one of the most important parts of the survey notes and the most difficult to make clear and complete. The **note keeper** should study conditions carefully before starting his notes and sketch clearly all the principal features to be located. The sketches shonld be clear and drawn to a proportionate scale. Plenty of space in the book should be allowed to avoid cramping and crowding of additional notes and measurements. The **note keeper** must not allow himself to be hurried, but take sufficient time to keep his sketches ahead of the actual measurements so as to enable him to record notes and dimensions clearly and neatly. He must make sure that all measurements are called to him clearly and distinctly and when in doubt have them repeated. Mistakes in measurements can often be corrected by the note keeper by checking with his own estimates and making comparisons

with definite measurements. This mental comparison should be made a habit in note keeping.

It is not necessary that the note keeper always be the Chief of Party. If another, who can keep good notes, is a member of the party, it is often advisable for the Party Chief to perform some other function where he can be free to give a more thorough examination of conditions and more thought to the planning and directing of the work. The Illustration in Part Two, Section 3-E shows a good example of topography notes.

Notes shall be made of all **right of way data** that can be obtained on the ground at the time of the survey. This shall include accurate ties to all property lines, property monuments and corners, where they can be definitely determined. Where such lines and corners are only approximate this shall be definitely stated in the notes. The notes shall also show the nature of the adjacent land; the type, color and condition of all buildings and fences; the type, size and condition of all trees, shrubs, flower beds, and any other fixed objects that have property value. Buildings or other important features that are over 50 feet and not more than 200 feet from the right of way line shall be noted with their estimated distances. Care must be taken in the index to make it comprehensive enough to readily designate the important features and all stations in the book.

Bench marks, cross sections, and profile notes are perhaps the easiest and simplest to arrange uniformly and neatly but the most difficult in which to avoid costly mistakes, therefore, accuracy should he particularly stressed in putting down rod readings and computations. Too much importance cannot bc placed upon the note keeper making constant comparisons and checks of the figures given him. Complete bench mark

notes shall he given showing all H.I.'s, T.P.'s, etc., together with all computations. Where **self-reading rods** are used and elevations are read direct the note keeper must be doubly careful to record elevations in their proper place, and keep a continual mental check by observation and comparison. It must be clearly noted on each page of the notes where direct elevations are used.

Sketches should accompany rod readings to show elevations of walls, bridges, streams, gutters, drainage structures, and any other unusual features that cannot be made clear by the notes alone. The Illustration in Part Two, Sect. 3D, shows samples of good bench mark, cross section, and profile notes. This method of note keeping shall be used where possible.

Note books shall be kept showing all **construction layout data.**

The notes shall consist of: All layout data and calculations concerning the alignment and elevations of all structures, intersections, ramps, etc., as well as the primary highway alignment itself; all borrow pit layout data and elevations; all ties to removable monuments, bench marks, important land marks or points necessary for reproducing important lines or grades; also notes shall be kept of any changes in the plans with reasons therefore, and any unusual circumstance to which further reference might be necessary. Because of the variable nature of these notes they should he revised and clarified frequently so that they will be readily understandable by other engineers long after the work has been completed.

Except for small projects, separate note books shall be used for **as-built survey notes.** These books shall be titled, indexed, and the notes kept in the same manner as topography and cross section notes. Since these notes are usually made at intervals during the course of construction as well

as afterward, they must be carefully planned and spaced, so that they follow as far as practicable in the same order as the stations of the project. Measurements of all construction items shall be shown in sufficient detail so that necessary construction quantities can be readily calculated. Sketches shall accompany measurements where necessary for clarity. New ties, bench marks, right of way measurements, or any other measurements showing changes made in the plans or topography must be clearly shown. In short, as-built notes should show a complete and accurate survey of the actual conditions of the construction plans at the time of the project's completion.

Notes for special surveys such as bridges, drainage, right of way, special construction or check surveys, etc., usually occupy only a few pages and therefore should, if possible, be placed in the topography or cross section note books of their respective projects. A careful explanation of these notes should be given and all necessary connections and ties to alignment, benches, etc., clearly shown. Clear sketches should be used to make all notes thoroughly understandable. Appropriate titles for each particular survey shall be placed in the index and the usual personnel information given daily.

CHAPTER II

RECONNAISSANCE SURVEYS

The **purpose** of a highway reconnaissance survey is to collect and record by maps, or otherwise, information and data from which can be determined the most desirable or economical location, type, and extent of any project to be undertaken. Such a survey will include projects to be studied, such as highways to be constructed over new locations, comparative studies between new and old locations, widening and rebuilding of existing highways; and special projects such as grade separations for highways or a railroad and highway, large river bridges, etc.

The **methods** to be followed and the investigations necessary will vary somewhat with the nature of the projects for which the reconnaissance survey is to be used. In nearly all cases it will be necessary to make a map or maps from which studies and comparisons can be made. Investigation should first be made of the availability of existing maps in the vicinity of the project. Geodetic survey maps and contour maps furnished by the U. S. Army are available for the entire State and can be used to ascertain the possibilities of location and to plan the extent and nature of the work. In urban and subnrban areas tax maps can be secured from the various municipalities. Other county, township or municipal maps are also usually available. Any, or all of these different kinds of maps may be used on a single project depending upon the extent and type of the project for which the survey is being made.

For grade separations, new alignment througb built-up districts, and locations in limited areas, tax maps are a valuable asset. With these maps in hand a small survey corps can go out on location and with simple measurements and estimates

can sketch on the prints all buildings and important topographical features. These prints can then be fitted together and a tracing of a map of the entire location made that will be sufficiently accurate for most reconnaissance work. Similarly, old construction plans, where available, can be used where the survey is to be along existing highways. County, township and municipal maps can also be used in a similar manner where the scales are sufficiently large.

For extensive projects over new alignment especially through built-up sections, airplane photographs are of great assistance. These photographs are now available for all parts of the State and can be ordered to any scale. However, except for special cases 400′ to 1 inch has been found to be the most practical scale to use for reconnaissance work. This scale is small enough to cover large areas in a workable space and at the same time large enough to see the important features and allow tracings for necessary maps to be made. In areas requiring more accurate and detailed studies a 200′ = 1″ mosaic photograph should be obtained. Accurate maps can be traced from these mosaics and preliminary design made.

Situations will often arise where no suitable maps are available; where the project is confined to a limited area; and where considerable care is necessary in determining the various layouts and comparisons. In cases of this kind it will be necessary to make topographic surveys in the field for the purpose of making a map suitable for the project to be studied. Before making this survey and the resulting map, careful consideration should be given to the possibility of using it also for the entire tract map described in Paragraph 2, Sect. 3, Chap. XXVI, Page 1. With a little foresight and planning many of the recon-

naissance maps can be made to also serve this purpose.

Before starting reconnaissance field surveys the Chief of Party should plan the work carefully with his supervisors, determining the degree of accuracy necessary and the extent of the survey. In many cases more detailed information than can be supplied by existing maps or airplane photography will be needed. In such cases a rough field survey will be necessary. Topographic features should, as a rule, then be located by stadia unless street lines or other definite lines can be quickly tied in and quick offset measurements taken from these lines. Only topography should be located that will have a bearing upon the location of the highway, such as buildings, approximate property lines, utilities, streets, roads, railroads, streams, bridges, etc. While topographic location is being made, necessary elevations can be taken during the same operation by stadia shots and rod readings, augmented by hand level readings. The hand level is a great time saver in this work and should be used wherever possible. Results from it can be accurate enough for reconnaissance work provided the hand level is kept in proper adjustment. Sufficient elevations must be secured to show profiles of important highways, railroads, drainage outlets, streams, bridges, and other features that may have important bearing upon the location. This, in addition to enough elevations to estimate profiles and earthwork for the different locations, must be recorded and made a part of the maps.

Where existing maps or maps made from air photography are used, all or parts of the above described field surveys can be tied into such maps. The amount of field work necessary will depend upon the details, accuracy and scale of the map required, which in turn will be determined by the nature and the extent of the project to be studied.

Besides the field surveys it will be necessary to collect considerable other **data and information** having important bearing upon the selection of the proper location. Included in this data must be:—approximate location of the sub-surface structures, their type, sizes and owners; location and extent of rock; depths of streams, rivers and marshes; borings showing hard bottom for wet excavation; elevations of tides; number of openings of draw-bridges; width of bridge spans in the vicinity, and any proposed special features or developments. Inquiries should be made of public and utility officials and local residents of any contemplated new plans or developments planned in that vicinity. Kept in mind at all times must be the thought that all data and information gathered is to be made a comprehensive part of the maps being prepared.

Where reconnaissance maps showing preliminary designs are made they must also show additional data as outlined in Sec. 7, Chap. IV, Page 1. After the maps have been completed a thorough study must be made to discover **all feasible locations** or layouts. These must then be drawn on the maps in sufficient detail to make true comparisons. Frequent consultation with the chief of party's supervisors must be made in making these layouts.

In order to make proper comparisons, profiles must be plotted, earthwork and other construction items approximately calculated for each location. With these completed, **estimates of cost** must then be prepared for each layout. Estimates of cost of all bridges shall he secured from the Bridge Division and estimates of right of way costs from the Real Estate Department. The necessary information shall be furnished these Departments as soon as possible in order that their estimates can be completed along with the other estimates.

The estimates and maps must be completed and shown in a manner that will enable them to be readily understood by those who have the authority to make the final decisions so that such decisions can be made with a full understanding of all factors involved.

CHAPTER III

ALIGNMENT

When the approximate location has been determined from the reconnaissance survey it next becomes necessary to lay out the lines of the proposed project accurately on the ground. Before going ahead with this work the Chief of Party shall consult his supervisors and obtain definite knowledge regarding the following general details of the project: departmental policies, extent of the work, widths of right of way, typical sections of roadways, maximum curvatures allowed, approximate grades and elevations necessary, location, widths and clearances of bridges, and other important requirements that might influence the exact location of the proposed alignment.

For nearly all projects an approved preliminary or reconnaissance map of the layout will be available. This must be thoroughly studied, compared and checked with the various topographical features on the ground and a plan for staking out the alignment determined upon before starting. Since all projects will begin or take off from an existing highway, plans of that highway should be secured where possible showing alignment data, ties, bench marks, etc. Where no plans are available, the center line of the existing highway must be located from the best information available, such as physical layout, tax maps, road returns, etc. The alignment of the new project must be definitely tied in with the existing highways.

Having studied the preliminary or reconnaissance map as a whole the layout of the alignment on the ground must be studied step by step in detail and carefully planned. This is one of the most important parts of the highway surveying. Haphazard alignment work can, and often does, cause considerable waste of money and time, unnecessary property damage, and poor design.

Hence the value of a very careful study of the exact line of the project cannot be over estimated. There are many features common to nearly all projects that will call for special study.

First the **alignment** of the various parts of the project must be carefully considered in itself. Although the preliminary map will usually show the general alignment many refinements will have to be worked out in making the exact layout on the ground. One of the most important of these is **curvature.** First the Chief of Party must consult his supervisors and obtain definite instructions regarding departmental curvature standards for each part of the project. He should also thoroughly familiarize himself with the standards set forth by the A.A.S.H.O., and the Public Roads Administratiou. However, in laying out the line, curves should be made as flat as possible or eliminated entirely where no prohibitive cost or property damage is involved. A careful study and good judgment must be exercised in this phase of the work as well as frequent consultation with supervisors. **Compound curves** can often be made to fit the situation more economically than simple curves and should be used where necessary to run the alignment through the exact locations desired, provided, however, the curves are flat and the differential complies with departmental uniform design speeds, otherwise the problem must be referred to supervisors or the designing engineer.

The exact points through which the alignment is to pass must be determined by a study of the reconnaissance survey, and also a very careful and detailed study of the topographical features on the ground. The purpose of this is to avoid unnecessary **property damage,** interference with public utilities, useless destruction of shade trees, excessive angles of crossings at bridge locations, passing through poor subsoil, causing unnecessary earth-

work or rock excavation, and causing construction of unnecessary drainage structures. Great savings can be made and the Department's good alignment policy still adhered to if sufficient time and study is given to this very important phase of alignment work. In fixing points of location there must be kept in mind the probable approximate grade of the highway at these points and a liberal allowance made for the slopes beyond the right of way line of both cuts and fills. Failure to do this often results in costly damage or unnecessary changes in alignment after plans have been drawn.

The technique of running in and **staking out the alignment** also requires considerable study and thought before starting. For ordinary highway projects the alignment shall be stationed and staked at fifty foot intervals. In selecting and designating curves even radii to the nearest 100 or 1,000 feet shall be used and the exact length of arc computed. All **curve data** can be computed from the "Curve Data Tables" furnished by the Department and also contained in this Manual. Where **transition curves** may be required the Chief of Party must confer with his supervisors and designing engineers and obtain the length of spirals or equivalent compound curves to be used. This matter must be considered when the location of the line is to be finally established. The "throw" of the new curve or compound curves over a simple curve must be known and the tangents established so that unnecessary property damage or a poor location will not result. If possible the transition curves should be established on the location plan when the line is first designed so that the layout on the ground will pass through the points desired. Stations shall be established along the arc and corrections made for chord distances where necessary. Curves must be made to check out so that an **error of closure** with the

laid out P.C.'s and P.T.'s shall be not more than six seconds of angle or 1/100 ft. of distance per each 100 ft. station.

Instrument work must be carefully checked and angles in the alignment measured to the nearest 30 seconds by tripling the angles and then by reversing and tripling again for a check, taking 1/3 of the total when no obvious error has been made.

All chaining shall be done by steel tapes and plumb bobs. Spring balance tapes are to be used only in special cases hereinafter described. Where necessary, tbe Chief of Party shall thoroughly instruct the chainmen in their duties and observe them constantly, checking their accuracy and especially their judgment in the use of plumb bobs and breaking chain over rough terrain. He must make sure that they familiarize tbemselves with and use approximately the standard 15 pound pull on the tape. Tack points shall be placed on each stake, and a nail or cross points used on existing pavements where possible. Marker stakes shall reference each station where practicable, otherwise station numbers shall be painted on the pavement or adjacent objects. A **standard length 100 foot steel tape** at 62° Fahrenheit shall be considered standard. All tapes that have had considerable usage and especially those that have been mended must be frequently checked by this standard. The allowable error in chaining shall not exceed 1/10,000. Where the differential in temperature will cause a difference greater than this, temperature adjustments shall be made. Check chaining shall be done where time will allow, however, in most cases the chaining can be checked more economically by the topographical survey party following.

Where **obstacles** are encountered in running the alignment, offset lines or triangulation may be nsed. However, extreme care must be taken in measuring both angles and distances in either

of these methods if the required accuracy is to be obtained. This is especially true where triangulation is used in crossing large streams or large inaccessible areas. Here permanent base lines and triangulation points must be established and carefully referenced or monumented. Where such triangulation is to be used for the design and layout for construction of bridge structures, the base lines shall be measured with a standard spring balance tape and the angles measured with an instrument reading to the nearest 20 seconds. These measurements shall be checked and re-checked until there is no possibility of error. Care must be taken in selecting the triangulation points. They should be outside the limits of possible construction, interference with traffic or utilities. A firm base for the instrument tripod legs must be constructed at each point.

Where dense wooded areas are encountered, in order to prevent unnecessary cutting of trial lines by the usual cut and try methods, offset lines or triangulation should be used where such areas are not extensive. For more extensive areas bearings of the alignment should he calculated from the reconnaissance map if it is sufficiently accurate, and where it is not, airplane photographs should be obtained and bearings calculated from these. With ordinary care the alignment can be made to check out with some adjustment and little or no additional cutting.

Bearings throughout the alignment shall be obtained from existing New Jersey Plane Coordinate System Survey Monuments wherever possible and the line definitely tied in to these monuments. The accuracy of the deflection angles can also be checked by such tie-ins. Where considerable stretches of alignment occur without any check up with existing true bearings, such bearings shall be obtained by observations on the sun or on Polaris.

Definite and permanent ties and references shall be shown for all P.C.'s and P.T.'s; for P.O.L.'s where set-ups are necessary and for P.I.'s where they are accessible. The ties shall consist of measurements to definite and permanent points sufficiently accurate and numerous to reproduce the exact point being tied in. Care must be taken that the points selected are outside the limits of construction and are not likely to be moved for any reason. Where no existing permanent points are available, measurements shall be made to stakes driven outside the limits of construction in order to hold the points until permanent monuments can be set.

CHAPTER IV

SURVEYS FOR CONSTRUCTION PLANS

After the alignment has been staked out the next step is to make **surveys** to obtain the necessary information and data for drawing the **construction** plans. The Chief of Party should first examine a number of sets of the latest New Jersey State Highway plans and thoroughly familiarize himself with the procedure, legend, standard details and general practice, before starting the field surveys. The survey work may be done simultaneously with the staking out of the alignment, or after all sections of it have been completed, depending on the type of project and the size of the survey force available. A decisive **plan of operations** must be carefully laid out at the beginning of the survey in order that all the forces may be fully utilized without loss of time or unnecessary work. With a large survey force all operations can be carried on simultaneously. Under most conditions it is more economical to begin cross sections and topography as soon as a section of the alignment is staked out, in order to have office work for all the survey forces in case of bad weather. This will also provide immediate work for the draftsmen or office men if any are available and not needed in the field work. However, care must be taken to make sure that alignment used for topography and cross sections has been definitely established and approved before this work is done, otherwise much of the work may have to be done over due to changes. Therefore, when other work can be found for the forces not needed for bench marks or alignment, it is sometimes advisable to complete the alignment for the entire project in order to have it definitely approved before beginning cross sections or topography.

Before profiles or cross section elevations of the project are taken, an accurate system of **bench**

marks must be established throughout. This work should start as soon as the location of the project has been decided upon in order that the cross section survey may be started at the proper time. Existing bench marks must first be located; those on the existing connecting highways and also the New Jersey Geodetic Control Survey bench marks. Plans of existing highways will usually give the former, and the latter can be found in Bench Mark Books supplied by the Department of Conservation and Development. These books also include U. S. Coast and Geodetic Survey Bench Marks that can be used in most cases. Mean Sea Level at Sandy Hook is the datum to be used for all New Jersey State Highway work.

A survey corps of three or four men will usually be sufficient to establish bench marks. However, if forces are available, one or more survey parties may work simultaneously on the same project. This is especially advantageous for long projects and will enable a line of benches to be established throughout the project and checked from end to end before cross section work starts. Checking on New Jersey Geodetic Control survey benches at frequent intervals will save time and re-checking benches.

The technique of establishing bench marks although simple requires considerable care and accuracy. Careful, accurate, levelmen and reliable rodmen must be selected and instructed in the details necessary to be observed in getting the required accuracy. The Chief of Party must never take too much for granted and must be constantly alert, making mental checks and observations of elevations, readings, choice of turning points, etc. He must also see that the instruments are checked frequently and kept in correct adjustment. The bench marks must be selected with care and discretion, and should be spaced at intervals that will not require more than one turning point.

They must be well beyond the limits of construction, easily accessible, and easy to find without being mistaken. Only points on permanent structures that will not be affected by frost action, settlement, or other movements, should be used. Clear, concise descriptions must be noted with station and offsets for each bench mark. All descriptions mnst be definite about the exact point at which the rod is to be held. Cross cuts or driven spikes may be used where no other definite points are available.

Bench levels shall be **checked and re-checked** until there is no chance for mistake. The allowable error for a line of bench marks in checking by re-running or in checking with existing benches shall not be greater than .02 for each mile. The total error shall be adjusted uniformly throughout the benches being established. When tying in with Municipal, County, or other State Highway projects already completed it will sometimes be necessary to show an equation of benches, since in some cases former datums were assumed or in error. The correct elevations for the new project should be used wherever possible and definite **equations of elevations** shown clearly wherever any uncertainty might occur.

CHAPTER V

TAKING TOPOGRAPHY

In order to design, let contracts for, and build highway projects it is necessary that the plans show in detail all the topographical features and existing conditions that will influence the work or be affected by it. The location of such features is commonly called "taking topography." This work is usually done following the staking out of the alignment, but may be carried on at the same time or alternately depending upon the nature of the project and the forces available. Considerable study should be given for determining the most economical method of procedure. In nearly all cases where the chaining has not been previously checked the party taking the topography should check the chaining of the alignment and the stationing particularly at point of curve and point of tangent.

The technique of location work varies somewhat with the nature of the project. For simple alignment the station and offset method from established base lines should be used whenever possible. This method makes easier plotting and designing, saves calculations and gives direct measurements from the construction lines to all objects affecting or affected by, either the construction work, or right of way lines. It is of great importance that such measurements be accurately determined. Therefore when other methods of location, such as measurements from offset lines, auxiliary base lines, and stadia locations are necessary, sufficient check measurements must be made to assure accuracy and furnish enough data to accurately calculate distances from the construction and right of way lines.

The topographic features located must include everything near the construction work or right of way lines that will have any bearing on the pro-

ject or right of way purchases, such as buildings, walls, steps, walks, trees, shrubbery, curbs, sidewalks, edges of roadways, streams, pavements, fences, property lines, cesspools, wells, etc. All surface and underground utilities must also be accurately located. In addition to location, notes shall be made of the condition and types of such physical features as buildings, walls, walks, roads, curbs, fences, wells, cesspools, etc., or any other features that may have some bearing on the design or be the subject of future controversy.

Existing monuments or markers on property corners that may be destroyed by construction of the highway, should be thoroughly tied in, so that they can be reproduced if necessary.

CHAPTER VI
CROSS SECTIONS

It is necessary to have complete **cross-sectional elevations** throughout the project in order to compute accurately the earthwork, layout profile grades, design drainage and other features of the work. This **operation** must be planned carefully to fit in efficiently with bench mark and topographic surveys. In general, cross-sections are taken immediately following the topography location. However, this will depend upon the nature of the project and the working forces available. If enough men are available, both operations should be carried on simultaneously in order to secure enough data for office work for all the forces in the event of bad weather. For special design of complicated intersections it is often better to wait until a specific plan has been worked out before taking final sections in order to determine the extent of the work, then take sections from the definite survey or base lines that will fit in with the design without unnecessary computation or re-taking of elevations. However, it may be desirable in some cases where interchanges are extensive, to take sections from auxiliary base lines in order to make contour maps to be used in the design.

A **survey party** for cross-sections usually consists of four men. A three man party can, however, do considerable work and when forces are small it is often advisable to split up parties and form three man parties in order to make more rapid progress.

The Chief of Party must see that his forces have been properly instructed in their duties and must himself understand fully the requirements of that particular project.

Care must be exercised to be sure that cross-sections are taken on **normal or radial** lines in

relation to the proposed base line or center line as the case may be. Where the sections are long and the terrain is hilly and irregular a transit or some other means of lining up the sections properly must be used.

In general, sections shall be taken at regular fifty foot stations on the base line or profile line, and at pronounced breaks in the contour of the ground between stations. However, where the contour of the ground is uniform, sections can often be stretched out to 100′ and 200′ intervals. Likewise when the terrain is fairly uniform, sections can be taken at the breaks in the contours and the even stations omitted. The Party Chief should study all features of the terrain carefully with the idea in mind that the sections taken when compnted will give accurate earth quantities. He must watch the man with the rod constantly and see that shots are taken at the proper points on "breaks" so that the resulting section is a true one. Shots must also be taken on all features or objects along the project that will in any way be connected with or affect the right of way or construction plans. Elevations of existing pipes, ditches, drainage outlets, curbs, walls, porches, steps, foundation of buildings, utilities, as well as profiles of all intersecting or parallel streets that may be affected must be taken. Alertness on the part of the Chief of Party in gathering this information at the time of the cross section survey will save many return trips for additional information.

At interchanges it will frequently be necessary to take sections for the purpose of plotting contours over a large area. Base lines for tbese sections must be carefully planned so that a complete and accurate coverage of the entire area is obtained. The resulting contours plotted should

be sufficiently accnrate for plotting cross sections and calculations of earth work.

Frequent checking in with the benches must be made and mental comparative checks by the Chief of Party throughout the work will often prevent mistakes and unnecessary repetition.

In rugged terrain, shots with the instruments can often be supplemented by the hand level and many additional set-ups avoided. The Chief of Party should thoroughly familiarize himself with the use of this instrument and also instruct other members of his party in its use.

The notes for cross-sections must be carefully planned on projects of considerable size, and sections of them placed in separate note books so that the reducing and plotting of the notes may be worked on by several members of the party simultaneously. When rapid progress is necessary it is often advisable to use carbon paper and loose sheets when taking cross-section notes in order to obtain carbon copies so that more men can work simultaneously on the computations.

CHAPTER VII

DRAINAGE SURVEY

The drainage of a modern highway project is one of the most important factors in its design and construction. A considerable part of highway planning is devoted to the problems of drainage. Therefore, it is of great importance that a complete survey of all the drainage features of the terrain through which the highway passes, be made. In addition to the elevations previously mentioned, detailed locations and cross sections of ditches and streams should be made, particularly at the approximate ends of proposed cross drains and structures; also at any location where it might be desirable to change the alignment of the course of flow. The locations and cross sections must extend sufficiently beyond all proposed work to show a complete picture. A profile for an additional distance should be taken. The distances will vary, depending on conditions, and must be left to the discretion of the engineer in charge of the work.

Signs of high water should always be noted and elevations taken, together with sizes of existing structures within a reasonable distance on each side. Where the drainage is connected with tidewater, elevations of extreme high, normal high, mean tide and low tide, must be obtained. Residents of the vicinity may be able to furnish information as to conditions during storms in the past. If it is of interest, it should be noted, giving the source. Wet, swampy or springy places should be located and shown in the notes, with extra levels being taken to show all conditions. All low places along the sides of the proposed work should be noted plainly, and levels taken to show their elevations and area.

The present use of the land within the drainage area should be noted, with estimated percentages

of cultivated, wooded, pasture or other types of land, together with any improvements or probable change in the use of the lands.

The size of the drainage area is very important; for smaller areas an estimate can be made by estimating distances around and across the area. Larger areas usually can be found and calculated from the Geodetic Survey maps or contour maps recently made by the War Department and on file at the Trenton Office and the field offices.

CHAPTER VIII

SOILS SURVEY

For the proper design of a modern highway it is necessary to have complete information regarding the composition and **nature of the soils** through which the project passes. For this purpose it is necessary to make **borings** and take samples of the soils. Contact with the Soils Engineer must be made and a general plan for the extent and nature of a soils survey effected. **Auger borings** are the simplest method and several outfits are at the disposal of each field office. These borings are more or less for information of a general nature and can be used satisfactorily to depths varying from 10′ to 25′ in solid earth or up to 35′ in muck and wet soils. Reasonably representative samples can be obtained from auger borings. The location of firm bottom in swamps, of rock surfaces, water tables, and various soil stratas can be found accurately enough for the purpose of designing the roadway. Under ordinary conditions where the highway grade is to be near the surface of the existing ground, borings should be made with **post hole augers** and accurate samples obtained. The intervals at which borings are taken will depend upon the uniformity of the terrain. However, they must be sufficient to cover all phases of existing soil conditions.

Where rock or other hard materials are encountered a drill outfit must be used and the depths, extent and nature of the materials determined and samples taken.

Where reasonably accurate **samples** of materials can be obtained they should be placed in glass jars labeled to show route, section, location and elevation; then stored for future reference.

The Chief of Party must **plan** for the borings at the time of the field survey work so that the necessary information is available for designing

the profile grades; and in some cases through swamps and rock cuts it is necessary to have the borings made before fixing the final alignment in order to secure the most economical location.

Auger borings can be arranged for by obtaining **men and equipment** from the Maintenance or Equipment Division and having their work supervised by men of the Survey parties. Application for these men must be submitted on form requests by the district offices to the Maintenance Division. Therefore, at least five days should be allowed in advance of the work to be done for submitting application and making arrangements with the Maintenance Division.

The men assigned to the work must be thoroughly instructed in the location, number, and depth of the borings to be taken. Accurate records and samples of materials must be kept. Notes also concerning the nature of the terrain, outcroppings of rock, springs, running water, ground water tables, growth of vegetation and any other information that might have a bearing on the nature of the soil must be recorded and used in combination with the boring data.

Arrangements for the taking of **wash borings** and **core borings** must be made with those in charge of the boring equipment. This work must be supplemented with the same instruction records and data as outlined under auger borings.

For extensive projects it sometimes happens that the Department's equipment is insufficient to provide the required borings in time and this work must be given out by **contract.** This factor must be anticipated in time for the necessary plans and surveys to be made for the awarding of the contract in order that the project is not delayed.

Throughout the soils survey close cooperation must be effected with the Soils Engineer or his assistants.

CHAPTER IX

BRIDGE SURVEYS

All bridge structures with spans of 5′ or greater are designed and their plans and specifications furnished by the Bridge Division. All the necessary survey data for these plans must be furnished by the Survey and Plans Division. Therefore, it is necessary for a complete survey plan to be made for each structure. This plan must contain all the information that may be needed by a designer in the office who is entirely unfamiliar with the project and has not seen the site of the proposed bridge.

Following is a list of such information that must be provided for **stream bridges:**

Complete and accurate cross-sectional elevations of the bridge site and surrounding ground that will be affected.

Complete and accurate topographic survey of all details at or near the bridge site that may affect the design or construction of the bridge.

A profile of the stream at least 500′ each side of the highway.

Cross sections of the stream and banks at least 200′ each side of the bridge.

High water elevations.

Approximate distance of adjacent bridges on the waterway with sketch of shape and size of openings.

Location and elevation of all public utilities that may be affected.

An effort should be made to get auger **borings** or wash borings when possible and determine soil conditions. Where such boring data has been obtained it shall be placed on the plan and profile of the Bridge survey plan.

A profile of the proposed highway at least 300′ each side of the bridge.

Cross sections of the proposed roadway on and adjacent to the bridge, showing type of pavement, curbs, etc.

Ties to the highway alignment and all curve data necessary to lay out the structure without unnecessary computations.

The plan must show all proposed highway construction details in the vicinity of the bridge.

For **railroad or highway** separations in addition to the above relative information the following must be provided:

Elevation of the rails and cross-sections of the tracks and banks at least 200′ each side.

A profile of the tracks for at least 500′ each side.

A complete and accurate tie in between the highway and railroad alignments sufficient to avoid unnecessary calculations by the designer.

For **highway separations** the plans must show accurately all necessary curve data that the designer will need to calculate the location of any point on the structure, as well as all other pertinent information outlined for stream and railroad bridges.

In all cases a **cross section** of the highway and of the roadway, railroad or stream being crossed, shall be shown in detail; with all dimensions necessary for the design of the bridge given where possible.

Where the structure is over a **tidal** stream the following additional information must be provided:

Extreme High, Normal High, Mean High and Mean Low water elevations. Mean high water lines must be shown where tidal lands are to be acquired.

The number of boats with maximum width and elevation that use the stream.

The information collected in the survey must

be placed on a "bridge survey plan" to be submitted to the Bridge Division.

The plans for most projects can be made in pencil on tracing paper. Only those projects of considerable magnitude or those that have to be submitted outside the Department need to be in ink on cloth. This work should be planned at the beginning of the survey and the Chief of Party must consult with his immediate supervisor and complete the bridge survey plans at an early date in order that the Bridge Division can begin the design as soon as possible. Much of the field work can be done when the regular cross-section and topographic surveys are made.

CHAPTER X

SPECIAL SURVEYS

The Survey and Plans Division is often called upon to make special surveys for specific purposes such as drainage complaints, maintenance construction, condemnation proceedings, and special right of way matters. The making of a survey map or sketch is nearly always necessary for these surveys. In general, the same rules apply to taking topography and elevations in this case as for the regular work. Some previous thought must be given as to the most efficient methods to use. Stadia surveys are usually the most economical unless extreme accuracy is required, then the line and offset method should be used.

The Chief of Party must make himself thoroughly acquainted with the special purpose of the survey and secure all information relative to that purpose.

For drainage surveys and investigations particular attention must be paid to the drainage areas, and any changes that have been made or proposed that will affect this area. Also note should be made of any damage that may have been done. A brief history of the situation with reference to previous conditions and changes that have been made should be noted. Elevation of all connections, inlets, and outlets must be secured. A complete tie in with highway right of way must he made, and where there is a probability of easements or property to be acquired, the necessary right of way data such as ownership, property lines, etc., must be obtained. In most cases a map and report covering the survey and investigation must be made. The map should contain all topographical and terrain features necessary to give complete understanding of the problem, and the report should clarify aud de-

scribe the situation and give recommendations for improvements where called for.

The Maintenance Division often requires a plan to carry out maintenance construction projects. The Survey and Plans Division is usually requested to prepare these plans and stake out the work for construction.

Full information should be obtained as to the nature and scope of the work to be done before beginning the survey. The same care and accuracy should be used in making these surveys as on the regular work, however only the necessities for the construction plans or the right of way plans where required need be considered since this work is done by the maintenance forces and no contract drawings need be made. For the purpose of filing, the plans should be made on standard size sheets. Key maps and standard details can be omitted, but complete estimate of quantities must be given.

The titles shown on these special plans must be such that they can be properly filed with the correct route and section number given as well as a name that will easily identify and locate the project.

CHAPTER XI

RIGHT OF WAY SURVEYS

In addition to the surveys for construction plans it is necessary to gather special information and survey data for Right of Way plans, i.e., plans for the acquisition of the property needed for the proposed project, such as The Entire Tract maps, General Property Key maps, and individual Property and Condemnation maps. Such data and information are also to be used in drawing legal contracts, description in instruments of conveyance, also by appraisers, negotiators, title examiners, and condemnation commissioners. Finally the resulting maps and documents will be filed for the various County records where they will be available for use by private surveyors and engineers engaged in public work, title companies, assessors and others.

This information must include facts regarding ownership, titles, road returns and other data used in all instruments of record. The work on location must include a survey of all physical features, direct information from owners and residents, and any other data present that might have influence on property acquisition.

Title and ownership searches and reports are usually made by men specially assigned to this work and as a rule the Chief of Party need only concern himself with such Right of Way surveys as can be made on the site of the project. Where such men have not been assigned the Chief of Party should consult with his supervisors and have such an assignment made. It may sometimes be necessary for one of the survey corps to be selected to make the owuership searches and reports. When this happens the Chief of Party must see to it that he gets full instruction in the nature of duties from the Right of Way and Title Departments.

Nearly all the survey data on location for right of way plans can be obtained and recorded by the survey corps taking topography and cross sections. Therefore, these parties should continually bear in mind that not only data having a bearing on the construction plans but also data that will influence the right of way acquisition must also be collected. This work must include the accurate location of property lines, side lines of roads, monuments designating property lines, streets and highways; location of buildings, showing type, size, and condition; also such details as shrubbery, trees, steps, walls, overhanging porches, etc. The survey corps must exercise care and ingenuity in ferreting out property corners and monuments and also in finding private utilities, such as water, gas, or electric conduits, as well as odd drainage and sewerage features such as house drains, road drains, wells, cesspools, abandoned wells, basins, etc.

Any of these features might be an item in right of way negotiation.

Where the exterior lines of any physical structure comes near the estimated construction limits or close to the right of way line all measurements shall be made as accurately as possible. Where this is definitely not the case measurements to the nearest foot will be sufficient. In the former case such locations should be made by actual right angle offsets from a base line which will be parallel to or easily tied in to the right of way lines. In the latter case stadia or other normal location methods may be used.

All members of the party should make close observations with the idea of discovering any irregularities of actual property holdings such as existing gores or overlaps which often exist in the field but are not shown in the records. Inquiry should also be made as to recent changes

or contemplated changes in ownership of properties in the vicinity. Such checks and observations will often save valuable time in preventing the necessity for redrawing maps and descriptions and holding up negotiations and condemnation cases.

CHAPTER I

GENERAL INSTRUCTIONS

In order to build proposed highway projects, plans and drawings must be prepared showing details of the work to be performed. These plans must show clearly and accurately all information necessary for the engineers to lay out the proper grades and lines needed by the contractor's forces to build the project as planned. They must also show all information necessary to inform the contractor of the nature and extent of the work to be performed in order that he may bid intelligently. In addition to this the plans are to be used by the Right of Way Department in determining the effect on adjacent properties and in showing conditions before and after construction. Public utility companies must also be given sufficient information when their facilities are affected. After construction of the project "as built" data will be placed on the tracings which will be filed as a record of conditions before and after construction.

The plans, except in special cases, will consist of a title sheet, one or more sheets showing typical sections and a list of estimated quantities, a take off sheet general plan and profile sheets, cross section sheets, earth work summary, detail sheets of special intersections and special structures, layout and tie sheets, standard detail sheets, and, where necessary, sheets of bridge plans and details. All contract drawings shall be on standard sized tracing cloth sheets 22" x 36". Plan, profile, and detail sheets are to be cut to size and given the proper border lines in the field offices. Standard cross section sheets will be furnished by the Department.

Before starting construction plans for a project

under his supervision, a Chief of Party must secure several sets of the latest plans of projects similar to the one he is about to begin that have been previously completed and approved. He must study these plans thoroughly noting the make-up of the title sheet, general arrangement of plans and details, also methods of showing construction details and itemizing and listing quantities. He must make certain that the draftsmen and designers who are to make the drawings and designs also study the plans thoroughly in regard to arrangements and extent of the details and items to be shown, as well as the technique and methods used.

He must also secure, study, and make certain that the draftsmen and designers under his supervision have in their possession and study copies of "Payment Items for Construction Contracts", "Pipe Designations", "Standard Specifications", and other special instructions that may be issued by the Department affecting plans and plan items. The nomenclature and order as given in these instructions shall be followed in making up the plans.

CHAPTER II

PLANNING, TIMING, AND COORDINATING THE WORK

In order to secure **maximum efficiency** in completing a set of construction plans, a Chief of Party must do a great deal of thinking and planning regarding the coordination of the work. Inasmuch as the size, type, and nature of Highway projects in New Jersey vary greatly, no definite procedure can be established. However, some general ideas of planning the work can be followed.

The forces available must have **work provided** for them at all times. In order to do this, office work must be provided for rainy weather. This means getting part of the cross sections and topography taken as soon as possible.

Where permanent office forces are available and where office and field work can be carried on at the same time, the designers and draftsmen should immediately proceed with preliminary sketches, transparencies, estimates, and investigations of special problems, such as grade separations, special intersections, and bridge layouts. For widening projects and connections to former work, skeleton plan sheets can be started at the time the survey is started. Skeleton Right of Way plans can also be started almost at once.

It must be kept in mind that **bridge survey** plans must be given to the Bridge Department as soon as possible. Therefore, designs affecting bridges should be given first priority where possible in order that bridge plans keep pace with the road plans.

Searches for the names of property owners, location of property lines, and **preliminary title data** must begin at an early date in order that right of way plans also keep pace with the road plans.

Bearing in mind the many operations of a survey and plans project and any time limit that may be set, a Chief of Party should, at the beginning of the survey, make out a complete schedule of the work coordinating the various operations with the forces available for maximum efficiency.

CHAPTER III

ESTABLISHING BASE LINES

Before proceeding with the layout of the plan work and right of way key maps, definite base lines from which to work must be established. If possible, these **base lines should be planned** before the field survey begins and the topography and cross sections based on these lines when taken. However, in some cases where the design is undecided before this can be done, survey lines must be used that are **not** suitable as base lines for laying out the plans and right of way.

When the general design has been decided on, all **construction base lines** should be fixed as soon as possible in order that the cross sections can be taken from these lines. This makes the plotting and the drawing of the finished sections much simpler. Construction base lines should be fixed with the idea of simplifying the design and drawings as much as possible. For this reason in the case of an **undivided highway** where the travelled roadway is to be on the center of the right of way, the center line of the right of way should be used as the base line for both the right of way and construction.

For **dual highways** two base lines for construction must be used. These should be the crown lines or highest points of each roadway, which will also be the grade lines or profile lines. Where both roadways are to be at the same grade only one profile need be shown, but both profiles should be shown where the grades differ. The selection of construction base lines for ramps and connections often presents a problem that needs careful studying and consultation by the Chief of Party and his supervisor. It must be a line that makes as easy as possible the design of the cross sections as well as other features and at the same time

make as simple as possible the staking out of the project for construction. Therefore, it must be a line from which the stations and offsets of construction details can be readily obtained. In most cases the center lines of the ramps or connections can be used to best advantage. However, other auxiliary lines are sometimes necessary. All base lines shall be prominently marked on the construction plans.

These designations on the plans shall be similar to the following:

Construction and Profile Base line for north bound or east bound, etc., roadway.

Centerline of existing R.O.W.-Base Line for construction and R.O.W.

Centerline of Proposed Highway-Base Line of R.O.W.

Ceuterline of Existing Pavement-Base for construction.

Centerline of Ramp "B"-Base Line for construction and R.O.W.

Centerline of Connecting Road-Base Line for R.O.W.

Curb Line of Maple Ave.-Base Line for construction and R.O.W.

Base lines for the acquisition of property must be fixed and shown on both the construction plans and all right of way maps. The two main ideas to be kept in mind in fixing right of way base lines is that first all property lines can be readily tied into this line and property descriptions simplified. Second that this base line is to be **permanently monumented** and therefore must be located so as to be readily adapted to this purpose. For other details of Right of Way Base Lines see "Right of Way Plans."

CHAPTER IV

TYPICAL SECTIONS

Before beginning the design, particularly the cross section templates, the Chief of Party must consult with and secure from his supervisor the **proposed cross sections** of all the uniform and standard portions of the project including all connections and ramps. These shall be drawn to a suitable scale in pencil on detail paper. They must then be checked carefully and placed at the disposal of the designers and plotters for reference in their work.

These sections are called **"Typical Sections"** and must be shown in detail in the construction plans. For uniform or small projects where three or less are to be used they can usually be made part of the Estimate of Quantity sheet. When the list of quantities has been determined they can be traced and spaced properly. Where there are more than three typical sections to be used it will be necessary to use one entire standard sheet. In some instances of complicated design two sheets for this purpose may be necessary.

These typical sections must show all **detailed dimensions** giving clearly the relative location of each point on the section by a reference to a level line through the profile grade. They must also give clearly the followiug information: depth and exteut of topsoil; rate of side slopes for various types of cuts and fills; depths and widths of various types of pavements, shoulders and subbase; location of guard rails, curbs, sidewalks, pole lines and right of way lines; and location of pay lines for rock and wet excavation. Under each section must be noted the stations between which it applies. The scale of all drawings must be shown.

CHAPTER V

PLOTTING TOPOGRAPHY

One of the first operations in preparing plan sheets is placing thereon the existing **topographic features** of the project. This information is obtained from the field note books of the topographic survey and also, in many cases, from existing plans of former State, County or Municipal surveys.

It is not always advisable to follow the same procedure in this operation. The nature of the project, the forces available, and the time limit imposed will all have a bearing on the **methods employed.** For those portions of the project where the highway is to be more or less of a standard design with no complications, the topography should be plotted in pencil direct from the note books to the tracing cloth. However, where there are grade separations and other complicated designs it is necessary to plot first on detail paper in order to have a plan of the design complete as a whole and also to enable sketches and maps to be made for preliminary layouts and designs.

The Chief of Party must observe and check at frequent intervals the manner in which the **plotting** is being done, making sure that the proper scales are being used; that the alignment is properly arranged; that the work is sufficiently clear and readable to be traced or inked.

It is not necessary to **check** the accuracy of the plotting of all topographic details, but sufficient checking should be done to make certain care is being taken and that **all critical features** affecting the design and estimate of quantities are carefully checked.

Existing topography should be inked or traced before any design work is placed over the pencil work.

The names and notes to be placed on the plans

must be carefully thought out in advance by the draftsmen and designers. It must be kept in mind when the names and descriptive notes are placed on the drawings that the proper space be reserved for construction notes. Proper names should be capitalized and no more space given to them than necessary to bring out their purpose. Other notes and lettering should be clear, concise, and readable. The **sizes of lettering** for the various places and details are shown in Part II, Section I.

All topographic **symbols or legend** shall be made clear and simple. All notes, lines, and symbols shall be unmistakably clear, simple, and readable, even under adverse conditions, for it must be remembered that road plans are to be used in dimly lighted offices and out on construction jobs.

CHAPTER VI

PLOTTING CROSS SECTIONS

In order to establish grades and profiles, calculate earth quantities, design drainage structures and furnish other incidental information for a Highway Construction project it is necessary to first **plot cross sections** of the existing ground elevations. These are plotted from the cross section note books, first in pencil on standard tracing sheets furnished by the Department and then inked in before adding to them any of the designs or templates of the proposed work.

This work should be begun as soon as possible and can usually be entrusted to the less experienced members of the party after careful instructions.

A Chief of Party must give considerable **thought and planning** to several items in relation to cross sections. First the **scales to be used** should be given careful consideration. Cross section sheets form a large part of a set of construction plans and often make them too voluminous to handle as well as adding considerably to the cost of printing. Therefore the scales and sheets should be selected and arranged so as to keep the number to a necessary minimum. It is not necessary to use the same scales throughout the sections but the scales should be clearly marked on all the sheets so there can be no doubt.

Where the **stripping method** is to be used for measuring areas the scales must be 1″=5′ for smaller sections or 1″=10′ for larger sections. The horizontal and vertical scales may differ in special cases, but shonld be carefully labelled.

Where the **"machine calculation method"** (see Part II, Sect. 2 E) for calculating areas is to be used the scales should be reduced as far as possible without causing crowding or confusion of the

written elevations. Scales 1″=20′ or 1″=25′ can usually be used under this method.

Both these methods can be used to advantage on some highway projects, but in general the "stripping method" is more advantageous on small or light sections, also on special and irregular sections, while the machine method will save much time and space and is more accurate on the larger standard sections.

The spacing of the existing ground sections must also be given careful planning, especially if the "stripping method" is to be used. The Chief of Party must estimate carefully an approximate profile from a general study of the ground in order to give proper instructions to the plotters to avoid wasting space or crowding sections together when the designed highway templates are added.

The general arrangement of the sections must likewise be carefully studied in order to make them conform to the proper base lines and stations. Clarity and ease of locating the various sections in the plans should be the main objective in arrangement. Match marks sometimes have to be used on large sections, but should always be clearly marked and used as little as possible. Where plans and cross sections are irregular and complicated, the cross section, plan and construction detail sheets should be cross referenced at the bottom of each sheet designating the sheet numbers corresponding.

All plotting must be carefully checked with the names of the plotters and checkers placed on each sheet.

CHAPTER VII

GENERAL DESIGN

Designing and drawing the plans for a highway project is a serious and responsible job. Carrying out these plans usually involves the expenditure of large sums of money as well as taking responsibility for service and safety to the motoring public. Therefore a great deal of time, study, and thought must go into the many phases of Highway Design.

Highway projects are so variable that a large portion of the plans cannot be standardized and must be designed to fit existing conditions. Many details go into a set of construction plans. Some are standardized and duplicate tracings of these can be obtained and incorporated into the plans. The Chief of Party must familiarize himself with what details are to be furnished and also with Departmental standards for other details and use these wherever possible.

Economy, safety, convenience, and utility must be studied and balanced against each other for all the details of design. There can be several solutions to most designs, but usually only one is the correct answer. It is the highway engineer's job to find this answer.

In general all study sketches, preliminary plans, special plans or any studies that are to be worked on or sent out for study and approval shall be made on tracing paper or cloth so that transparencies and prints can be made for further study and distribution.

The order in which details of design are taken up is of considerable importance for the efficient and orderly progress of the work. Much work will have to be re-designed if the details are not made to dovetail properly. No definite order of procedure can be set up that will apply to all pro-

jects, but in general for regular highway design the establishing of grades, base lines, typical sections and cross-section template will follow in the above order. With these established drainage structures, intersections, curbs, slopes, slab layouts, and other details can be designed in their proper order. Care must be taken not to proceed too far with the details of any designs befor a definite approval from the supervisor has been obtained.

CHAPTER VIII

ESTABLISHING GRADES

The grades for highway projects may be divided into four parts: the general profile grades, profile grades for ramps and special intersections, curb grades, and gutter grades for special drainage problems.

The **general profile grades** must be thought out thoroughly and diligently with many considerations in view. First the rate of grade itself must be considered. "Geometric Design Standards" shown in Part 2, Sect. 2, Page G, should be adhered to where possible; but it is desirable to keep grades nearer the minimum rather than the maximum in order to increase safety and reduce operating costs. It will sometimes be necessary for economic reasons to establish grades outside these limits. In such cases the Chief of Party must consult with his supervisor to determine the economic justification.

Sight distances are an important feature of safety. The Highway Department "Design Standards" for sight distances must be studied thoroughly. Also for Parkways and Freeways, special **design requirements** are sometimes desired. An endeavor must be made to comply with these requirements. Where they are difficult to meet because of economic or other considerations, it may be necessary to lower the standards but this should be done only after a complete study of the problem and when the approval of the supervisor has been obtained.

Consideration must also be given to **aesthetics** in fixing the grades. Careless fixing of the profiles often mars the symmetry and beauty of many good highway alignments. Short reverse vertical curves, low points in cuts and summits on fills, and bad combinations of vertical curvature and horizontal curvature must be avoided. In fixing

or checking the grades a Chief of Party must try to visualize the scenic effect of these grade changes by comparing them to some similar situation already existing. There are in existance throughout the State many good and bad examples of the scenic effect of profiles.

Fixing the profile grade in relation to **drainage and soil conditions** is of great importance in securing a lasting and economic design. During the course of the field survey a Chief of Party must study thoroughly all ground and drainage conditions visible, as well as the boring data obtained. He must obtain high water and high tide elevations, estimate the size and vertical clearances of drainage structures, and secure elevations of possible outlets.

Wherever possible grades should be kept well above ground water and the best soil strata followed in cuts. Following too close to the surface where top soil or other inferior soil is present should be avoided. In such cases it is usually better to keep well above or below the surface. **Low points** must be kept high enough to allow sufficient grades for storm sewer outlets. In the vicinity of streams or tides the highway should be kept sufficiently above high water to prevent flooding and damage to embankments. Five feet above mean high tide should be the minimum for the low point of the profile unless important economic considerations deem otherwise.

Another very important consideration in fixing highway grades is making them conform to the necessary **clearances** for bridges over streams and rivers and at highway and railroad separations. At an early date the Chief of Party must secure from the Bridge Division or his supervisor the necessary clearances for such bridges. The preliminary data submitted to the Bridge Division must be sufficiently complete to enable them to

make a reasonable accurate estimate of the necessary thickness of the bridge decks and the proper clearance at the "tight point" of the profile. The grade may then be established with a factor of safety of about two inches. Any slight deviation that occurs in the actual design can be readily adjusted.

Property damage is also a very important factor. Of course other more important considerations often make it impossible to avoid property damage caused by the highway grade, but many times with the proper study and investigation, property damage resulting in considerable cost to the Department, as well as adverse criticism from owners and the general public, can be avoided. Therefore, it is necessary to consider this damage throughout the project in fixing profiles. The effect of slopes on trees, walls, lawns, porches, utilities, driveways and buildings must be studied thoroughly. Such studies must also be made on intersecting streets and highways where grade changes are to be made. When the profile of the existing ground is plotted, elevations of these various features to be considered should be shown, so that in designing the grades and calculating the tops and bottoms of slopes the resulting effect of the slopes can be seen. In some cases where damage may be serious and accurate limits are necessary, cross sections shonld be used to determine exact slope limits.

Economy of construction in grade design must be kept constantly in mind in designing grades to fit the various other considerations. Costs of earthwork, drainage, and drainage structures, slope protection and maintenance must be estimated and continually balanced against other considerations. Many times it will be difficult for the designer to know just where to draw the line between economy of construction and utility,

safety and good appearance, since it is desirable to meet not only the required standards but to make the grades as good as possible within reasonable economic limits. Much thought and study must be given to this phase of comparative values. Supervisors must be consulted, and the history and results of similar designs of former projects studied. **Future traffic needs and real estate developments** must likewise be anticipated as far as practicable in fixing grades and these also considered in relation to economy of construction.

Balancing and keeping down **earthwork quantities** is desirable but should not be allowed to greatly influence the design. It will generally be found that sacrificing good grades for limited savings in earthwork is neither good design nor economy.

This fact, however, should not preclude a thorough study of the possibility of fixing grades to save earthwork costs, especially where rock excavation is to be encountered. Many times all the desirable factors of a profile can be retained and the grade still designed economically if the proper study is made. The designer should constantly keep in mind an estimate of the cuts and fills involved and also have located on the existing profile the limits of rock and wet swamp, or muck areas, that will have to be excavated or filled in.

Situations will arise where it will be necessary to sacrifice desirable standards in order to avoid prohibitive earthwork costs or property damage. In such cases or where doubt arises the Chief of Party should consult his supervisors as soon as possible in order that a decision is reached before the work is carried too far.

The profiles for the **ramps and connections** usually have narrow limitations with not much room for choice, and standards considerably lower than those used on regular grades may be used.

However, these grades will require a very detailed study in order to meet many fixed conditions and considerations. These, although limited, must be given the same attention and study as other grades. On ramps aud connections the maximum standard grade is often exceeded with grades running up to six per cent (and grades up to seven per cent may bc used in special cases). In general such grades should be used where traffic is light, with little or no truck traffic or where economic considerations make it imperative. A consultation with supervisors must be had well in advance of the grade design and the desired grade limitations for each project obtained. Where ramp or intersection grades below the minimum are used, it must be made certain that the lateral grades and gutter grades are sufficient to carry off the water. Also, consideration must be given to banking and the blending of these grades with those of the main roadway. Since grade changes will be rather abrupt, and reversed in many instances, considerable attention must be paid to the profiles of the travelled lanes. These must be plotted, studied and smoothed out to secure a good riding surface. When the profiles have been satisfactorily established, cross-sectional elevations for all irregular sections must be calculated for 25 ft. intervals throughout and shown on the plans. The use of contours at 0.2 foot intervals on the surface of the pavement is often helpful to the designer and can be of great assistance duriug construction.

Curb grades that are not parallel to the regular profile grades sometimes have to be established to meet fixed conditions, such as sidewalks, buildings, railroad tracks, etc. For this purpose the Chief of Party must ascertain from his supervisor the maximum allowable deviation from the normal typical section, also the minimum and maxi-

mum allowable curb face. With this information and a plotting of the elevations to be met the curb grades can be established. However, it will at times be found necessary to revise the regular profiles or work out both profiles coincidentally in order to meet the required conditions for both grades.

In general, these same considerations and methods must be given to **gutter grades** that must be established to carry water to fixed outlets where they cannot be made parallel to the regular profiles.

Throughout the designing of all highway grades the designer must bear in mind that there is just one ideal grade for each situation and it is his job to find it.

CHAPTER IX

PREPARATION OF CROSS SECTION PLANS

Plotting of the cross section templates shonld begin as soon as the grades and templates have been designed and approved and a reasonable assurance obtained that they will be final. The method to be used in making the earthwork calculations must be definitely decided upon before the sections are plotted. If the machine method, stripping method, or a combination of both is to be used for measuring cross section areas, considerable thought must be given to the **scales to be used.** The purpose for using each method must be kept in mind and a general study made of all earthwork features of the project. In general the machine method is advantageous for larger uniform standard sections to give greater accuracy and save time and space; the stripping method is better for irregular sections and sections with very light cuts and fills. It is often advisable to use both methods on the same project. Careful instructions must be given by the Chief of Party to the plotters. All standard sections should be plotted first; the irregular sections remaining until the designs of intersections and connections have been approved and completed. Careful **timing** will often save much re-plotting and calculating Elevations must be carefully computed for all irregular templates. Sections must be matched up carefully and accurately so that a complete and accurate earthwork quantity may be obtained. Match marks where used should be definite and readily understood. Where the machine method of calculations is to be used, sufficient elevations and offsets must be shown to give complete accuracy.

Care must be taken to show **critical sections** affecting buildings, walls, driveways and other

structures. Such details of construction as retaining walls, curbs, special slope protection, side ditches, must be shown on the sections in their correct position. Where sub-surface structures might be affected they should also be shown. Rock slopes with proper pay lines (see Highway Specifications) must be shown and marked. Care must be taken to see that all excavation to be paid for as one of the excavation items is included in the quantity measured in the cross sections. Where excavation is included in the cost of the structure or pay item, it should not be measured.

It is not always desirable and in most cases not economical to make the slopes of a modern highway standard throughout. Therefore the Chief of Party must take nothiug for granted but discuss the various situations and details with his supervisors as they arise. Slopes of 2-1 in cuts and embankments over 10′ and 4-1 for lesser embankments are desirable and a slope of 1¾ to 1 is the required minimum in cuts and fills hut such questions as flattening the contouring slopes for purposes of beautification, elimination of guard rail, prevention of excessive property damage, widening for borrow, material, making use of waste material and many other questions need much thought and discussion to arrive at the correct answer.

The design of slopes also depends on the knowledge obtained in **soil surveys.** The location of unsatisfactory soil on the project is noted, and borrow material is selected suitable for the fills to be made. The soil conditions should be discussed by the Chief of Party and the Soils Engineer as to the possibility of slippage or other cut and fill failures especially where fills are to be placed under water.

CHAPTER X

DRAINAGE STRUCTURES

Drainage constitutes an important and extensive part of highway design. Almost every phase of a highway project involves consideration for drainage and the design of drainage structures. Therefore, from the very beginning of a highway survey the Chief of Party must be mindful of the necessity of proper drainage and make sure that all the necessary information is at hand for the designer.

In addition to designing the grades and elevations of a highway for drainage, many drainage structures, such as storm sewers, inlets, manholes, cross drains, head walls and several types of gutters and ditches must be designed.

Storm sewer systems constitute an expensive and important item and need considerable detailed study to obtain economical and adequate design. First the necessity and extent of the sewer system must be given careful study and much thought in order to answer properly the following questions: Is the sewer necessary for the safety of the motorist in preventing flooding, formation of ice and water pockets? Is it necessary for the prevention of damage to adjacent property? Is it necessary for the prevention of erosion and excessive maintenance costs? Can the normal gutters adequately carry the water to outlets? Are the outlets large enough and at the proper elevation for the discharge? These questions must all be studied in detail from the standpoint of economy and safety. Similar situations in previous designs must be brought to mind and the results analyzed. Frequent consultations with the **drainage engineer** and other supervisors will be necessary. Much valuable information can be obtained from the maintenance forces and residents of the vicinity. All facts must be correlated and studied in order

to determine whether each storm sewer system is a necessity or only a luxury.

Where a storm sewer has been found necessary, the next step is to determine the size of the pipes to be used and the location of catch basins, manholes, and connections. Throughout the design of all drainage facilities, frequent checks and consultations should be had with the drainage engineer.

Many volumes have been printed and many formulae devised for obtaining the correct size of storm sewers; but inasmuch as in all cases several important factors must be estimated, a too theoretical approach to the problem is usually a waste of time. Good practical results can be obtained by computing graphs for run off and discharge and combining them in a chart shown in Part II, Sec. 2, Drainage. This chart with the corrections shown, and good judgement used in the selection of proper run off and rainfall coefficients if used intelligently and in conjunction with observations and investigations of local conditions, especially efficiency of existing structures, will in most cases, give results sufficiently accurate for all practical purposes. However, for long sewer systems and for critical areas, such as low points nuder bridges and other structures, where considerable damage would result from failure of the sewer to carry off the water, the value of "Q" should be checked by the Rational Method and then applied to the remainder of the chart. Where any doubt exists, the drainage engineer should be consulted as soon as possible. It is the policy of this Department to use 18″ pipes for cross drains as a minimum size in most storm sewers that will be susceptible to clogging by ice, snow, leaves, or sand. In some cases where there is little likelihood of clogging and the area drained is small, 12″ and 15″ sizes may be used, especially at the beginning of a

sewer near the summit of a grade. These smaller sizes are often necessary for the clearance of public utility structures. In general, however, these sizes should not be placed under permanent pavement.

The run-off factor, the slope of run-off, and the rate of rainfall must be estimated with care. Rainfall data for various design periods in the central section of New Jersey have been tabulated and a plotting of them is shown on Part II, Sec. 2, Drainage. The maximum variation from these curves for any other part of the State is about 10%; the amounts indicated may be increased up to 10% for the southernmost part and decreased up to 10% for the northern section, with proportionate amounts for areas in between. The time of concentration for each given area must first be determined or estimated. The rate of rainfall selected will depend on the design period to be selected, this period in turn will depend on the nature and extent of the damage to be expected when the sewer fails to function adequately. When this failure will cause only moderate damage a ten year period should be selected. When the damage will be considerable, a twenty or twenty-five year period should be selected and sometimes, in extreme cases, a sewer should be designed to be adequate under all conditions.

In selecting the run-off factor full consideration must be given to the possibility of future development of the run-off area into streets, buildings, and paved areas.

The run-off slope should be obtained from actual ground elevations or from an accurate topographical map.

The size of the pipe having been determined, the location of the sewer and the disposition of catch basins and manholes must be given thorough study in order to get the most economical results.

In general, the location of all pipe lines must be such that the least amount of pipe is necessary; that the grades are most efficient, and catch basins placed where they will do the most good. **Self-Cleaning Grades** for pipes should be obtained where possible. A velocity of 3′ per second when flowing ¼ full is desirable. (See chart in Part II, Sec. 2, Drainage.) An accurate location of all utilities and underground structures must be determined and the sewer designed to cause as little damage to these as possible without too greatly impairing its efficiency. Locations of rock must also be determined by borings and the location and grades of the sewer economically designed in respect to rock excavation in trenches. The distance between **catch basins** on the main highway will depend on the grades, the shoulder pavement, and the amount of drainage intercepted, varying from a minimum of 300′ for untreated gravel shoulders on grades over 2%, to 600′ for permanently paved shoulders on grades over 1% where the intercepted drainage is light.

On intersections, ramps, and connections, a carefnl stndy of the grades and elevations must be made in order to place the basins at all low points on the gutter grades and at the same time provide a smooth riding surface. On the main highway a study must be made of all low points and the amount of drainage that can be expected to collect at that point. It must be kept in mind that a considerable amount of water can be expected to bypass basins on long grades and thus pile up at the bottom; therefore in many cases one or two extra basins must be placed at such locations in order to avoid pondiug and flooding.

The **depths** at which sewer lines are laid will of course depend on several factors, such as the location of utilities, elevation of outlets, location in the highway, and many others. No standard re-

qnirements can be set np but in order to make economical use of reinforced concrete or vitrified clay pipe the cover over the pipe should be at least 30″ measured from the bottom of sub-base to top of pipe. Where such cover cannot be obtained the use of cast iron culvert pipe is necessary. This is true also where the pipe will be under a fill of more than 12′ unless it has been placed in a substantial cut in existing firm ground. In this case R. C. Pipe may be used under fills up to 18′. Under sidewalks and island areas where there is no possibility of future widening or crossing of traffic, cover as shallow as 6″ may be used. Under cultivated fields the cover should not be less than 16″. Cognizance must be taken of the possibility of future widening of the highway when placing sewer lines in curb, sidewalk or island areas and the grade established at a safe depth when such widening takes place. Also the fact that where sub-base is used the prepared sub-grade must be rolled and compacted and therefore sewers must be at a safe depth in order to avoid breaking under heavy equipment.

Manholes are to be used only where necessary. Usually a catch basin can be made to serve the purpose of a manhole. However, where sewer lines will be inaccessible, manholes must be built not more than 600′ apart where uo catch basins exist. Only in cases of extreme necessity should manholes be placed in the pavement or the paved part of a sidewalk area. Where used to allow a break in liue or grade if possible, the sewer should be designed so that the manhole can be placed in an island or unpaved sidewalk area.

CHAPTER XI
DITCHES

In rural and undeveloped areas it is often economical and necessary to use open ditches for drainage purposes. The most extensive use being **outfall ditches** for cross drains and storm sewers. Lateral and miscellaneous ditches are also often used for various purposes, such as **lowering the water table** through swamp areas, draining out water pockets, preventing slope erosion in cuts and relocating existing ditches and water courses obstructed by the highway construction. Careful study must be made of possible and necessary **grades**, the capacity required, and the type of soil through which the ditch is to be constructed. The outlet and the probable property damage that will be caused must also be carefully investigated to a point where the ditch enters a well defined water course. The **cross section** of the ditch must be designed not only for capacity but with slopes sufficiently stable to stand up. These slopes will vary from 2:1 in sandy loam to ½:1 in shale slopes or rock. Ditches constructed in loose, loamy, or other easily eroded soils on grades greater than 1% often become a serious erosion problem, especially outfall ditches subjected to the discharge of an outfall sewer having considerable velocity. Special designs must be provided for such cases. The Chief of Party must consult the drainage engineer and his supervisor in order to obtain the best design for each particular case. Various types of paved gutters from sod to concrete can be used. Several different types of erosion baffles have been used successfully. This problem must receive considerable study and thought in order to arrive at the correct solution.

All ditches except those adjacent to the shoulders, which are part of the cross sections, and the standard ploughed ditches at the tops of slopes

must be shown clearly on the construction plans. Where the standard details do not conform, **special details** must be shown on the detail sheets. When a ditch exceeds a width of 5′ at the bottom it shall be referred to in the plan as a channel and paid for as **Channel Excavation.** The same general precautions as outlined for ditches must be taken for channels and, in addition, consideration must be given to the velocity of the stream and changes in the direction of flow in relation to bank scour and erosion. At such changes in direction it is frequently necessary to design one of the several forms of rip-rap slope protection described elsewhere.

CHAPTER XII
CROSS DRAINS AND CULVERTS

Where low areas, ditches, dry water courses, and running streams are obstructed by highway construction it is necessary to pass the water under the highway through pipe cross drains or culverts. Many of these drains or culverts will also be outlets for storm sewer systems. Their design entails detailed study and consideration of numerous factors, among which the following may be considered the most important: the required capacity, grades, economy of design, property damage, and walls and protection from erosion.

The **capacity** required must be computed with the same care and in the same manner as outlined for storm sewers. However, in the case of open pipes and culverts consideration must be given to the elevation to which the water at the intake can be raised before causing property damage by flooding lands on the upstream side. Many times in order to prevent this, structures of greater width than depth must be used.

Culverts having a span of five feet or more are considered by the Department as a bridge and will be designed by the Bridge Division. Therefore, all necessary information must be given and a bridge survey plan submitted.

In fixing the **grades** of a culvert or cross drain several factors must be carefully investigated. The flow line must be placed low enough to drain all the low spots in the vicinity and possible future storm sewers and ditches. To do this, the **Mosquito Commission** and the **Municipal Engineers** should be contacted where there is a possibility of any future need regarding any plans they might have that would affect the grades or design. For larger streams it will be necessary to consult the Water Policy Division of the Department of Conservation and Development. This

matter should be taken up with the drainage engineer as soon as possible. The grades of the outlet ditches must also be studied carefully and a grade sufficient to carry the water away without too much erosion or stoppages obtained where possible.

The type of cross drain to be used will become largely a matter of economy; and accurate estimates of cost must be secured for the varions possible types, such as cast iron culvert pipes, reinforced concrete (regular and extra heavy) culvert pipes, corrugated metal culvert pipes of various types, and standard reinforced concrete culverts of different sizes. Considerable study must be given to all factors in order to select the most economical design for each particular situation.

Through farm lands consideration must be given to the possibility of utilizing culverts as **cattle passes.** Often a slight change in design or grade may save much property damage or eliminate dangerous cattle crossings.

Standard **end wall details** are provided for protection at the ends of culverts and cross drains. However, changes in this design must be considered in some cases to prevent erosion and increase efficiency of intake and discharge. Paved outlets and sometimes rip-rap must be designed to prevent erosion.

CHAPTER XIII

SUB-SURFACE DRAINAGE

The most important function of sub-surface drainage is to take water away, or keep it away from the pavement sub-grade. Many variable situations arise where underdrains are needed for this purpose and a thorough study of soil and drainage conditions must be made throughout the project as previously outlined. The most common use of **underdrains** is at locations where a roadway cuts through a seepage channel or is sufficiently close to one that capillary action will bring water to the sub-grade. In such cases French drains as shown in the standard details should be placed on the up-hill side. In some cases where the highway is in a deep cut or the grade is close to the water table it is necessary to place underdrains on both sides of the highway in order to lower the water table sufficiently to prevent its reaching the sub-grade.

Valuable data concerning sub-surface drainage may be derived by consulting people living adjacent to the proposed alignment or from "Highway" personnel, either State or municipal, who have been familiar with the location. One of the best **sources of information** about sub-surface drainage is found in the data resulting from the soil borings. These borings should be studied thoroughly for sub-surface water conditions throughout the project.

Occasionally **undergrounnd springs** of free water are encountered, and if not properly taken care of will cause frost blow ups and much damage to the pavement. In such cases it is usually necessary to use a section of French drain to pick up the water and a small storm sewer to carry it to the drainage system or to some outlet. It is however better, if possible, to cut the spring off with underdrains before it reaches the highway. It is

also sometimes necessary in the case of a deep bubbling spring to design a concrete box structure to enclose it in order to properly pick it up in a drain.

Often in deep cuts seepage channels will be cut part way up the slopes, and, if allowed to remain uncared for, will cause slides and formations of ice that sometimes reach out into the highway. In these cases it is necessary to construct French drains in the slopes to collect the water and lead it into a drainage system.

A careful search must be made of the surrounding terrain, especially through farmlands for existing underdrains where they might be obstructed by the highway construction. Where such a condition is found, they must be re-located or connected to the drainage system.

The whole problem of underdrains should be discussed thoroughly by the Chief of Party with his supervisor after he has collected all the information available and studied the possible requirements of the project. He should also study the results of similar situations that have occurred on previous highway construction, and interview maintenance men or others who might have information of value. The economics of the situation should be thoroughly studied. Often in the past much money has been wasted by the excessive and blind use of underdrains as well as damage caused by the lack of it. Always the question arises whether the cost of the damage to be prevented is comparable with the cost of the drain.

CHAPTER XIV

SUB-BASE MATERIAL

It is the **policy** and practice of the Department to place a layer of sub-base material under all permanent pavements on State Highways where there is any indication that the soil sub-grade is such that the presence of moisture will reduce its bearing value to such an extent that appreciable damage will happen to the pavement.

The thickness and extent of the sub-base material will depend on the data derived from the soil survey of the project. The Soils Engineer should be consulted regarding the depth and location of sub-base and the proposed drainage of the material to be used.

In general a nominal **thickness** of sub-base material will be placed, usually over the entire graded width, where no bad soil conditions are encountered and soils are more or less uniform. Where bad sub-grade conditions, such as heavy clay stratas, free water, springy and spongy soils and other materials having a low bearing value are encountered, additional depths of sub-base must be placed after excavating the bad material. Sometimes where such areas are extensive the bad soils can be excavated and replaced with suitable borrow material which can be topped with a normal thickness of sub-base material.

Sub-base drains should be placed at all low points in the grade. The desirability of using these drains at other locations should be discussed with supervisors. Where **rock excavation** has been made under the sub-grade, the sub-base material must be carried down to the rock surface. If there is any probability of water seeping up through seamy rock strata additional depth of rock should be excavated and backfilled with sub-base material.

In some parts of the State, especially the southern sections and on portions of some projects, existing soils have vertical drainage and are sufficiently stable when wet so that sub-base material is not necessary. Tests of the soils throughout each project where doubt exists should be made to establish the locations, as near as possible, where sub-base can be eliminated.

Locations of the nearest sources of suitable material must be known in order to determine the probable cost and economy of the proposed design. Where good material can be obtained at a low cost, the quantity of sub-base can be generous, especially on borrow projects. Where the cost is high, the economy of use should be thoroughly considered. Extravagant use can sometimes be less economical than providing too little.

CHAPTER XV

CURBS

The Departmental policy regarding the construction of curbs cannot be defined by any hard and fast rules. Each situation must be studied in light of its particular requirements. In general in the case of **vertical curbs** it is customary to construct curbs on heavy grades where full width pavement is constructed; where city streets already curbed have become part of the highway or its connections; on ramps and intersections where full width paving is used; at locations where there will be considerable parking and pedestrian traffic; and to replace existing curbs where removed. In the case of **sloping curbs** or island curbs it is the general policy to place the standard sloping curbs around islands in intersections and at such places where traffic will be heavy; where protection to the raised island will be needed; or to make the islands more visible.

The Chief of Party should gather all facts pertinent to each problem and consult his supervisor before beginning the detailed designs and final cross sections.

The **standard designs** as shown on the detail sheets for both vertical and sloping curbs must be used where possible. However, it will sometimes be necessary to vary the curb face of vertical curbs in order to meet the grades of existing sidewalks and buildings, but the minimum face should not be under 5 inches nor the maximum over 9 inches, except on Bridges where a 10" curb face is usually standard. In municipalities where any change of the ordained curb face is made the municipal authorities should be consulted.

CHAPTER XVI

SIDEWALKS

The policy in regard to paved sidewalk construction is very much the same as that for curbs. In general they are to be constructed where the pedestrian traffic warrants, or where Federal regulations require them. The type of pavement to be used may be taken from the following list: gravel, cinders, stone screenings, fine slag, bituminous surface on gravel or stone, soil cement concrete, or concrete. Each situation must be thoroughly studied and the type used that is best suited for each particular case, considering particularly the amount of pedestrian traffic, the location of the sidewalk and economy of construction. Where connecting to, or building on municipal streets, local authorities should be consulted.

CHAPTER XVII

GUARD FENCE

Guard fences should be constructed primarily for the **protection** of the motorist; to prevent vehicles from going over heavy embankments or into obstructions where the damage to the vehicle or its occupants will be greater than that caused by the contact with the fence itself. In many cases less damage will be caused if the vehicle runs over the slope, or embankment instead of striking a guard fence, provided the slope is flat enough or sufficiently low to prevent a vehicle from turning completely over.

Considerable thought and study must be given by the Chief of Party to these matters. Guard fence should be built only **where definitely necessary,** for it is an expensive item having high maintenance and replacement, as well as high initial costs.

Where embankments are not over 10 feet high, it is more economical to widen sidewalk areas or use a slope of 4:1 or flatter. Sloping and widening should be limited to areas where right of way costs are reasonable and not attempted where such costs are very expensive and where considerable property damage will result.

The nature and distribution of the earthwork on a project will also affect the **economical use** of guard fence. Where there is an excess of excavation, sidewalk areas should be widened and slopes flattened to eliminate as much fence as possible.

Beautification of the project should also be kept in mind when using guard fence. It should be avoided wherever possible where it would be an eyesore or obstruct natural scenery or beautification.

It is often necessary to include in the contract an item for **temporary guard fence** to be used to

eliminate danger during the course of construction or at the end of an uncompleted project. Such fence should be of the wood type selected from previous designs to fit the required purpose.

It is also necessary at times to design **extra heavy guard fence** where there are extremely high and dangerous embankments or along Railroad tracks and electrified utilities. In such cases the Chief of Party should consult his supervisor and a design to fit the situation selected.

A **standard guard fence** detail plan is furnished by the Department and the designer should thoroughly familiarize himself with its use, methods of construction, specifications and items of payment.

CHAPTER XVIII

SHOULDERS

The term, **shoulders,** in connection with highways is taken to mean that portion of the graded width of the roadway not ordinarily used by moving traffic but constructed for parking, drainage or emergency traffic. It is usually paved with materials inferior to that used in the pavement of the regular lanes of travel. Variable conditions and needs occur on each project as well as on different projects. Therefore some thought and study must be given as to what **type of shoulder** is best fitted for each situation. It is the **policy** of the Department to construct some type of improved shoulder on all state highways and important connections. The type of materials that are most economically available as well as their suitability should be carefully looked into for each project. Samples and **information** as to available quantities of such materials as gravel, slag and broken stone or stone screenings should be secured. Where considerable water must be carried along the shoulder and on grades where the velocity of flow will be high, it will be found economical to construct a more permanent type of shoulder such as bituminous concrete surface course on a gravel or stone base, or cement soil stabilized shoulder pavement; and in some extreme cases full width pavement and curbs can be used.

Situations occur in urban and suburban areas where there will be considerable traffic and parking on the shoulders. Some thought should be given to the amount of such traffic and the advisability of constructing a permanent type shoulder or **full width** pavement. The departmental policy for full width paving in Municipalities as outlined on Chap. V, Page 1, should be followed where possible.

The Chief of Party must collect all available information, make a thorough study of these various problems and consult with his supervisor until a definite solution is reached.

A **detailed section** of each type of shoulder used must be shown in the plans and the location and extent of each clearly marked.

CHAPTER XIX

SLOPE PROTECTION AND BEAUTIFICATION

It is **standard practice** of the Department to protect and beautify highway slopes and unpaved island surfaces with top soil and seeding. This must be kept in mind when plotting the **cross-sections templates** and the bottom of the top soil line shown since the top soil will not be included in the earthwork but paid for as a separate item. Two types of top soil are used, classed as top soil 6″ thick and top soil 4″ thick. The former is to be used on island surfaces and on unpaved sidewalk areas in urban sections of the project. The latter is used on nearly all slopes and on sidewalk areas outside urban sections. Exceptions to these rules may occur in cases where a large amount of top soil is to be stripped from the existing ground surface and the quantity will be sufficient to construct 6″ top soil on the island and embankment slopes in fills. In such cases the 6″ thickness should be used in order to save borrow material as well as getting better protection.

Along with seeding of the slopes, consideration and thought must be given to **erosion** and slides on the slopes, especially heavy cut slopes over 12′ high. The nature of existing soil, probabilities of water seepage, and the run off and discharge of drainage water down the slopes must be carefully studied, and where there is a strong probability of damage, some preventive construction details must be designed, such as bench cuts in the slopes, diversion ditches and inlets at the tops, storm sewers and paved gutters down the slopes, underdrains to cut off seepage, sodding of slopes and other details. The Chief of Party should familiarize himself with similar situations of past work noting failures as well as successful operations; also consult maintenance forces and others who have helpful information. Above all, these de-

signs must be made permanent and adequate, for water soon finds the weaknesses of inadequate structures and renders them useless.

Along with slope protection consideration must also be given to **beautification** of the highway. Opportunities should be used where possible, for blending the normal sections of the roadway and slopes with the surrounding ground by rounding slopes, filling up depressions, eliminating unsightly conditions, regrading and seeding abandoned portions of the roadway, and protecting trees and shrubs outside the roadway limits. These details should be worked out in consultation and cooperation with the landscape or parkway engineer.

CHAPTER XX

WET EXCAVATION AND EMBANKMENTS OVER WET AREAS

It is necessary on many projects to build a portion of the highway over marshlands, swamps and other wet and mucky areas. These situations call for careful surveys and a collection of information necessary for an adequate design and economic method of procedure. **Borings** must be taken of wet areas to determine the depth and nature of the mud and muck in order to find the line of firm bottom upon which the embankment can be stabilized. In making such borings care must be taken to penetrate far enough into what may be thought to be a firm bottom to make sure it is not a comparatively thin layer with more muck or soft material underneath. Auger borings may be used for depths up to 30 ft. where materials are not too dense. Otherwise wash borings must be made or samples taken by the Porter sampler or some similar method.

The usual **method** used for constructing a stable roadway over wet and muddy areas is the removal of the unsuitable material by excavation or dredging and back filling with suitable material. However, in special cases where the muck has considerable depth or disposal areas are lacking the **"sand drain"** method of stabilizing the muck in place may be more economical.

When all pertinent information has been secured, the Chief of Party must consult his supervisor about the **method of procedure** and the nature of the construction to be employed in each individual case.

In nearly all cases the removal of wet excavation is a **pay item** and the payment is made on a cubic yard basis. Therefore the **pay lines** for this excavation must be well defined, and definitely

marked. The location of these pay lines will depend a good deal on the depth and nature of the material. The fundamental purpose being to get sufficient embankment down to firm bottom to support the roadway. Consideration must also be given to the practicability of working to the lines given from the Contractors' view point.

A thorough study must be made of all factors and consultations held with the construction forces, the soils engineer, and supervisors, before any definite pay lines or slope lines are fixed.

Final payment for wet excavation may be paid for on the basis of borings taken after completion of the fill. The amount allowed being that which is displaced within the limits of the pay lines. However, in shallow wet material and where the hydraulic dredging method of removal is used, the quantity can often be measured by cross sections at the time of excavation, just prior to the placing of the fill. This method is more economical and accurate and should be used where feasible.

CHAPTER XXI

INTERCHANGES, INTERSECTIONS AND DRIVEWAYS

Highway intersections are of many types varying from simple entrances and exits at grade to complicated grade separations with multiple interchanges. It is not the purpose of these instructions to go into the purposes, methods and uses of highway intersection or interchange design. These functions belong to designing engineers and those in charge of offices and districts.

It is the function of the Chief of Party to supervise the making of the detailed drawings from the general design plans that have been approved; also to collect and tabulate all the necessary information related to each problem of design so that the designer's information can be as complete as possible. This includes showing the results of traffic counts and types of traffic for all directions and turns, the possibility of increased traffic by reason of new developments or other reasons, and traffic speeds to be expected. This information can be obtained from the Division of Planning and Economics. Possible drainage outlets, and other special information as well as the complete topographical survey of the location of the proposed design must also be shown.

A tabulated list of information to be submitted with each intersection study plan is shown on the memorandum of instructions shown in Sect. 7, Chap. IV.

In order to have a good understanding of the nature of these requirements the Chief of Party should study the Booklets issued by the American Association of State Highway Officials entitled, "A Policy on Grade Separations For Intersecting Highways", "Highway Intersections at Grade",

and also the requirements of the Public Roads Administration.

In making **detailed drawings** for the approved designs a careful study must first be made of the layout, and plans formulated for laying out the most efficient base lines, detail sheets, and division lines for plan sheets and cross sections. The scales used must be such that all construction details can be clearly shown and yet not make the plans too cumbersome, difficult to handle, or match up. 50′=1″ or 30′=1″ are scales that can be generally used for detail drawings. However, special cases may make it necessary to use a larger or smaller scale.

Special detail sheets must be made showing features that cannot be shown on the standard drawings, such as slab layouts and elevations of banked and warped surfaces for concrete pavement. Such elevations must be worked out for intervals of not less than 25′ or even closer where necessary to obtain a smooth riding surface.

The use of 0.2′ **Contours** on extensive intersections and pavement areas is often helpful in determining good drainage and smooth riding surfaces.

The designer must study thoroughly the **slab layout requirements** and select one that will be the most efficient to construct and mark out for traffic after construction. Standard slab lengths should be used wherever possible. A careful study must be made of the instructions regarding markings for pavement joints and all necessary markings placed on the detail sheets.

For large or complicated separations a detail sheet must be made showiug a comprehensive general layout of the entire interesction to a scale small enough to give the complete picture on one sheet if possible. In some cases, however, two sheets may have to be used. These detail sbeets

should show the following: a general plan, base lines and their curve data; the layout of the cross section sheets with a key of the section lines; references by number and location of the various detail sheets; and other related general data such as permanent monuments, traffic data and sight distances.

The design of **minor highway** and drive **intersections** at grade must also receive careful study. Grades must be carefully laid out for proper drainage and minimum property damage; necessity for channelization considered, and supervisors and designers consulted. In many cases, especially where roads and streets are relocated, municipal and county engineers should be consulted concerning widths of streets, radii, sidewalk areas and public utilities.

CHAPTER XXII

TYPES OF PAVEMENT

Before final cross sections are begun, approval must be given to the selection of types of pavement for the main highway, street relocations, ramps, etc. The Chief of Party must secure all necessary information regarding traffic, existing pavements, ideas of municipal and county engineers, utilities that will be affected and other pertinent data, then consult his supervisors until a decision is reached on the types of pavement to be selected at the various locations. Typical sections of each type of pavement must be shown and station to station locations given.

CHAPTER XXIII

FINAL TRACINGS

Completing the final drawings is an operation that requires considerable specialized ability and experience on the part of the draftsman and a good deal of thought and supervision on the part of the Chief of Party. The less experienced the draftsman the more supervision is necessary. When experienced draftsmen are not available others must be taught and carefully supervised in the many **plan details** to be drawn. Good samples of former plans must be procured and used for references and examples. A clear, neat, readable and **orderly arrangement** of construction notes should be strived for at all times. Before any construction notes are inked in on a tracing detail, a complete layout plan for all notes on each sheet should be made. Each note should be as near as practicable to the item described with clear and definite reference arrows used. It must be remembered that the plans are to be used under adverse weather and light conditions, often by those whose plan reading knowledge and experience is limited. Therefore simplicity and clarity as well as accuracy should be the most important objectives. The **size of lettering** to be used is outlined in Part II, Section 1. The draftsman should aim to comply as nearly as possible to these instructions. However, situations will occur where this is impracticable and good judgment will then have to be relied on.

After the detail sheets have been inked in and completed they shonld be turned over to a competent checker for **final checking** who must go over them thoroughly in detail and check for accuracy and completeness. Competent checking is one of the most difficult and most important phases of plan work. Therefore the Chief of Party must select reliable men who are fitted for the

CHAPTER XXV

CALCULATIONS AND ESTIMATE OF QUANTITIES

One of the most important features of highway construction plans is the **estimate of quantities** of the various items of work to be performed by the contractor. It is the policy of the Department to indicate on the plan sheets quantities of each item of construction where it is shown, and also to summarize on each plan sheet the totals of the different items. In addition, an **"Estimate of Quantity Sheet"** and a **"Take Off Sheet"** must be prepared. The "Estimate of Quantity Sheet" must be a complete summary of all quantities of each item. The nomenclature of each item should conform to the nomenclature as shown in the specifications. In Part II, Section 4 M is a referenced list to be used for this purpose. This list also shows the proper order in which the items are to be listed. Identifying and clarifying notes should be added to the names of the items, sometimes called **"Pay Items"**, meaning the items contained in the proposal upon which the Contractor bids and is paid for. Such notes should be very brief, merely noting thicknesses, depths, mixes, types, etc., so that the contractor definitely knows upon what he is bidding.

The **"Take Off Sheet"** is laid out to show the distribution of quantities throughout the plans, to simplify checking and summarizing, to aid in making monthly estimates, and to assist the contractor in distributing materials.

Both the **"Estimate of Quantity Sheet"** and the **"Take Off Sheet"** should be first laid out in pencil. Consideration must be given for the **"Bridge Items"** which will be furnished by the Bridge Division and proper space provided. Crowding of the items should be avoided. In some small contracts the typical section sheets and Estimate of Quantity sheets may be combined. The lettering

should be clear, neat and comply with instructions in Part II, Section 1.

Before the inking in or tracing takes place all quantities must be thoroughly and completely checked, cross-checked and double-checked by different competent individuals. The Chief of Party must make certain that this is done and at no time allow the estimate of quantity sheet to be inked in without the approval of his supervisor. After the inking or tracing a comparison check must also be made.

Where there is a possibility of other items being added to the plans before advertising, space should be provided so that the insertions can be made without crowding.

Calculating and estimating the quantities to be placed on the plan sheets, on the estimate of quantity sheets, and in the proposal for bidding requires extreme care and very careful checking in order to avoid errors and mistakes. For this purpose, and also to enable the Trenton office and the Public Roads Administration to efficiently and conveniently check and take off quantities, all calculations must be shown on forms provided for that purpose or on paper from which blue print copies can be made. Form No. 73 should be used wherever possible. In order to obtain good prints a No. 2 or similar pencil should be used. The calculations should be arranged orderly and neatly and crowding avoided.

It must be kept in mind that these figures must be so complete and so arranged that they can be readily understood by others who are not familiar with the plans.

In order to facilitate breaking down quantities for Federal Aid or other divisions, calculations must be arranged to show the totals of each item for each plan sheet rather than for each item carried throughout the plans. This also makes

checking easier and facilitates the making of changes where necessary.

In order to make clear to others the method used for irregular pavement, walls or other complicated areas and volumes, **sketches** should accompany the calculations either on Form No. 73 alongside the figures or on tracing paper attached.

Where it is definitely known that Federal Aid is to begin or end on a project, the calculations should be **broken down** and totaled at the **division points.** This should also be done where the cost of a project is being shared by municipalities or others.

For **earthwork calculations** two methods can be used, one by stripping areas and computing volumes by making up earthwork calculation sheets, and the other by calculating areas by machine, using elevations and offsets shown on the cross section sheets, then computing the volumes by machine, using areas and station distances.

Where the machine method is used, volumes shall be totaled at least every 1000′ or at Federal division lines or at breaks on the earth chart.

An **earth chart** shall be prepared for all projects where cuts and fills are involved to such an extent that a chart will provide useful information to the contractor and others. This chart shall provide a clear picture of the earthwork to be performed on the project, showing cuts above the line and fills below. The scales used must depend upon the length of the project and must be distorted to give a clear picture and allow ample space for summation and totals of results.

This **earthwork summary** must show, where found in the project, such items as the total cuts, fills, pay items of earth excavation, borrow excavation, rock excavation and wet excavation. Also must be shown the estimated amount of excavation that is available for use as embankment with the

shrinkage factor used to arrive at the estimated borrow. This **shrinkage factor** must be considered carefully and selected to fit the materials expected to be encountered. As built plans of previous projects encountering similar materials should be studied to find what actual shrinkages occurred, and whether the project calls for light grading, heavy grading, rock excavation or wet excavation, all of which will have considerable influence on the factor to be used. Other totals such as driveways, deductions for stripping, filling in foundations, subsidence, or other estimated quantities, must be shown if they occur, to make the earthwork summary complete.

CHAPTER XXVI

PLANS FOR RIGHT OF WAY

In drawing plans for right of way (which to the field office, fall into two categories; namely, General Entire Tract Maps and General Property Parcel Maps), emphasis should be placed upon a complete layout and upon apportioning the time, if feasible, in order that right of way plans will proceed concurrently with and be finished at the same time as construction plans.

The **Entire Tract Map** might well be laid down in advance of other plans in order that an efficient allocation of space and a wise choice of scale may be made for each sheet of the other plans. Wherever necessary the alignment may be broken so as to place the highway in that position best suited to the purpose of the map. Where greater detail and clarity are required, that area may be boxed off and referenced to the General Property Parcel Map, for such detail and clarity. In this case the latter map will contain information omitted within the aforesaid "Box". With the General Entire Tract Map shall be submitted an assembly of basic data for title work. Assembling the basic data shall be construed to mean, (1) the making of proper abstracts of the deeds or the deed conveying the entire properties of which the parcels taken form a part, preferably by a title searcher, (2) obtaining copies of development, tax, partition and other maps, and (3) collecting such other information as may be required in the establishment of the ownership and boundaries of the parcels to be acquired and the entire properties of which they form a part; together with the compilation of such other necessary data which may come to the attention of the engineer or the title searcher as being essential for the completion of

the General Entire Tract and **General Property Parcel Maps.**

Depending on the type of terrain traversed, General Entire Tract Maps are usually of one scale throughout—either 100′ or 200′ to the inch. These maps may be made in pencil on pencil tracing cloth.

On the selection of a scale for the General Property Parcel Maps the following is offered as a suggested guide:

1. For open country where parcels are large, such as large farms, etc. and where few building or other improvements exist, (1″ = 100′).
2. In suburban areas where lots are not too small, say, 150′ x 200′, (1″ = 50′).
3. And in metropolitan areas where lots are small and there is much detail to be shown, (1″ = 30′).

If the Highway passes through all three types—city, suburban, and country—there will be no objection to the use of the three scales on the one map in which case the scale should be clearly marked on each sheet of the map. In general, however, not more than two scales should be needed.

Details to be shown on General Entire Tract Maps are:

1. A complete outline of each owner's entire property at this location, including the outlines of all separate tracts comprising the whole tract as revealed by the various instruments of conveyance. (Where tracts are too large to show in their entirety make an insert on a smaller scale).
2. Reference to deed or to any instrument conveying rights or easements; i.e., by book and page.
3. Bearing and distance of all outlines listed under No. 1.
4. All deed areas.
5. Buildings, and whenever possible, the nature

and type of land through which the highway passes, such as marsh land, cultivated land, woods, pasture land, etc.

6. The State Highway parcel number enclosed within a circle, thus (5).

7. The name of the owner of record.

8. The right of way lines of the highway, including bearings, distances, curve data and, in figures, the width between the right of way lines.

9. Municipal lines.

10. North Point.

11. Areas remaining on each side of highway.

Details to be included on the General Property Parcel Map are:

1. Location of the highway reference lines; i.e., the base lines, with their appropriate sub-designations with bearings thereon. Where a magnetic bearing is given the year in which the bearing was taken should be indicated. Where different sections of a given route join it is essential that it be indicated whether the reference line is an extension of or makes an angle with the connecting line. Existing designations of old reference lines should be retained.

2. The location of right of way lines.

3. Parcels to be acquired or conveyed.

4. Slope, drainage or bridge easement lines (usually for grading the full right of way width).

5. Essential topographic features; i.e., structures, construction and drainage features near to and outside the right of way lines.

6. Municipality and County (near upper right or left corner) in which property shown on sheet is located.

7. A schedule sheet showing the following: Plan sheet number, parcel number, parcel area, easements (slope, drainage, bridge), side (right or left), station location, name and address of owner.

deed reference (where not supplied on General Entire Tract Map) and a "Remarks" column.

8. Data re: road returns.

The location of reference or **base lines** after construction is to be made according to an order dated October 11, 1944. This order should be referred to as a guide with special emphasis on the topic, **"Monumenting the Base Line."** The 'base line' to which right of way acquisition is referenced shall be permanently located and monumented. . . ." Where a base line is not to be monumented reference should be made by supplying adequate ties from permanent points, well outside the right of way lines, to all basic control points. At least 3 ties or a permanent monument are essential to each point. Basic control points should include intermediate points on long tangents at critical points of sight. The purpose is to facilitate the reproduction of these lines on the ground.

The location of the right of way lines is to be shown by referring all points which are the beginnings of a change in direction of said lines to the base line by survey or calculated measurments. The order of October 11, 1944 states, "During the construction of each project the survey forces will place a **hub and marker stake** at all corners of the right of way lines that are not parallel to the pavement lines and that cannot be located by direct and uniform measurements from the curb or pavement lines. - - -"

Parcels are to be outlined by heavier lines or some method to make the boundries clearly outstanding. They shall be numbered thus (12) within the parcel or with a curving directionary arrow from the (12) pointing within the parcel, where space is limited. Near the (12) should be lettered its area and in cases where parcels are too small to hold the necessary information a log should be

made showing owners and areas in numerical order for the entire sheet, but only for such small parcels.

Calculated and fixed data must be supplied (nearly all measurements are best set or determined, leaving only one to be computed). The object of this work is to enable a private surveyor to reproduce the right of way lines by using only the filed key map as a guide.

Ties and dimensions shown should be liberal and appropriately placed. Distances between base liue and right of way line should be placed frequently and clearly enough so as to leave no doubt about fixing the latter line. Ties between control or set points, and the primary or secoudary reference lines should also be ample and clear. Set and calculated curve data must be shown and any data incidental to set points or lines should be indicated in the interest of clarity. The primary feature of all plans is legibility; therefore, all letters, figures, aud other data should be appropriately placed on plans with this consideration in mind. All lettering should be far enough away from lines so that erasing either will not endanger the other.

Sample blue prints of all or any types of maps are always available at the Trenton Office of Survey & Plaus. Recent maps should always be requested, stating the purpose for which they are to be used, in order that the best examples may be furnished.

CHAPTER I

GENERAL INSTRUCTIONS

Laying out **lines and grades** for construction projects requires extreme care and accuracy and at times, also speed. **Co-ordination** and timing must be planned well beforehand. The representatives of the department in charge of construction and the contractor's forces must be consulted frequently and complete co-operation between all forces obtained in order to secure efficiency and prevent delays and hold-ups in the construction work.

First the supervisor must be consulted and decisions arrived at as to **what lines are to be staked,** what stakes are to be given and where placed, also how the stakes are to be marked and what information is to be provided for the contractor. Inasmuch as New Jersey highway projects are of such a variable nature no definite standards of staking can be fixed, but for dual or other wide highways, grade and offset hubs with tacks shall be placed on both sides of the construction at fifty foot stations. Each hub shall be referenced by a marker stake showing the station, offset, and cut or fill to the construction base line being used. For single highway construction of not too great a width one line of stakes is sufficient. Careful studies must be made in order to provide stakes where they will be of the greatest service and in places where they will not have to be removed by construction.

It is the policy of this department to provide **grade sheets** for stakes marking the base lines or curb lines of the main highway, ramps, and connections. These sheets must show the date, station, offset, elevation, and cut or fill to the points

referenced. They must be made on paper that will enable blue printing of several copies.

As soon as it is definitely known when a construction project will begin the **layout survey** must be started well in advance of the work of the contractor's forces. The construction base lines must be re-established and permanent tie points fixed outside the limits of construction. These ties must be so placed that lines can be reproduced quickly. Also adequate bench marks must be established throughout the project beyond the limits of construction.

A notebook of all construction staking and layout work must be kept; and neatly and carefully arranged. Controversies over discrepancies in lines and grades often arise and a careful record will show what happened. The Chief of Party must keep a **diary** or record of all procedures of staking out and important incidents bearing upon this work, especially conferences, changes, delays, destruction of stakes, requests of contractors, or other happenings that might have some relation to the final settlement.

Among the first items to be worked on by a contractor are the **drainage structures**; therefore, this staking should proceed in most cases immediately following the general line and grade stakes. It is often necessary to start drainage staking before all general stakes are placed. Consultations with the inspection forces and contractor must be made frequently in order to keep ahead of the work and avoid hold-ups.

Hub and marker stakes shall be placed showing offsets and cuts or fills to the flow line of the pipe at intervals of not more than 50′. These stakes must be placed out of the way of construction. The center of all catch basins and manholes must be staked and in the case of catch basins at least two stakes must be placed giving

the line and grade of the curb line for the basin. For cross drains grade and offset stakes must be given for each end of the pipe.

In staking out drainage a Chief of Party must take nothing for granted. **Grades and lines** taken from the plans shall be used where given but must be **checked,** and a careful study made to make certain that they fit the situation at hand; that they will drain the areas intended to be drained; that they have the proper clearances for pavement, driveways, utilities, and other permanent structures. Where the location of **underground structures** is suspected, but indefinite, the trenches for the pipe should be opened up until they are found and a definite grade fixed to avoid them where possible. In cases of this kind the Chief of Party must stand by with his party ready to lay out grades so that the work may proceed.

Placing grades and lines for **concrete pavement** is an important and often an intricate operation of construction layout. It is the policy of the Department to provide grades and lines near enough to the concrete form lines so that they can be transferred to the forms by means of a grade board not over 10 ft. in length. Hubs and markers may be used to provide these grades, but often it is more efficient both for the Department and the Contractor to mark the grades on iron pins on the form line or on a one or two foot offset line. Measurements should be taken from the pin face nearest the concrete. This method should not be used, however, except where the grades are to be used almost immediately and the pins fully protected until grades are taken off.

Many **intersections, ramps,** grade separations, and complicated connections require variable widths and lengths of slabs, broken lines, curved lines, and warped grades. For such cases a definite

procedure for staking should be planned beforehand and the elevations calculated at close enough intervals to give smooth riding surfaces. These intervals should be not greater than 25′ and in some cases less. They should be calculated where possible for the longitudinal joint lines and in the cases of warped slabs intermediate elevations must be given. Curved and broken alignments at joint lines must also be calculated well in advance of the work so that the giving of lines and grades may proceed at any point; for in order to work efficiently and provide for the maintenance of traffic the contractor must pour concrete in different lanes and often in isolated slabs during the same day. Therefore, it is of great importance that the Chief of Party, the inspection forces, and the contractor's men co-operate fully in planning this work.

Special stakes must often be given for miscellaneous items such as bridges, culverts, walls, curbs, and gutters.

In **staking out bridges** the Bridge Division must be consulted to find out what lines and grades they desire and their wishes granted as far as practicable.

Other miscellaneous items must be given sufficient stakes to enable the builder to get the correct lines and grade without unnecessary difficulty.

The **calculations** for construction layout and all grade and line stakes must be so **thoroughly checked** that their accuracy cannot be questioned. The Chief of Party must be constantly on the alert looking for errors in the plans or in the work of the personnel. Even after grades and lines are accurately given, where time is available, **observation checks** should be made of the work of the contractor's men to see that the grades are being properly used. This should be done espe-

cially in the case of bridge layout. Serious mistakes can often be prevented by making comparative observations of the various working lines laid out and the work being done.

During the course of the work on a construction project it often becomes necessary to make changes in the plans or to perform additional construction work not shown on the plans. It is the duty of the Chief of Party in charge of the layout work to make a survey and a plan of the changes or additional work as per instructions of his supervisors and the district construction engineer. These plans must be made on standard sized tracing sheets. Where the details are small they should be so spaced on the sheet that additional details can be added to the same sheet as they are needed. The same standards should be used for these plan details as for the original plans. The plan quantities and the new quantities must be clearly shown and carefully checked. Calculations for these quantities must be made on standard calculation sheets.

On projects that call for borrow excavation layout and cross-sections must be taken of the borrow pits after they have been stripped and approved by the construction forces as borrow material. Permanent base lines and bench marks must be established and well referenced so that a grid system of elevations of the ground taken at the same points before and after excavation can be laid out. These points must be close enough to give correct contours of the ground, sufficient for an accurate calculated determination of the earthwork. Elevations at many additional points are often necessary for the "after sections" especially where the excavation has been left in a very rough condition. The "before" elevations of these points can be calculated from the original ground line sections.

Careful and accurate notes must be kept of all borrow pit layouts and sections. The sections must be plotted on standard cross-section tracing cloth and all calculations clearly shown. Machine methods of calculations should be used where possible.

The necessity for checking and **re-checking** accurately all construction layout work cannot be emphasized too much. Where possible, checking should be done by using different methods or different personnel, for the same work. A Chief of Party should not allow any work to go unchecked when there is the slightest uncertainty in his mind of a possible error of any consequence.

CHAPTER I

GENERAL INSTRUCTIONS

For the purpose of establishing a permanent record of the finished construction project, and in order to determine accurately the final quantities and estimates, it is necessary to have a complete as-built survey and plans of the project exactly as it was constructed.

Plans must be made to **begin this work** as soon as construction work on the project starts in order that the plans are completed as soon as possible after the project has been completed. Delays in the as-built plans will delay final estimates and payments to the contractor. Close **co-operation** and frequent conferences with the construction forces should be carried out.

The first step in the preparation of these plans is to procure one or more complete sets of black or blue line **white prints** and the tracings of the contract drawings. These will be released to the field offices after a set of VanDykes are made and filed at the Trenton office. The white prints are to be used as working plans upon which to place all data and measurements when collected. The survey or measurements of each construction item should be made as soon as a substantial amount has been constructed and the **as-built plans** kept apace with the project. The data from the white prints shall be transferred to the **original tracings** in orange colored ink by a competent draftsman. This work shall be done carefully, neatly and accurately, keeping in mind that prints made must be easily read and understood. To do this the **arrangement of the notes** must be carefully planned beforehand. Construction notes for items not built as planned must be crossed out and corrections made.

Copies of construction plans indicating work completed, by date and location, are available on the job in most Construction offices. A properly recorded set of figures on this plan can be of invaluable aid to the Chief of Party in completing his "As-Built" work.

Note books must be kept of all as-built survey data in the same manner as described for original surveys and plans.

The **survey data acquired** must include accurate measurements of all construction items exactly as constructed. Elevations and locations of all drains, sewers, utilities, and other structures encountered, not part of the project, but which may affect future maintenance or construction must also be obtained. Arrangements should be made with the Construction forces to notify the Survey & Plans forces when such structures or utilities are encountered so that their location can be established before work is completed. Elevations must be taken of all drains, streams, walls, underclearances of bridges, and similar items that may provide necessary future information.

All monuments, right of way markers, ties, and bench marks must be accurately located and shown. Where property or municipal monuments have been removed by construction accurate ties to the former location must be sbown or a new monument, referenced to the old, placed and noted on the plans. All "**change of plan**" drawings must be included or attached to the As-Built Plans. Such changes should be noted on the plan sheets and a summary of the items shown on the estimate of quantity sheet.

As-built **profile elevations** shall be taken of the new work and the new elevations shown. Except on ramps and other special cases, these elevations may be taken at one hundred foot stations.

New **cross-sections** of the project must be taken

when the grading is completed. These sections should be started when a substantial section of grading has been completed and the sections plotted and calculated as soon as possible.

In taking cross-sections good judgement must be exercised in getting enough elevations to allow reasonably accurate final earthwork figures, but no time wasted in unnecessary refinements. For example in a long stretch of uniform standard highway sections elevations at the top and bottom of slopes, on the edges of the pavement, on the curbs, and on center islands are sufficient if it is evident that the grading has been done carefully and is within an inch or so of the required section. The Chief of Party must study carefully the required sections, and the grading as built, to determine just how many sections and elevations are required for reasonably accurate results, without unnecessary refinements.

Final borrow pit measurements and elevations must be taken as soon as practicable after all material has been taken out that is to go into the project. Care must be taken to adhere to the original base lines and cover the area worked on thoroughly with enough elevations to get an accurate earthwork figure. The original base lines, bench marks, and section measurements should be checked thoroughly and several check shots should be taken on the original undisturbed ground at the ends of the sections.

Where sub-base or other materals are taken from or near a borrow pit arrangements must be made to segregate the work and sufficient cross-sectioning done to show accurately the material used for borrow. This may mean sectioning different parts at different times and a thorough understanding of the procedure to be followed should be planned beforehand hy consultation with the construction forces and the contractor.

Measuring pavement areas requires special care. Pavement is paid for on the basis of surface measurement and each project must be chained throughout along the surface. Thus the "as-built" length of the project will be longer than the original length which was a horizontal measurement. Irregular pavement areas must be measured carefully and sufficient measurements taken to simplify the calculations as much as possible. Before measuring a complicated area, a definite plan of how the calculations are to be made should be worked out.

A Chief of Party must study the plans, the instruction to bidders, and the specifications. The measurements for all **pay items** must be made to comply. It is often necessary for cross-sections and measurements to be taken of work such as **rock excavation,** wet excavation, extra excavation and similar items during construction. This work should be anticipated as far as possible and plans laid beforehand to have the necessary forces ready to take the measurements at the proper time. The Resident Engineer in charge of construction must be consulted and decide where sections for rock, wet or extra excavation shall be taken. It is his responsibility to decide what is to be paid for under those items.

All calculations for as-built quantities must be made carefully and accurately, checked and placed on calculation sheets in the same manner as described under calculations for original plans. Where it is necessary to separate quantities for Federal Aid or municipal participation instructions from supervisors should be obtained. All measurements and calculations for the as-built survey and plans must be certified to by the Assistant District Engineer of Surveys and Plans, by letter, or by a subordinate designated by him. The Resident Construction Engineer must also certify to all pay items measured by his forces.

CHAPTER I

GENERAL INSTRUCTIONS

The Federal Government shares in the cost of many of our State Highway Projects. The plans, specifications and construction of these projects must meet with the approval of the Public Roads Administration. Therefore it is necessary to comply with certain methods of procedure and requirements of that Bureau. A Chief of Party must become familiar with all such requirements pertaining to his duties. Following are some of the requirements requested by the Public Roads Administration.

Length of projects should be expressed to the nearest one-thousandth of a mile. The various constituent parts may be rounded up or down as necessary so that the sum of the parts equals the whole.

Length is usually measured along the center line or profile line taking into account all equations or other interruptions. However, minor breaks in pavement as at an intersection need not be deducted.

Length of a project is the pavement length not the length of the shoulder, flares, drainage, transitions, etc., beyond the end of the main pavement.

A **bridge** is a structure with a clear span measured along the center line in excess of 20′ However a twin box culvert with 2-11′ spans would be considered a bridge. Note that it is not the right angle span distance but the center line distance that determines if the structure is a bridge. Generally the length of the roadway slab is taken as the length of the bridge. The bridge length of arches or rigid frames with an earth cover is computed between the inside faces of the abutments.

Roadway length is exclusive of bridge length no matter whether the bridge is already built or to

be built either with or without Federal Aid. Center island construction across a bridge need not be called bridge construction if the bridge proper is not altered.

At underpasses, the roadway length is continuous through the underpass.

Where a bridge occurs in only one lane of pavement on a divided highway the other lane being continuous pavement, the roadway length is carried without interruption along the pavement. The bridge length is computed as usual with a note added that it is included in the roadway length.

For length at traffic circles measure along the center line to the outside edge of the circle pavement (if the pavement varies in width measure to a point representing the average width of the circle pavement). Add the circumference of the circle measured along the center line of the circle or the center line of the average width.

Resume measurement of length at the outside edge of the circle pavement (or edge of the average width).

For elongated circles, it is satisfactory to take the average distance along the center lines either side of the center island.

The length of grading or landscape projects is computed the same as for pavement projects. Stop and resume stations are usually used at overpasses since no grading or landscape work can be done within those limits. However, the exact stations at which a bridge slab will begin or end is often not known when grading plans are prepared. In such cases it will be satisfactory to disregard the proposed bridge and not break the stationing.

Minor breaks in continuity of grading or landscape work as at intersections, etc., usually need not be deducted in determining length of project.

Federal Aid projects are now designated by a letter or letters, a number and sub-number. The

letters represent the type of Federal fund being used and other data as follows:

F—Regular Federal Aid funds
U—Urban Federal Aid funds
S—Secondary Federal Aid funds
I—On interstate highway system
G—Railroad-highway improvement

The number locates the project as within a certain section of highway route while the sub-number indicates the number of the construction agreement made between the state and Public Roads. For example: UGI 198(4) would represent a project on which "urban" federal funds were to be used, a railroad was involved, the project was on the interstate system, the section was number 198, and this was the fourth improvement to be made within the project limits.

If a new project intersects another at an angle, the point where the new center line intersects the outside edge of the existing pavement is the point used in determining the length of the new project.

Estimates:—

Separate estimates are required:—

(1) For each different type of pavement (exclusive of miscellaneous paving of intersections, flares, transitions, etc.). Center island construction is a separate type if no other pavement is laid in conjunction with it.

(2) For each incorporated municipality if the design geometrics are such that a pro-rata determination would be inaccurate. Townships may be grouped in one estimate. For two counties a percentage, based on the length of the work in each, is sufficient.

(3) For projects which cross an urban line as set up by the State Federal Aid Engineer and Public Roads and separate funds are used. [This

will usually be indicated by the project number such as FI-UI 185(3)].

(4) For different projects under one contract. [Indicated by two numbers such as U-82(1) and U-183(3)].

(5) For each bridge over 20′ span measured along the center line. However, if two bridges are indicated in type of construction and purpose, eg two arches over streams or two I beam bridges for bighway overpasses, etc., the estimates may be combined.

Separate estimates are **not** required:—

(1) For different widths of pavement.

(2) Center island construction across a bridge where pavement is constructed on the approaches. (Include the island in the roadway estimate.)

(3) Between counties.

The 10% added for engineering and contingencies may not exceed that percent. If the contract estimate is $15,189.98, the maximum allowable addition is $1,518.99, not $1,519.00. A smaller figure may be used to get a total in even dollars or even ten dollars.

The 10% added on force account estimates should be on materials, labor and equipment only, not on taxes or salvage.

The railroad inspector's salary which is part of the engineering charges for the project may not he added to the force account work unless a corresponding deduction is made in the 10% added for engineering and contingencies in the contract work. This is because he is considered as already included in the maximum allowable 10% addition.

Non-participating items within project limits should be shown separately on the estimate. When outside project limits no estimate is necessary.

Since Federal funds cannot be used for construction work which can be considered as in lieu

of right of way purchase, work outside the right of way generally must be investigated as to eligibility for Federal participation.

A good general rule is that the line of demarcation between a right of way consideration and work eligible for Federal participation is whether or not the proposed work is for the benefit of the property owner and not necessary for the highway construction; or whether the proposed work is for the benefit of the project and necessary for its proper completion.

General Administrative Memorandum No. 35 discusses the eligibility of Federal funds in moving buildings, etc.

General Administrative Memorandum No. 58 discusses eligibility of fence construction and reconstruction.

Federal Aid Marker Posts

The triangular post should be placed with one apex toward the center of the road, as close to the end of the project as feasible.

If only two posts are placed they should be on the driver's right as he approacbes the project, with the project number on the side of the post toward the project. The number for a later adjoining project can then be placed on the side of the marker post toward the new project.

Existing Drainage

Plans should indicate the size and type of all existing drainage and where known the direction of flow and the condition of the pipes.

Existing drainage structures shonld be noted to remain or to be removed as the case may be.

CHAPTER I

ENTRY UPON LANDS TO MAKE SURVEYS

Section 46:11-1. Right of entry to make surveys in certain proceedings.

46:11-1. RIGHT OF ENTRY TO MAKE SURVEYS IN CERTAIN PROCEEDINGS. In any proceeding to lay out, alter, vacate or open a public road or street, or to determine which of the proprietors or possessors of the lands adjacent to any highway have narrowed or encroached on the same, and in any proceeding under the act entitled "An act to enable the owners of swamp or meadow ground to drain the same, and to repeal a law heretofore made for that purpose," approved November twenty-fourth, one thousand seven hundred and ninety-two, and the several supplements thereto, and in any other proceeding touching a public improvement, any practical surveyor, with the necessary assistants, employed by any person interested in any of such proceedings, may enter on the lands adjacent to such highways or streets, or the lands to be drained under the provisions of said act, or other lands for the purpose of making necessary surveys, doing as little damage as possible to the owner or owners of such lands.

Source. L. 1887, c. 158, §1, p. 212 (C.S. p. 5064, §22).

Note. The act cited in this section is saved from repeal in §40:57-10 of the title Municipalities and Counties.

CHAPTER II

CONSTRUCTION DIVISION, HOURS OF WORK, 5-DAY WEEK

1. **Employees Assigned to Office Work**
   9:00 A.M. to 5:00 P.M. (¾ hr. for lunch).
2. **Field Engineering Forces**
   8:00 A.M. to 5:00 P.M. (1 hr. for lunch).
3. **Construction Inspectional Forces (Engineers & Inspectors).**
   Same hours contractors' forces work. Time credited over 44 hours per week to be allowable as XP Overtime.

All Employees:

When employees are required to work overtime they will be entitled to equivalent compensatory time off if time credited is in excess of 40 hours for groups 1 & 2 and 44 hours per week for group 3. Such time off shall be taken during the same calendar year and as designated by the superiors of the employees.

Upon approval of the Division Head, the starting and stopping time and length of lunch period may be arranged differently when circumstances make it desirable. However, the number of hours worked must remain the same.

CHAPTER III

PROCEDURES FOR PLANS PREPARATION FOR STATE HIGHWAY PROJECTS

FIRST STEP

(Responsibility of Division of Planning and Economics)

1. Prepare brief report on purpose of highway, giving its functions:
   (a) To serve through traffic
   (b) To serve local traffic predominantly
   (c) To develop recreational, industrial, residential and agricultural areas.
2. Recommend classification of highway:
   (a) Density of traffic. (30th peak hour, 30 years hence)
   (b) Passenger cars (P), Mixed Traffic (M), Trucks (T)
   (c) Design speed.
3. Recommend Type of highway:
   (a) Two lane
   (b) Three lane (not normally recommended)
   (c) Four lane undivided (not normally recommended)
   (d) Four or more lanes divided (not more than four lanes normally recommended)
   (e) At grade "land service highway"
   (f) At grade with major intersections separated (either initially or eventually)
   (g) Freeway
   (h) Parkway.
4. Recommend location of Termini.
5. Recommend general area of location and reasons therefor.
6. Preliminary recommendations on traffic Interchange locations.

7. Justification:
   (a) Traffic
   (b) Economic factors
   (c) Benefit-cost ratio
   (d) Priority
   (e) Place in comprehensive plan.
8. Review of report by Department of Design and Construction.

After approval (or modification) of above report by the State Highway Engineer he will transmit to the Chief, Department of Design and Construction for progressing Surveys and Plans. (Copies of this report shall be sent to Public Roads Administration if participation in financing is expected).

SECOND STEP

(Responsibility of Department of Design and Construction)

1. Reconnaissance surveys and proposed typical cross-sections.
2. After approval by the State Highway Engineer of Item 1 prepare "Hearing Map" precedent to line adoption. After line has been adopted by the State Highway Commissioner, design shall proceed.
3. Develop typical main roadway cross sections (including right-of-way width) based on satisfactory maximum roadway capacity for the 30th peak hour, thirty years hence. (In some cases this may be desirable, tolerable, or maximum roadway capacity, in which case it will be the subject of individual decision of the State Highway Engineer with review by the State Highway Commissioner).
4. Develop geometric design standards for approved design speed.
5. Field reports on Interchange locations as out-

lined in Memo of State Highway Engineer dated October 3, 1946, shall be submitted.

6. Detailed traffic and economic data relating to Interchange sites shall be obtained from Planning and Economics and transmitted to field.
7. Preliminary sketch designs of Interchanges based on data included in (6) above shall be submitted by field for approval.
8. Submission of a general plan (generally $1'' = 200'$) and profile showing widths, alignment, grades, and tentative Interchanges to State Highway Engineer for Approval. (After approval, prints of this plan shall be submitted to Public Roads Administration).
9. On approval of Interchange sketches and alignment and grades an accurate layout of Interchange design shall be submitted for approval before being tied down mathematically.
10. Submission of proposal for developing order and extent of construction contracts shall be submitted to the State Highway Engineer for approval plus special or unusual specification provisions.
11. Approval of construction plans and specifications by State Highway Engineer and State Highway Commissioner.

In developing plans it is expected that Planning and Economics and Department of Design and Construction will cooperate closely and draw freely on information and techniques each from the other and that the Maintenance Division and Parkway Engineer will be consulted freely on matters of mutual concern.

CHAPTER IV

INTERCHANGES

When preliminary studies and sketches for traffic interchanges are submitted by field offices to the Trenton Office for review they shall be accompanied by a statement covering:

(1) Character of the area surrounding the interchange:
   (a) Residential
   (b) Industrial
      (1) Type of Industry
      (2) Employment (heavy or light)
   (c) Whether room for future expansion and trend of expansion.

(2) Condition of the highway to which it is proposed to connect:
   (a) Where road starts and ends
   *(b) Traffic areas it taps
   *(c) Possibilities for increased traffic developing along road
   (d) Right-of-way width
   (e) Feasibility of widening right-of-way
   (f) Pavement
      (1) Type
      (2) Condition
      (3) Width
      (4) Curbs
   (g) Alignment and grades
   (h) Apparent existing traffic bottlenecks.

* To be furnished by Planning and Economics Division.

These data for the existing road shall be furnished for a distance of ten miles each side of the State Highway.

A statement shall also be submitted as to the general character of main feeder roads which connect into the existing cross-road.

CHAPTER V

POLICY RELATIVE TO PARTICIPATION BY MUNICIPALITIES IN FULL WIDTH PAVEMENT

Policy

The following general policy is hereby established covering participation by Municipalities where full width pavement may be constructed:

(1) In instances where a Mnnicipality desires full width pavement with curbs, the State will provide for a snfficient width of pavement to accommodate the necessary number of lanes for moving traffic, and any normal drainage that may be required except as noted herein.

(2) In cases where a portion of the highway is to be used for parking and it is not feasible to elimiuate parking, the State will constrnct and pay for the pavement carrying the moving lanes of traffic and the normal width shoulder. In case the Municipality participates in the cost, it shall be allowed credit for the estimated cost of the shoulder toward the construction of the type pavement determined upon. The Municipality shall bear the cost of the fnll length of curbing, if desired by it for appearances or other reasons and not required by the State to reduce maintenance cost as in (3). In cases where the State would normally construct earth berms to retain drainage and the Municipality desires curbs for reasons as mentioned above, the Municipality will be allowed credit for the estimated cost of the berms as well as for the shoulders.

(3) In cases where it is determined that the cost of maintaining a standard improved shoulder would be excessive under normal highway usage, excluding parking, the State will provide full width pavement at its own expense, including curbs, where required to reduce maintenance. This procedure shall also apply where drainage conditions

are such that excessive maintenance would occur.

(4) In cases where the roadway width is such that it is desirable to eliminate parking in order to accommodate moving traffic, and the Municipality passes ordinances prohibiting parking, the State will bear the entire cost of full width pavement, including curbs and drainage; provided, however, that if the Municipality should at any future date repeal the local parking ordinance, the cost of the paved area utilized for parking shall be paid for by the Municipality at the original cost to the State.

(5) Where street intersections occur at grade and the intersecting street is curbed, being paved full width, the State will bear the entire cost of paving such intersections on its own roadway and as much else as may be required to afford proper grade and riding surface.

(6) Where interchanges and channelization are required, generally the State will bear the entire cost of construction. Special designs shall be prepared and a determination made as to whether or not the Municipality should bear any share of the cost.

Sept. 4, 1947.

PART TWO

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PART TWO

MISCELLANEOUS INFORMATION, TABLES, FORMULAE, DIAGRAMS, AND CHARTS

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SECTION 2—DESIGN

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SIZE OF LETTERING TO BE USED IN PREPARING CONSTRUCTION PLANS

Title Sheet

For the Key Map showing the location of the project use ¼ inch capital letters for county, names, and title under map.

The names of Municipalities lettered with 3/16 inch high capital and lower case letters.

All other lettering on the Title Sheet should be ⅛ inch high capital and lower case letters.

Typical Sections

For Typical Sections use ⅛ inch high letters, except the titles should be 3/16 inch high capital letters.

Estimate of Quantities

The lettering of the Estimate of Quantities should be 3/16 inch high capitals for construction items and total quantities, all other notes ⅛ inch lower case letters.

Take Off Sheet

The take off of quantities should be lettered with ⅛ inch high letters, using capital letters for items of construction.

Plan and Profile

All lettering on the plan and profile sheet should be ⅛ inch letters, using capital letters for proper names.

For existing structures and special notes where space is needed use 3/32 inch high letters.

Cross-Sections

For the cross-section use ⅛ inch high letters.

Construction Details

The lettering on the details should be 3/16 inch high capital letters for detail titles and all other lettering should be ⅛ inch high letters.

Where it is impracticable to comply with above requirements the supervisor should be consulted and a practical solution worked out using these standards as a guide.

SIZE OF LETTERING TO BE USED ON PROPERTY PARCEL MAPS AND INDIVIDUAL PROPERTY MAPS

1. For municipalities, owners' names, names of streets, etc. preferable $^{3}/_{16}$ inch minimum ⅛ capitals of good weight to be used. Parcel number to be designated thus (5)

2. For owner's name, parcel number and parcel areas use not less than ⅛ inch high capital letters of good parcel number to be designated thus (5)

3. Owners of property not affected should be ⅛ inch high letters of lighter weight.

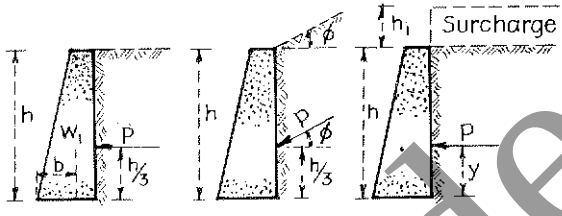
4. Set data should be not less than $^{3}/_{32}$ inch high lettering of good weight. Preferably ⅛ inch if space is available.

5. For hand lettered titles of General Property Parcel Maps use printed title from an approved plan as a guide.

6. Titles of Individual Property Maps or maps supplemental to the General Property Parcel Map should emphasize Route and Section and parcel numbers and the size of lettering used should not be less than ⅛ inch high of heavy weight. All other lettering in the title should be lighter although of the same size or larger.

GRAVITY RETAINING WALLS

Formulae



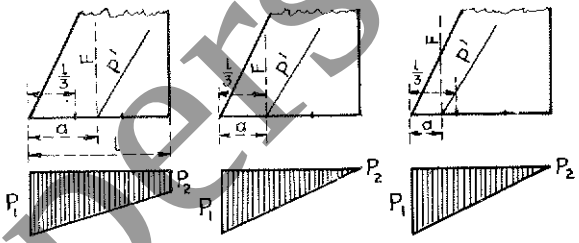
Horizontal Surcharge | Sloping Surcharge | Loaded Surcharge

$P = \frac{1}{2} w h^2 \frac{1-\sin\phi}{1+\sin\phi}$ $P = \frac{1}{2} w h^2 \cos\phi$ $P = \frac{1}{2} w h (h+2h_1) \frac{1-\sin\phi}{1+\sin\phi}$

w = weight of filling per C.F.

$y = \frac{h^2 + 3hh_1}{3(h+2h_1)}$

Foundation Pressures:



Resultant in middle third	Resultant at edge of middle third	Resultant outside middle third
$P_1 = (4l-6a)\frac{F}{l^2}$	$P_1 = \frac{2F}{l}$	$P_1 = \frac{3F}{3a}$
$P_2 = (6a-2l)\frac{F}{l^2}$	$P_2 = 0$	$P_2 = 0$

When $a = \frac{l}{2}$ $P_1 = P_2 = \frac{F}{l}$

Overturning Moment $M = P \times h/3$ and $P \times y$

Resisting Moment $M_1 = b \times W_1$ (weight of wall)

Sliding Force = P

Resistance to Sliding $Rs = W_1 \times .5$ Coeff.

NON-PASSING SIGHT DISTANCE

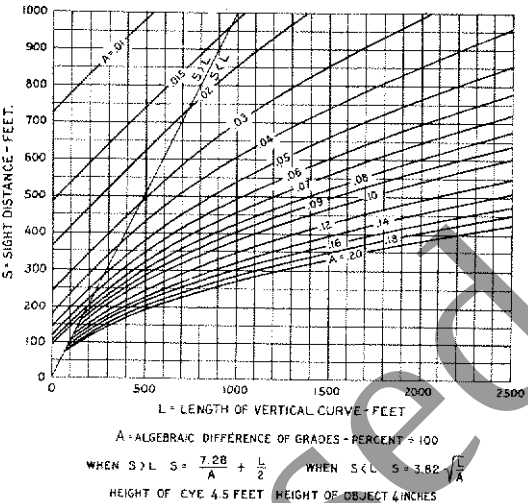
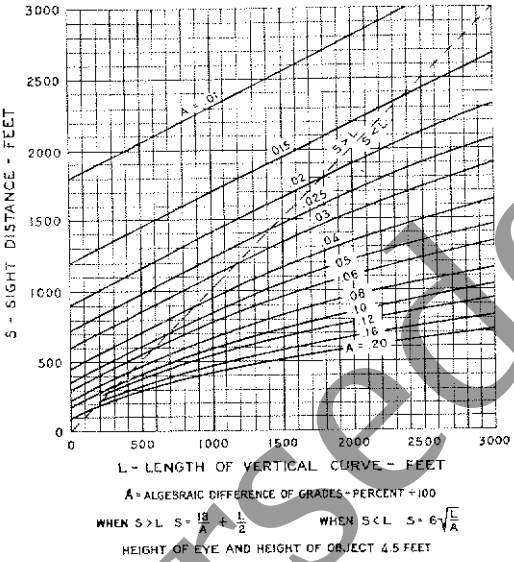


FIGURE 3
NON-PASSING SIGHT DISTANCE
RELATION BETWEEN SIGHT DISTANCE, HIGHWAY GRADES AND LENGTH OF VERTICAL CURVE

The sight distance at every point on a highway should be as long as possible and shall be at least as great as the following non-passing minimum sight distances:

Assumed Design Speed of Highway	Minimum Non-Passing Sight Distance
Miles per hour	Feet
30	200
40	275
50	350
60	475
70	600

PASSING SIGHT DISTANCE



PASSING SIGHT DISTANCE
RELATION BETWEEN SIGHT DISTANCE, HIGHWAY GRADES AND LENGTH OF VERTICAL CURVE

On two-lane highways sections safe for passing shall be constructed at frequent intervals. The passing minimum sight distance for two-lane highways shall be as follows:

Assumed Design Speed of Highway	Minimum Passing Sight Distance	
	Desirable	Absolute
Miles per hour	Feet	Feet
30	600	500
40	1100	900
50	1600	1400
60	2300	2100
70	3200	2900

(From "A Policy On Sight Distance For Highways")
A.A.S.H.O.

TO BE USED ON 2 & 3 LANE HIGHWAYS ONLY

HEADLIGHT SIGHT DISTANCE

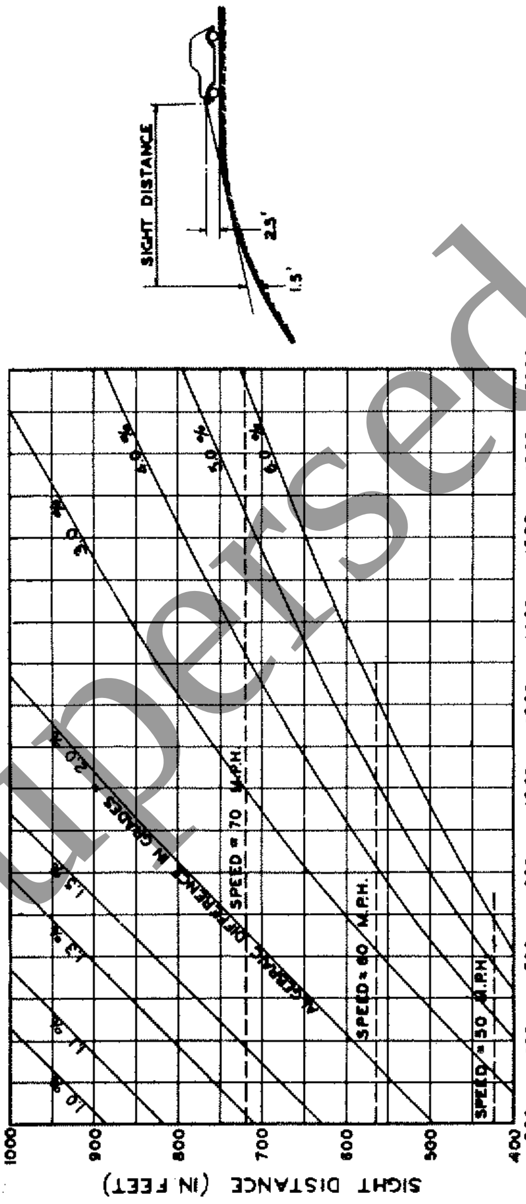


Fig. 8—Minimum Length of Vertical Curves on Summits (in feet). HEADLIGHT SIGHT DISTANCE

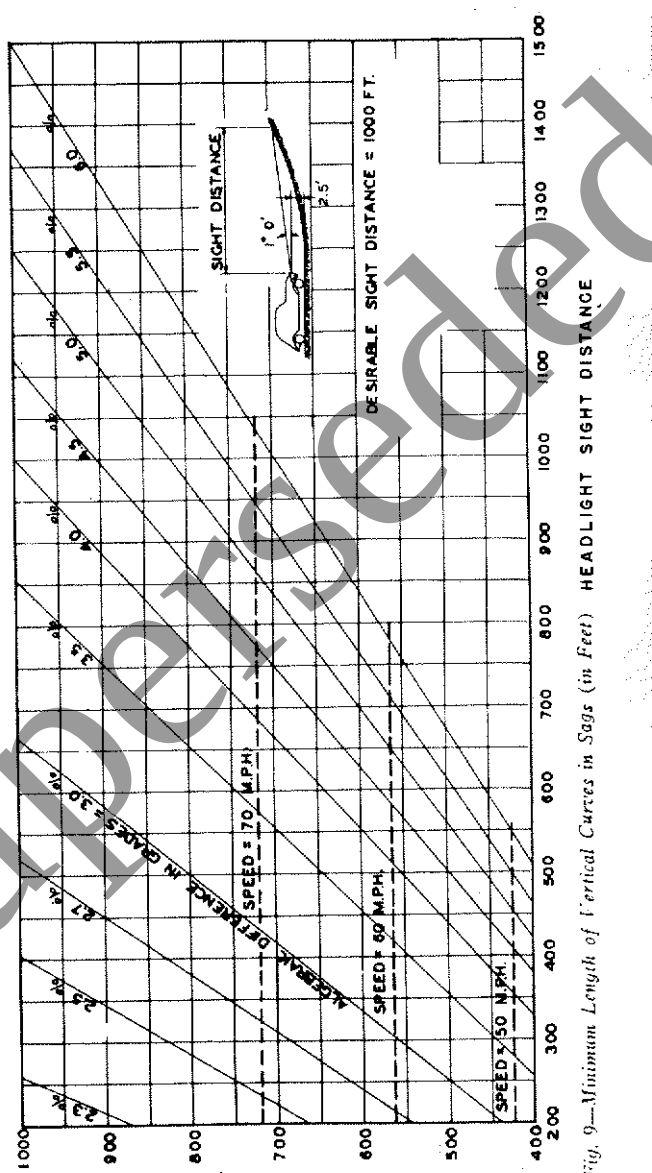


Fig. 9—Minimum Length of Vertical Curves in Sags (in Feet) **HEADLIGHT SIGHT DISTANCE**

SIMPLE BEAMS

WOOD BEAMS – Allowed Fibre Stress 1600 p.s.i
Allowed Shear Stress 100 p.s.i.
Allowed Bearing Stress 350 p.s.i.

These values are approximate and vary with different kinds of wood.

Depth of Beam = d inches – Width of Beam = b inches

To find required Section Modulus – $S = M \times 12 / 1600$

Choose a beam so that $bd^2/6$ is equal to or larger than S. Check that $3R/2bd$ is less than 100 p.s.i.

To find required bearing area – $R/350$ Sq. inches.

CONCRETE BEAMS –

Allowed fibre stress in reinforcement – 18000 p.s.i.
" compressive stress in Concrete – 1000 p.s.i.
" tension stress in Shear Reinf. – 16000 p.s.i.
" shear stress in plain Concrete – 60 p.s.i.
" bond stress between Conc & Reinf. – 150 p.s.i.
" bearing on Masonry – 700 p.s.i.

Width of beam = b inches

To find required distance from Top of beam to center of reinforcing $d = \sqrt{\frac{2M \cdot 12}{\cdot 27b\ 1000}} = 0.3\sqrt{\frac{M}{b}}$ ins.

To find required Area of steel reinf. $As = \frac{12M}{18000 \times 9d} = \frac{M}{1350d}$ Sq. ins. To find shear stress $S = \frac{R}{9bd}$

If S is less than 60 p.s.i. no shear reinf. is needed.

If S is between 60 & 150 p.s.i. find V_1 $\frac{S-60}{S} \times R$ (shear taken by Concrete)

Assume stirrup Area total cross-section area at all vertical legs of the stirrup = Av. Sq. inches

To find required stirrup spacing $C = \frac{16000 Av \times 9d}{V_1}$ in.

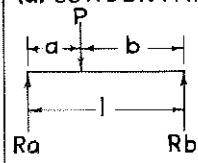
To find total circumference of all tension steel = O sq. in.

Check that Bond stress $U = \frac{R}{.9d \times O}$ is less than 150 p.s.i. To find required bearing area on Masonry $\frac{R}{700}$ sq. in.

SIMPLE BEAMS

To Find Moment (M) in Foot lbs. and Reactions (R) in lbs.

(a) CONCENTRATED LOADS – P = lbs.



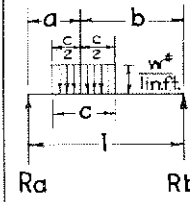
a, b & l = Feet

$$M = \frac{Pab}{l}\ ;\ Rb = \frac{Pa}{l}\ ;\ Ra = \frac{Pb}{l}$$

for load in Center – $a = b = \frac{1}{2}$

$$M = \frac{Pl}{4}\ ;\ Ra = \frac{P}{2} = Rb$$

(b) PARTLY DISTRIBUTED LOAD



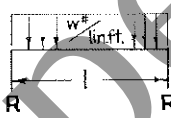
w = lbs. per lin.ft. ; a, b, c & l in Feet

$$M = \frac{wcab}{l} - \frac{wc^2}{8}\ ;\ Ra = \frac{wcb}{l}\ ;\ Rb = \frac{wca}{l}$$

for load in Center – $a = b = \frac{1}{2}$

$$M = \frac{wcl}{4} - \frac{wc^2}{8}\ ;\ Ra = \frac{wc}{2} = Rb$$

(c) UNIFORMLY DISTRIBUTED LOAD



w = lbs. per lin.ft. ; l = Feet

$$M = \frac{wl^2}{8}\ ;\ R = \frac{wl}{2}$$

TO FIND THE REQUIRED BEAM SIZE

Steel Beams: Allowable fibre Stress 18000* p.s.i.

Allowable shear stress 11000* p.s.i.

Allowable Bearing on Masonry 700* p.s.i.

To Find required Section Modulus $S = M \times 12 / 18000$

Look up beam with this or larger S in hand book

Find Web Area (Web thickness × height of beam) = Aw sq.in

Check that R/Aw is less than 11000* p.s.i.

To Find required bearing area on Masonry = R/700 Sq. in.

NEW JERSEY STATE HIGHWAY DEP'T. RAINFALL INTENSITY-FREQUENCY CURVES

Based on Charts in U.S.D.A. Misc. Pub. No. 204 by David L. Yarnell

To show conditions in central Jersey. Results for North Jersey may be reduced up to 10%, while for South Jersey may be increased up to 10% of the rates indicated.

NOTE: Where the time of concentration for a given area (critical time) is 15 min. The hourly rate for that period to be expected in Central Jersey once in 2 years is 3.5 ins., once in 5 years is 4.1 ins., once in 10 years is 4.85 ins. etc.

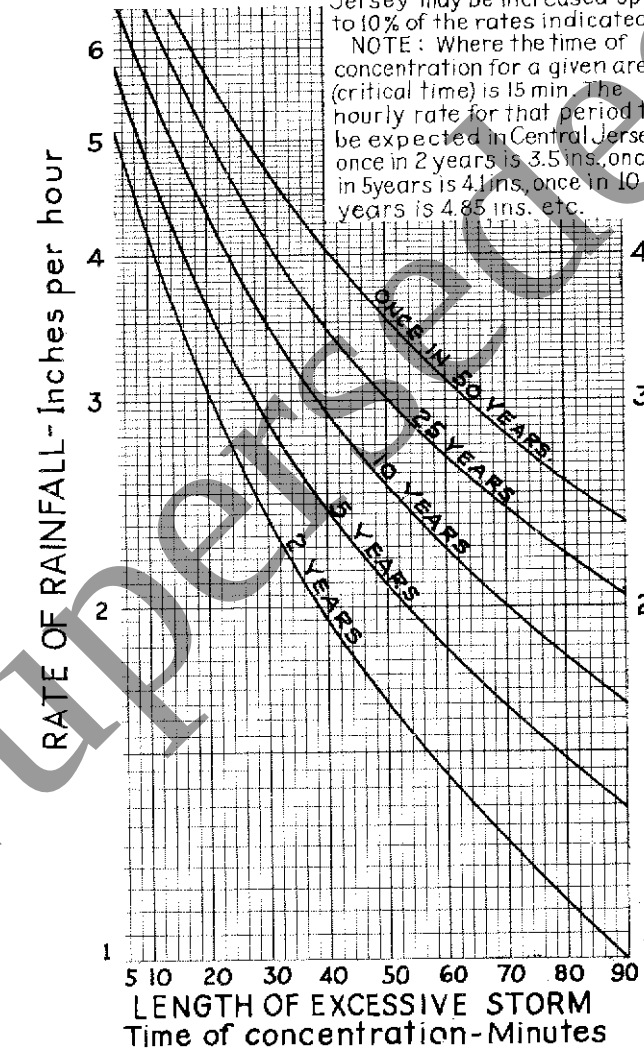
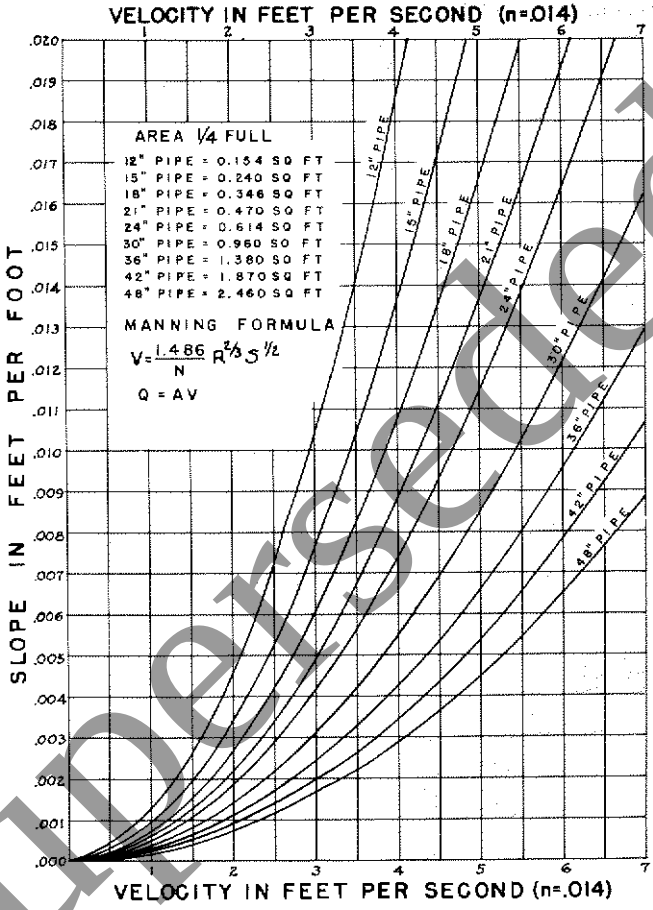


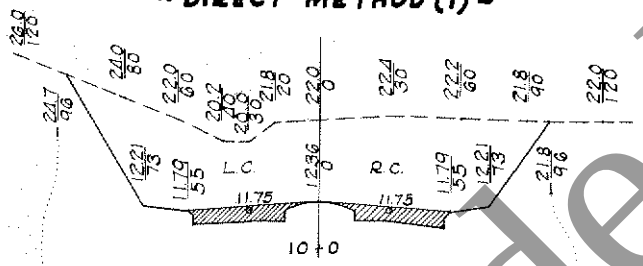
TABLE OF SUGGESTED VALUES FOR RUN-OFF FACTORS

Type of Surface	Min.	Max.
Pavements, Concrete or Bit. Concrete	0.75	0.90
Pavements, Bit. Macadam or Surf. Tr.	0.65	0.80
Pavements, Gravel, Macadam, etc. . .	0.25	0.60
Sandy soil, cultivated or light growth	0.15	0.30
Sandy soil, woods or heavy brush . . .	0.10	0.25
Loams, aver., cult. or light growth . .	0.20	0.40
Loams, aver., woods or heavy brush	0.15	0.30
Gravel, bare or light growth	0.20	0.40
Gravel, woods or heavy brush	0.15	0.35
Clay soils, bare or light growth	0.35	0.75
Clay soils, woods or heavy growth . .	0.25	0.60
City business sections	0.60	0.80
Dense residential areas	0.50	0.70
Suburban, normal residential areas . .	0.35	0.60
Rural areas, parks, golf courses	0.15	0.30

In applying the above factors to any given case, consideration must be given to the desirability or necessity of designing for maximum conditions. Where the design is to be adequate for a certain period without flooding under extreme conditions, such as when the ground is frozen and there is no infiltration, the maximum factor or perhaps greater should be used. For normal conditions, the designing factor should be determined from a careful study of the area both as of the present and for a probable change or development within a period of about 25 years. It is also advisable to refer to any soil maps or record of borings which may be available to determine the type of underlying material. In many cases, it will be desirable to combine two or more factors as listed to get the best result, as the use of good judgement on the part of the designer is most essential.


VELOCITY IN FEET PER SECOND (n=.014)
SLOPE IN FEET PER FOOT
VELOCITY IN FEET PER SECOND (n=.014)
AREA 1/4 FULL
12" PIPE = 0.154 SQ FT
15" PIPE = 0.240 SQ FT
18" PIPE = 0.346 SQ FT
21" PIPE = 0.470 SQ FT
24" PIPE = 0.614 SQ FT
30" PIPE = 0.960 SQ FT
36" PIPE = 1.380 SQ FT
42" PIPE = 1.870 SQ FT
48" PIPE = 2.460 SQ FT
MANNING FORMULA
V=1.486/N R^2/3 S^1/2
Q = AV
12" PIPE
15" PIPE
18" PIPE
21" PIPE
24" PIPE
30" PIPE
36" PIPE
42" PIPE
48" PIPE

CALCULATING MACHINE COMPUTATION CROSS SECTION END AREAS ~ DIRECT METHOD (1) ~



NOTE: INDICATION OF THIS FIGURE IS OF GREAT VALUE TO CONTRACTOR

PLOT X-SECTIONS AND TEMPLATES TO A SUITABLE SCALE SHOWING PROFILE GRADE ELEVATIONS; (SEE SECTION ABOVE). LIST ELEVATIONS & OFFSETS AS INDICATED BELOW; (FOR COMPUTERS CONVENIENCE ONLY-NOT TO BE SUBMITTED). AFTER PRACTICE AND FAMILIARITY WITH METHOD, COMPUTER SHOULD OMIT TABULATION, AND CALCULATE AREAS DIRECT FROM CROSS SECTIONS BY MACHINE.

IN EACH HALF SECTION, START & END WITH UPPER ELEVATION & OFFSET AT OR NEAREST THE ℄. LIST CLOCKWISE IN LEFT HALF, & COUNTER-CLOCKWISE IN RIGHT HALF. IN PART CUT & PART FILL SECTIONS, LIST ALL CUT AREAS SEPARATELY FIRST. A CONSTANT, (HATCHED AREA), MAY BE COMPUTED TO ELIMINATE SEVERAL MULTIPLICATIONS, AND IS TO BE ADDED IN CUTS, OR SUBTRACTED IN FILLS, ON SIMPLE SECTIONS.

TABULATION - SHOWING OPERATIONS

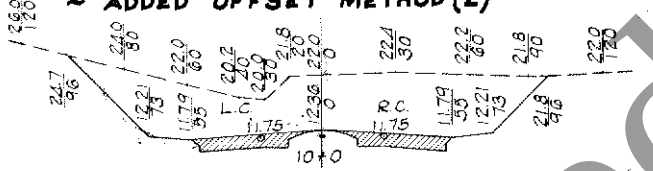
10+0 L.C. $\frac{22.0}{0}\ \frac{12.36}{0}\ \frac{11.79}{55}\ \frac{12.21}{73}\ \frac{24.7}{96}\ \frac{24.0}{80}\ \frac{22.0}{60}\ \frac{20.2}{40}\ \frac{20.0}{30}$

$\frac{21.8}{20}\ \frac{22.0}{0} = \frac{1630.02}{2} = 815.01 + 75.6 = 890.61'$

SUB AREA — CONSTANT — SUB-TOTAL AREA

FOR MACHINE COMPUTATION OF ABOVE LISTING, MULTIPLY ALONG THE MARKED DIAGONALS LEAVING THE PRODUCTS ON THE MACHINE TO BE ADDED. AT THE END OF THE RUN, START BACK MULTIPLYING ALONG THE UNMARKED DIAGONALS. USING THE MINUS KEY OR LEVER, SUBTRACTING THE PRODUCTS. THE REMAINDER ON THE LOWER DIAL IS THE DOUBLE AREA.

CALCULATING MACHINE COMPUTATION OF CROSS SECTION END AREAS ~ ADDED OFFSET METHOD (2) ~



PLOT X-SECTIONS AND TEMPLATES TO A SUITABLE SCALE SHOWING PROFILE GRADE ELEVATIONS. (SEE SECTION ABOVE). LIST ELEVATIONS & OFFSETS AS INDICATED BELOW. (FOR COMPUTERS CONVENIENCE ONLY - NOT TO BE SUBMITTED). AFTER PRACTICE AND FAMILIARITY WITH METHOD, COMPUTER SHOULD OMIT TABULATION AND CALCULATE AREAS DIRECT FROM CROSS SECTIONS BY MACHINE.

IN EACH HALF SECTION, START & END WITH UPPER ELEVATION & OFFSET AT OR NEAREST THE ℄. LIST CLOCKWISE IN LEFT HALF, & COUNTER-CLOCKWISE IN RIGHT HALF. IN PART CUT & PART FILL SECTIONS, LIST ALL CUT AREAS SEPARATELY FIRST. A CONSTANT, (HATCHED AREA), MAY BE COMPUTED TO ELIMINATE SEVERAL MULTIPLICATIONS, AND IS TO BE ADDED IN CUTS, OR SUBTRACTED IN FILLS, ON SIMPLE SECTIONS.

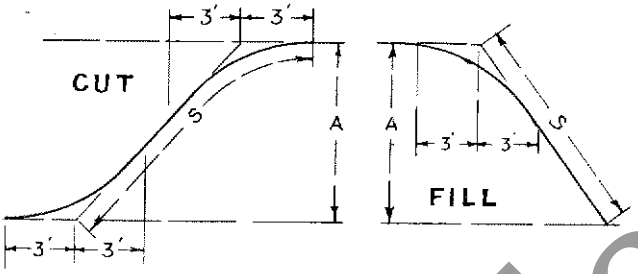
OFFSET	ADDED OFFSET	ELEV.
10+0 L.C.		
0	0	22.0'
0	55	12.36
55	128	11.79
73	169	12.21
96	176	24.7'
80	40	24.0'
60	100	22.0'
40	70	20.2'
30	30	20.0'
20	20	21.8'
0		22.0'

ADD EACH OFFSET TO THE OFFSET BELOW AND PLACE THE SUM OPPOSITE THE UPPER ONE OF ADDED OFFSETS, AS INDICATED.

1630.02
2
815.01
+75.6
890.61 sq'

FOR MACHINE COMPUTATION, PLACE & LEAVE 1ST. ELEV. ON UPPER DIAL OF MACHINE. PLACE 1ST. ADDED OFFSET ON KEYBOARD & CRANK UNTIL THE 2ND. ELEV. APPEARS ON UPPER DIAL. STILL WITHOUT CLEARING MACHINE, PLACE 2ND. ADDED OFFSET ON KEYBOARD & CRANK TO THE 3RD. ELEV. CONTINUE THUS TO LAST ELEV. (WHEN 1ST. ADDED OFFSET IS 0, THE 2ND. ELEV. MAY BE PLACED DIRECTLY ON THE UPPER DIAL.) THE REMAINDER ON THE LOWER DIAL IS THE DOUBLE AREA.

ADDED DISTANCE METHOD (3) IS THE SAME AS (2) EXCEPT THAT OFFSETS R.& L. OF ℄ ARE CHANGED TO DISTANCES FROM A BASE LINE AT OR OFF ONE OF THE EXTREMITIES OF THE FULL SECTION.



DISTANCES TO BE ADDED TO BEGINNING OF SLOPE IN COMPUTING TOPSOIL AREAS

S = Slope Distance to be added, including roll.

A = Vertical Distance between top and bottom of slope.

1½:1	In Cuts	S = 1.80 A + 2.6′
	In Fills	S = 1.80 A — 0.2′
1¾:1	In Cuts	S = 2.02 A + 2.6′
	In Fills	S = 2.02 A — 0.2′
2:1	In Cuts	S = 2.24 A + 2.6′
	In Fills	S = 2.24 A — 0.2′
3:1	In Fills	S = 3.16 A — 0.1′
4:1	In Fills	S = 4.12 A
5:1	In Fills	S = 5.10 A
6:1	In Fills	S = 6.08 A

CLASS A DESIGN

(Not applicable to Freeways and Parkways)

General Notes: These are minimum standards. Use greater when feasible (except do not vary design speed). When not considered feasible to provide minimum standards submit to Engineer of Surveys and Plans.

Dual roadway construction shall be utilized or the roadway shall be designed for stage construction with initial roadway located off center on adequate width R.O.W. in order that highway may be converted to dual type in future. Design shall include the separation of all grades either initially or in future.

At junction area where highways of different class join, effect gradual change in design standards by use of straight line variation in the standards. In the variation area, the desirable difference in operating speeds on adjacent curves (based on .1 friction) should not exceed 5 miles per hour.

For high speed direct connection interchanges use main roadway standards as desirable minimum.

I. Design Speed

(A) Main Roadways

(1) "Rural" 103 feet per second.

(2) "Urban" 88 feet per second.

Urban sections to be designated without relation to Urban Areas as set up for Federal program, but shall be based on density of buildings and industrial faeilities which will limit alignment.

(B) Ramps

Radius in Feet	Design Speed M.P.H.
100	20
150	25
200	30
300	35
400	40
500	45

II. Alignment

(A) Main Roadways

(1) Generally use the flattest possible curvature.

(a) Rural, minimum radius 3000 feet.

(b) Urban, minimum radius 1600 feet.

(2) Minimum length of curve 600 feet (including transitions)

(3) Minimum desirable distance between reversed curves.

(a) Rural, 1000 feet.

(b) Urban, 800 feet.

(4) Minimum desirable distance between same direction curves 2500 feet, when the tangent and part of both curves can be seen by the driver. In such cases "broken back" curves with less than 2500 feet between, to be connected with flat curve.

(B) Ramps and Approaches

(1) On exits from main roadway use "spiralled" approach to minimum desirable radius of 125 feet. See attached diagram for deceleration lane turnout.

(2) Minimum distance between reversed curves on ramps to depend on runout distance for super-elevation.

III. Grades

(A) Maximum Grades—Main Roadways

(1) Mountainous country.
3% maximum. 4% may be used for short distances.

(2) Hilly country.
3% maximum

(3) Rolling country.
3% maximum

If more direct route or improvement alignment

is feasible by using greater grades refer to Engineer of Surveys and Plans.

Note. Maximum desirable grade, 2%, all cases.

(B) Maximum Grades—Ramps
(1) Upgrade 7%, desirable maximum 5%.
(2) Downgrade 5%.

(C) Minimum grades
0.5%.
In flat country where difficult, refer to Engineer of Surveys and Plans.

IV. Vertical Curves
Minimum length of vertical curves on main roadways 600 feet except as follows:

(A) Algebraic difference in grades 2%, minimum V.C. = 600 feet.

(B) Algebraic difference in grades 1½%, minimum V.C. = 500 feet.

(C) Algebraic difference in grades 1%, minimum V.C. = 400 feet.

(D) Where gutter drainage is difficult, submit report to Engineer of Surveys and Plans.

(E) For opposite direction grades when (a) distance between vertical curves is 600 feet or less, or (b) entire length of V.C. and 600 feet of both tangents cannot be seen by driver, minimum length of V.C. in Stations to be equal to twice the Algebraic difference in grades in per cent.

V. Superelevation

(A) Main Roadways

Radius in Feet	Superelevation in %
1600	5.0
1800	4.5
2000	4.1
2200	3.8
2400	3.6
2600	3.4

2800	3.2
3000	3.0
3200	3.0
3400	2.8
3500	2.8
3600	2.6
3800	2.4
4000	2.2
4500	1.8
5000	1.5
5500	1.3
6000	1.2
6500	1.0
7000 to 10,000	1.0
over 10,000	No superelevation

(B) Ramps and Approaches

(1) Maximum superelevation 8% except for upgrade onbound which shall have maximum superelevation of 6%.

(2) Minimum desirable superelevation on 500 foot radius curves or sharper 5%.

(3) Rate of change of cross slope should not exceed 2% per second of time for the design speed.

(4) Changes in transverse grades should not exceed 2% per lane.

VI. Transition Curves

(A) Main Roadways

Radius in Feet	Desirable Minimum Length of Transition
1600 to 1800	300′
1800 to 2200	250′
2200 to 3000	200′
3000 to 3500	200′
Over 3500	No transition curve

(B) Ramps

Transition curves to be omitted in general except at

(1) deceleration lane turnout (see at-

tached diagram).

(2) at high speed direct connection interchanges use main roadway standards as desirable minimum.

VII. Sight Distance—Main Roadways

(A) Daylight—Non-passing

(1) "Rural", minimum of 600 feet based on height of eye at 4½ feet to an object 4 inches high. Provide more when feasible.

(2) "Urban", minimum of 475 feet based on height of eye at 4½ feet to an object 4 inches high.

(B) Daylight—Passing Sight Distance

(1) If stage construction is used, 2 and 3 lane roads (initial construction) should have passing sections at frequent intervals (3 lane roads not normally constructed).

(2) The minimum passing sight distance shall be as given in "A Policy on Sight Distance." The design speed should be selected so as to be adequate until such time as the road is dualized.

(3) Data on non-passing areas shall be furnished to the Maintenance Division.

(4) Where 2 and 3 lane roads are utilized, design shall be based on stage construction for ultimate conversion to dualization (3 lane roads not normally constructed).

(C) Night—Head Lamp

(1) Where feasible provide minimum of 700 feet (desirable 1000 feet at sags)—Modify where horizontal curvature reduces visibility, in which case provide distance permitted by such curvature.

(2) Head lamp sight distance not ap-

plicable on adequately illuminated highways.

VIII. Sight Distance—Ramp & Approaches

Minimum sight distance $= 4.4V + \frac{V^2}{6}$

Sight distance shall be based on height of eye at 4½ feet to an object 4½ feet high.

IX. Acceleration and Deceleration Lanes. See attached diagrams.

GEOMETRIC DESIGN STANDARDS CLASS B HIGHWAYS

(Not applicable to Freeways and Parkways) General Notes: These are minimum standards. Use greater when feasible (except do not vary design speed). When not considered feasible to provide minimum standards submit to Engineer of Surveys and Plans.

At junction area where highways of different class join, effectuate gradual change in design standards by use of straight line variation in the standards. In the variation area, the desirable difference in operating speeds on adjacnt curves (based on .1 friction) should not exceed 5 miles per hour.

Class "B" Highways may be any of the types listed under item 3 of "Procedures Preliminary to Plan Preparation for State Highway Projects" dated December 24, 1946.

For high speed direct connection interchanges use main roadway standards as desirable minimum.

I. Design Speed

(A) Main Roadways
88 feet per second

(B) Ramps

Radius in Feet	Design Speed M.P.H.
100	20
150	25

200	30
300	35
400	40
500	45

II. Alignment

(A) Main Roadways

(1) Generally use the flattest possible curvature. Minimum desirable radius 3000 feet, absolute minimum radius 1600 feet.

(2) Minimum length of curve 400 feet including transitions.

(3) Minimum desirable distance between reversed curves 800 feet.

(4) Minimlm desirable distance between same direction curves 1500 feet, where the tangent and part of both curves can be seen by the driver. In such cases "broken back" curves with less than 1500 feet between, to be connected with a flat curve.

(B) Ramps

(1) On exits from main roadway use "spiralled" approach to minimum desirable radius of 125 feet. See attached diagram for deceleration lane turnout.

(2) Minimum distance between reversed curves on ramps to depend on runout distance for superelevation.

III. Grades

(A) Maximum Grades—Main Roadways

(1) Mountainous country.
4% desirable maximum. 6% may be used for short distances.

(2) Hilly country.
4% desirable maximum.

(3) Rolling country.
3% desirable maximum.

If more direct route is feasible by using

greater grades refer to Engineer of Surveys and Plans.

(B) Maximum Grades—Ramps

(1) Upgrade 7%, desirable maximum 5%.

(2) Downgrade 5%.

(C) Minimum grades 0.5%.

In flat country where difficult, refer to Engineer of Survey and Plans.

IV. Vertical Curves

Minimum length of vertical curves on main roadways 400 feet except as follows:

(A) Algebraic difference in grades 2% minimum V.C. = 300 feet.

(B) Algebraic difference in grades 1%, minimum V.C. = 200 feet.

(C) For opposite direction grades: When (a) distance between vertical curves is 400 feet or less or (b) entire length of V.C. and 400 feet of both tangents cannot be seen by the driver, minimum length of V.C. is Stations to be equal to twice the Algebraic difference in grades in per cent.

V. Superelevation

(A) Main Roadways

Radius in Feet	Superelevation in %
1600	5.0
1800	4.5
2000	4.1
2200	3.8
2400	3.6
2600	3.4
2800	3.2
3000	3.0
3200	3.0
3400	2.8
3500	2.8
3600	2.6
3800	2.4

4000	2.2
4500	1.8
5000	1.5
5500	1.3
6000	1.2
6500	1.0
7000 to 10,000	1.0
Over 10,000	No superelevation

(B) Ramps

(1) Maximum superelevation 8% except for upgrade onbound which shall have maximum superelevation of 6%.

(2) Minimum desirable superelevation on 500 foot radius curves or sharper 5%.

(3) Rate of change of cross slope should not exceed 2% per second of time for the design speed.

(4) Changes in transverse grades should not exceed 2% per lane.

(5) The difference in the two curb line profile gradients along the two edges of the pavement should not exceed 1%.

VI. Transition Curves

(A) Main Roadways

Radius in Feet	Desirable Minimum Length of Transition
1600 to 1800	300′
1800 to 2200	250′
2200 to 3000	200′
3000 to 3500	200′
Over 3500	No transition curve

(B) Ramps

Transition curves to be omitted in general except at

(1) deceleration lane turnout (see attached diagram.

(2) at high speed direct connection interchanges use main roadway standards as desirable minimum.

VII. Sight Distance—Main Roadways

(A) Daylight—Non-passing

Minimum of 475 feet based on height of eye at 4½ feet to an object 4 inches high.

(B) Daylight—Passing Sight Distance

(1) 2 lane roads

Minimum of 2300 feet based on height of eye at 4½ feet to an object 4½ feet high.

(2) 3 lane roads (not normally constructed)

Minimum of 1500 feet based on height of eye at 4½ feet to an object 4½ feet high.

(3) On two and three lane roads sections safe for passing shall be constructed at frequent intervals. Data on non-passing areas shall be furnished Maintenance Division.

(4) If stage construction is used, 2 and 3 lane roads (initial construction) should have passing sections at frequent intervals. The minimum passing sight distance shall be as given in "A Policy on Sight Distance". The design speed should be selected so as to be adequate until such time as the road is dualized.

(C) Night—Head Lamp

(1) Where feasible provide minimum of 560 feet (desirable 800 feet at sags) —Modify where horizontal curvature reduced visibility, in which case provide distance permitted by such curvature.

(2) Head lamp sight distance not applicable on adequately illuminated highways.

VIII. Sight Distance

Ramps

(A) Vertical Over Crests
Minimum of 250 feet based on height of eye at 4½ feet to an object 4½ feet high.

(B) Horizontal
250 feet minimum, 350 feet desirable minimum.

IX. Acceleration and Deceleration Lanes

(A) Right Turns
See attached diagrams.

(B) Left Turns
120′ min., plus taper of 250′ min., 300′ desirable.

GEOMETRIC DESIGN STANDARDS CLASS C HIGHWAYS

(Not applicable to Freeways and Parkways)
General Notes: These are minimum standards. Use greater when feasible (except do not vary design speed). When not considered feasible to provide minimum standards submit to Engineer of Surveys and Plans.

At Junction area where highways of different class join, effect gradual change in design standards by use of straight line variation in the standards. In the variation area the desirable difference in operating speeds on adjacent curves (based on .1 friction) should not exceed 5 miles per hour.

Class "C" highways may be any of the types listed under items 3 of "Procedures Preliminary to Plan Preparation for State Highway Projects," dated December 24, 1946.

For high speed direct connection interchanges use main roadway standards as desirable minimum.

DETAILED DESIGN STANDARDS

I. Design Speed

(A) Main Roadways
73 feet per second

(B) Ramps

Radius in Feet	Design Speed M.P.H.
100	20
150	25
200	30
300	35
400	40
500	45

II. Alignment

(A) Main Roadways

(1) Generally use the flattest possible curvature. Minimum desirable radius 1600 feet, absolute minimum radius 1000 feet.

(2) Minimum length of curve 400 feet (including transitions).

(3) Minimum desirable distance between reversed curves 600 feet.

(4) Minimum desirable distance between same direction curves 1000 feet where the tangent and part of both curves can be seen by the driver. In such cases "broken back" curves with less than 1000 feet between, to be connected with a flat curve.

(B) Ramps

(1) On exits from main roadway use "spiralled" approach to minimum desirable radius of 100 feet. See attached diagram for deceleration lane turnout.

(2) Minimum distance between reversed curves on ramps to depend on runout distance for superelevation.

III. Grades

At Underpasses grades may have to be less than maximum to give required sight distance under bottom of structure based on height of eye of 6′ and object 1.5′.

(A) Maximum Grades—Main Roadways

(1) Mountainous country.
5% desirable maximum. 6% may be used for short distances.

(2) Hilly country.
4% desirable maximum.

(3) Rolling country.
3% desirable maximum.

If more direct route is feasible by using greater grades refer to Engineer of Surveys and Plans.

(B) Maximum Grades—Ramps

(1) Upgrade 7%, desirable maximum 5%.

(2) Downgrade 5%.

(C) Minimum grades
0.5%.
In flat country where difficult, refer to Engineer of Surveys nad Plans.

IV. Vertical Curves

Minimum length of vertical curves on main roadways 300 feet except as follows:

(A) Algebraic difference in grades 2%, minimum V.C. = 250 feet.

(B) Algebraic difference in grades 1% minimum V.C. = 150 feet.

(C) For opposite direction grades, when (a) distance between vertical curves is 300 feet or less or (b) entire length of V.C. and 300 feet of both tangents cannot be seen by the driver, minimum length of V.C. in Stations to be equal 1½ times the difference in grades in per cent.

V. Superelevation

(A) Main Roadways

Radius in Feet	Superelevation in %
1000	6.0
1100	5.5
1200	5.0
1300	4.7
1400	4.4
1500	4.1
1600	3.8
1800	3.5
2000	3.2
2200	2.9
2400	2.6
2600	2.3
2800	2.0
3000	1.7
3200	1.4
3400	1.1
3600	1.0
3800	1.0
4000	1.0
Over 4000	None

(B) Ramps

(1) Maximum superelevation 8% except for upgrade onbound which shall have maximum superelevation of 6%.

(2) Minimum desirable superelevation on 500 foot radius curves or sharper 5%.

(3) Rate of change of cross slope should not exceed 2% per second of time for the design speed.

(4) Changes in transverse grades should not exceed 2% per lane.

(5) The difference in the two curb line profile gradients along the two edges of the pavement should not exceed 1%.

VI. Transition Curves

(A) Main Roadways

Radius in Feet	Desirable Minimum Length of Transition
1000 to 1600	350
1600 to 1800	300
1800 to 2200	250
2200 to 3000	200
Over 3000	No transition curve

(B) Ramps

Transition curves to be omitted in general except at

(1) deceleration lane turnout (see attached diagram).

(2) at high speed direct connection interchanges use main roadway standards as desirable minimum.

VII. Sight Distance—Main Roadways

(A) Daylight—Non-passing

Minimum of 350 feet based on height of eye at 4½ feet to an object 4 inches high.

(B) Daylight—Passing Sight Distance

(1) 2 lane roads

Minimum of 1600 feet based on height of eye at 4½ feet to an object 4½ feet high.

(2) 3 lane roads (Not normally Constructed).

Minimum of 1100 feet based on height of eye at 4½ feet to an object 4½ feet high.

(3) On two and three lane roads sections safe for passing shall be constructed at frequent intervals. Data on non-passing areas shall be furnished Maintenance Division.

(C) Night—Head Lamp

(1) Where feasible provide minimum of 450 feet (desirable 650 feet at sags) —modify where horizontal curva-

ture reduces visibility, in which case provide distance permitted by such curvature.

(2) Head Lamp sight distance not applicable on adequately illuminated highways.

VIII. Sight Distance

Ramps

(A) Vertical Over Crests

Minimum of 250 feet based on height of eye at 4½ feet to an object 4½ feet high.

(B) Horizontal

250 feet minimum, 350 feet desirable minimum.

IX. Acceleration and Deceleration Lanes

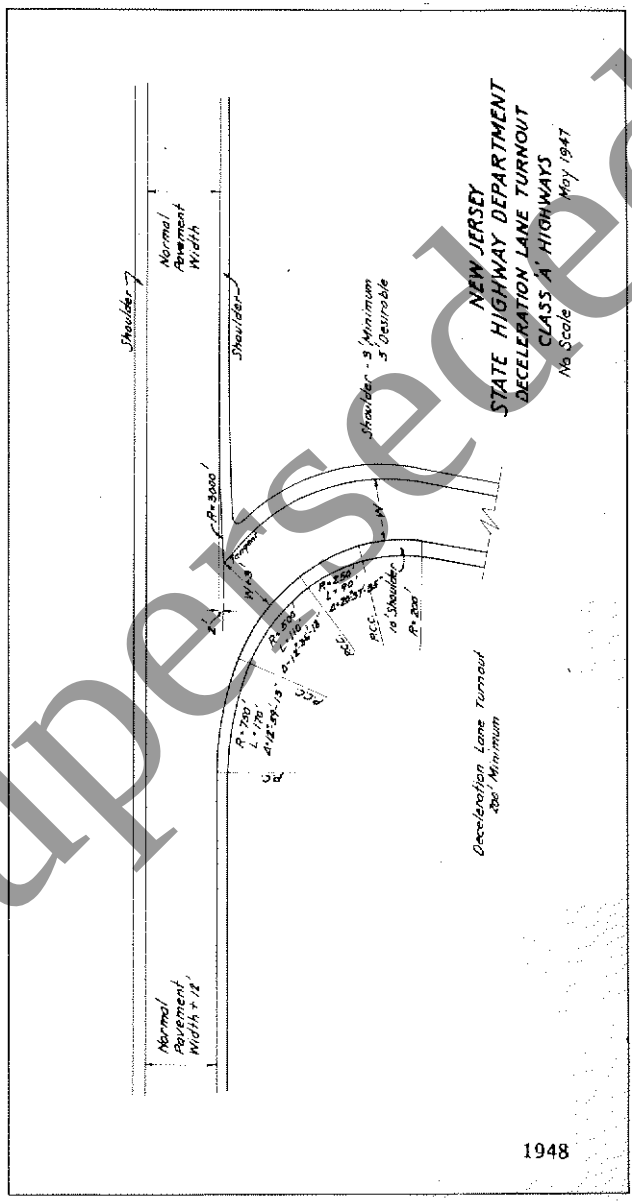
(A) Right Turns

See attached diagrams.

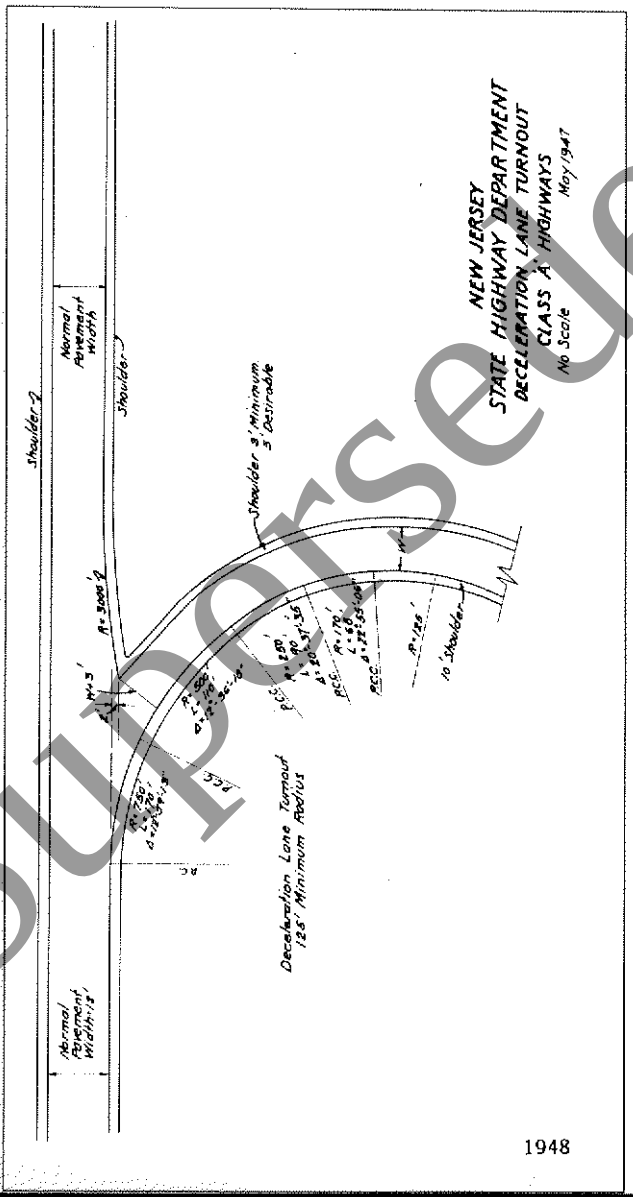
(B) Left Turns

120 feet minimum, plus taper of 250 feet minimum.
300 feet desirable.

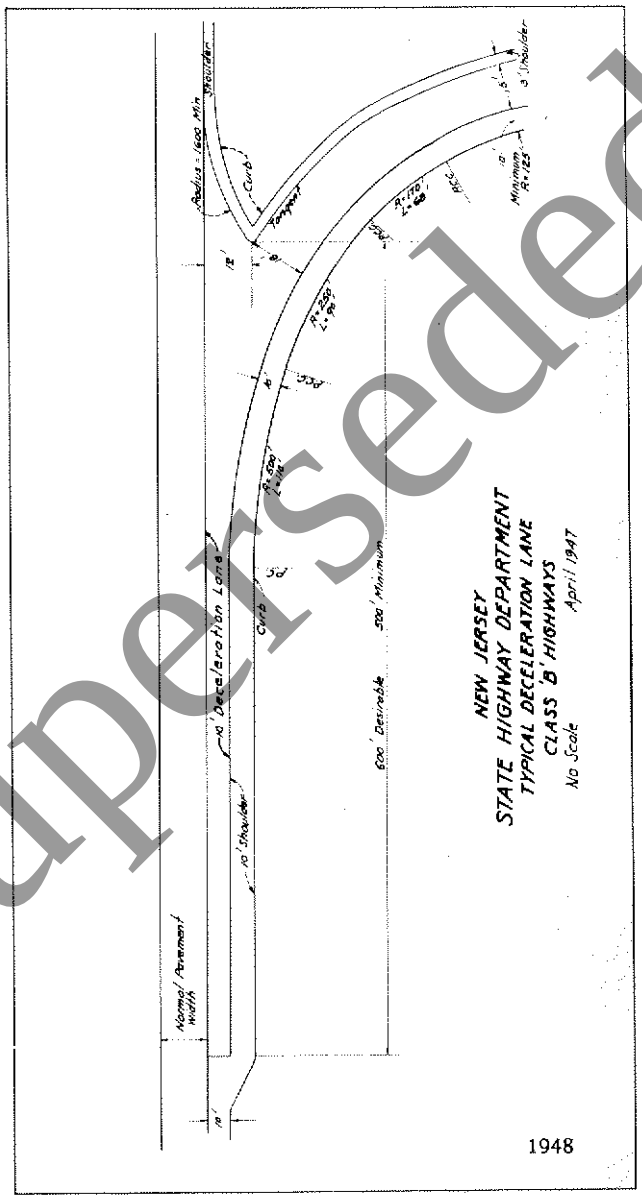
DECELERATION LANE TURNOUT
CLASS A HIGHWAYS



DECELERATION LANE TURNOUT
CLASS A HIGHWAYS



DECELERATION LANE CLASS B HIGHWAYS



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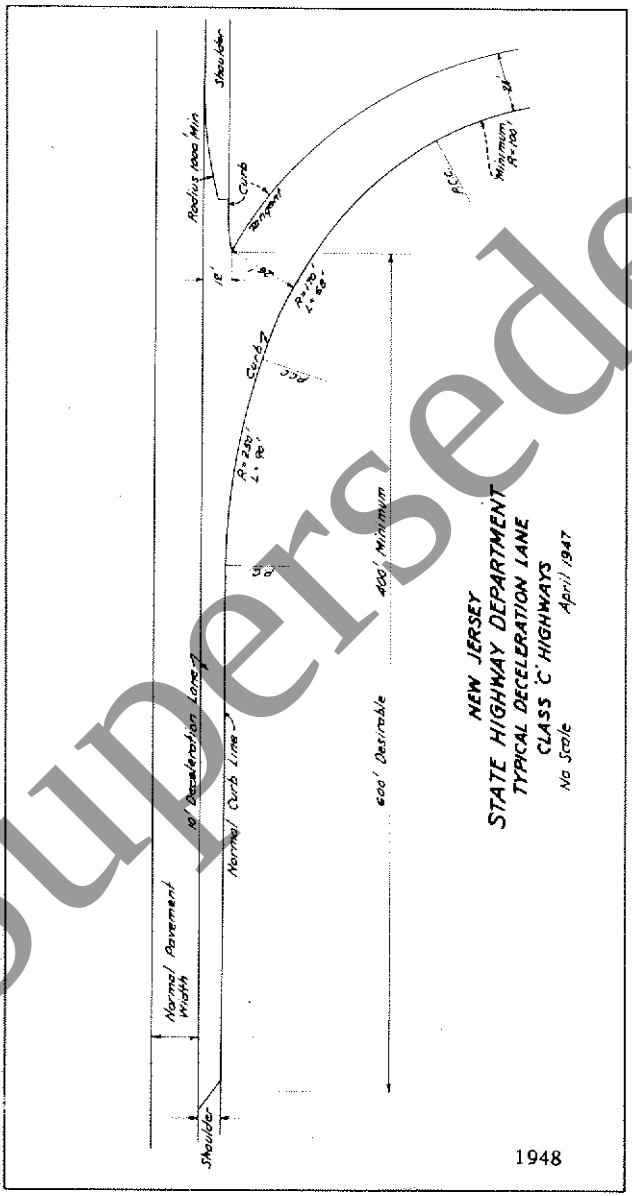
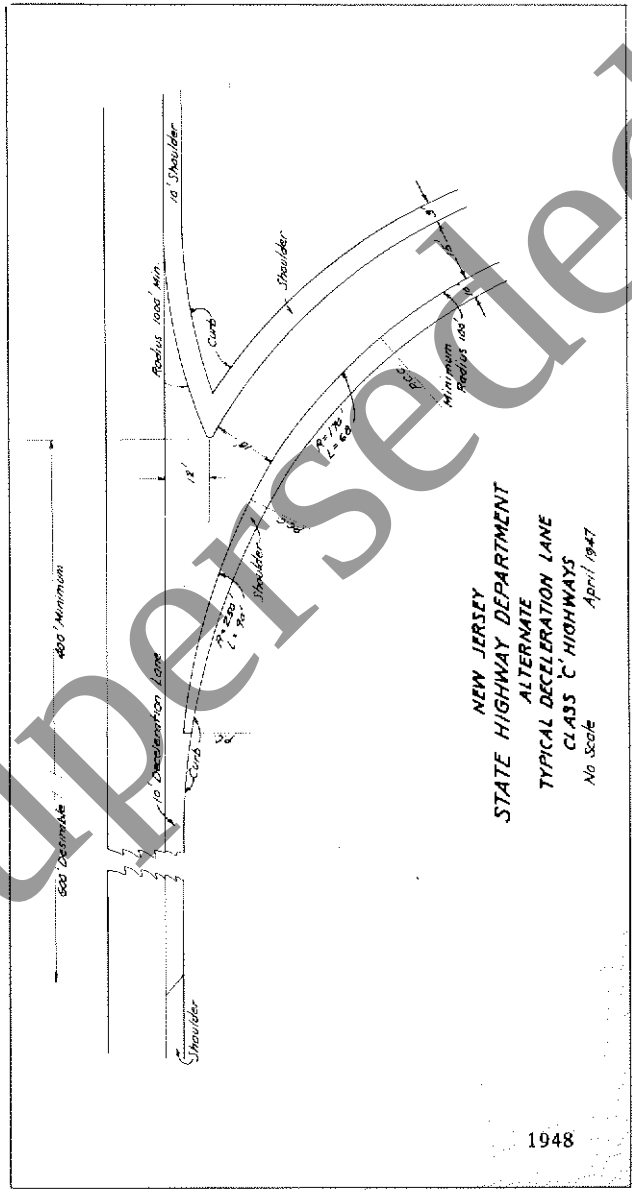
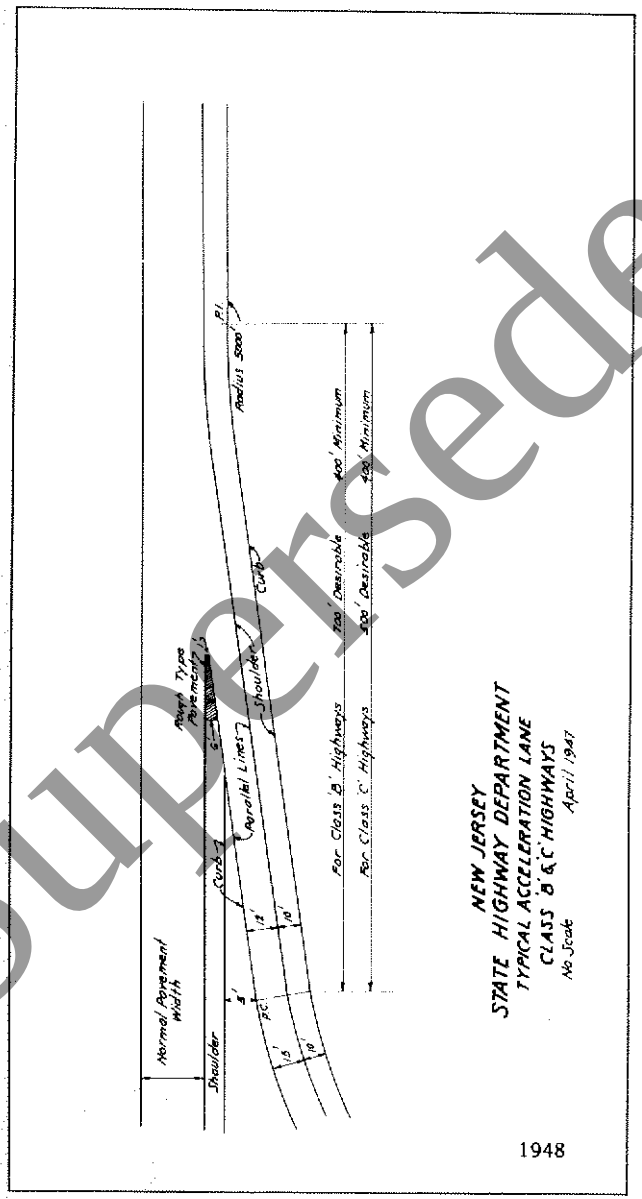
DECELERATION LANE CLASS C HIGHWAYS



ALTERNATE—DECELERATION LANE
CLASS C HIGHWAYS



ACCELERATION LANE CLASS B & C HIGHWAYS

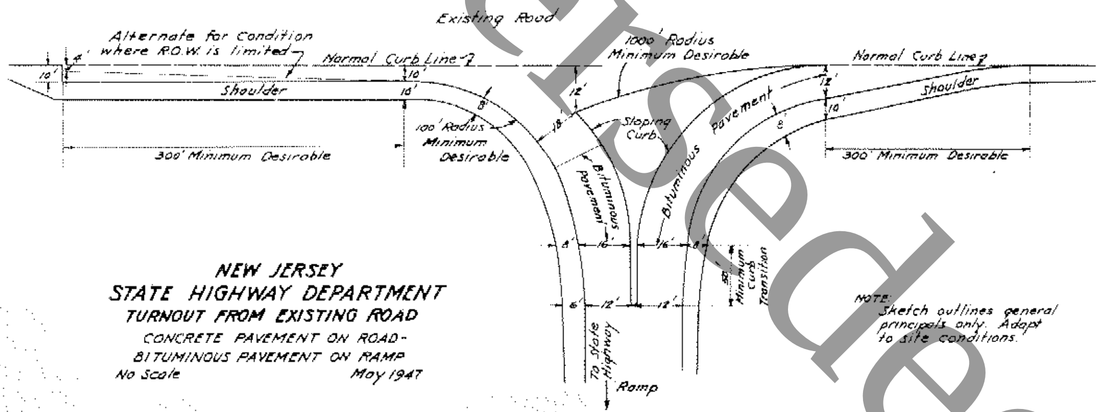


TURNOUT FROM EXISTING ROAD— CONCRETE PAVEMENT ON ROAD BITUMINOUS PAVEMENT ON RAMP

Acceleration and deceleration lanes may be omitted if—

(a) The 30th peak hour volume (one way) is less than 150 vehicles. The R.O.W. is to be acquired unless excessive costs are involved.

(b) Where the right-of-way is restricted and excessive costs are involved. When preliminary plans are submitted doubtful cases to be noted on prints with factors involved.

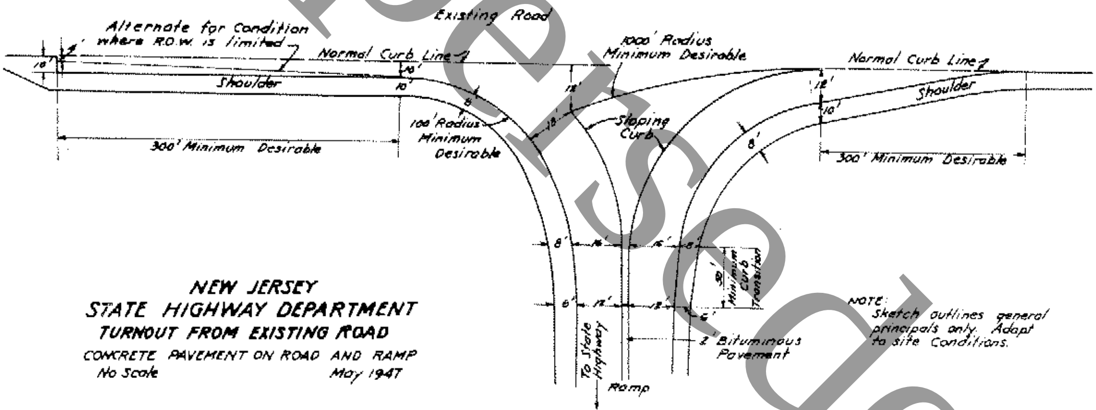


TURNOUT FROM EXISTING ROAD—CONCRETE PAVEMENT ON ROAD AND RAMP

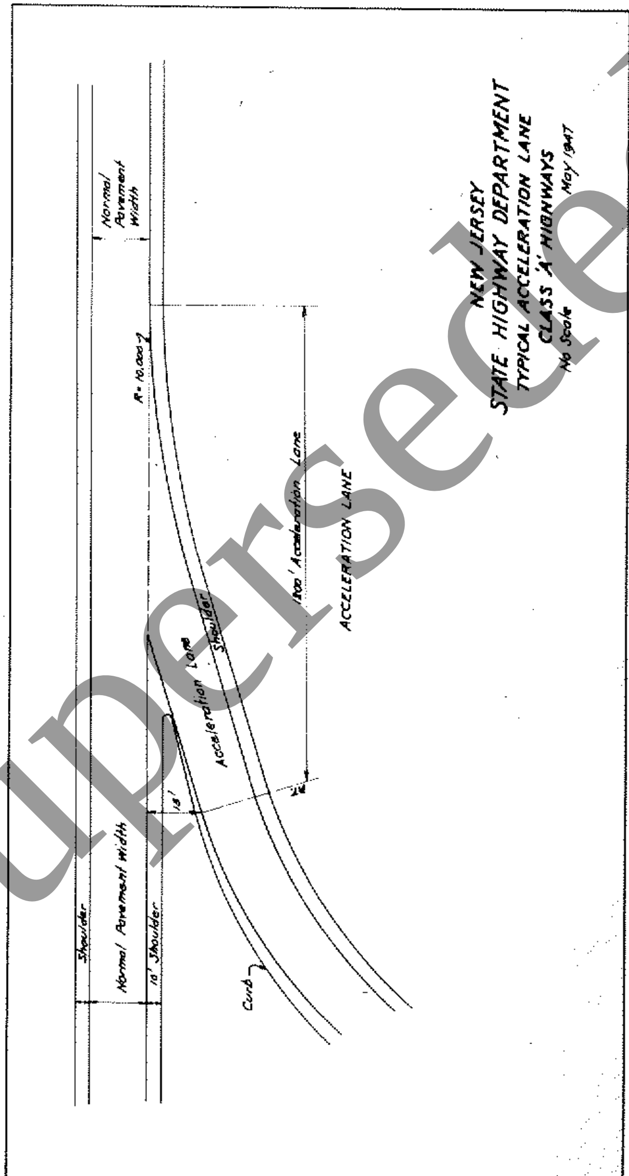
Acceleration and deceleration lanes may be omitted if—

(a) The 30th peak hour volume (one way) is less than 150 vehicles. The R.O.W. is to be acquired unless excessive costs are involved.

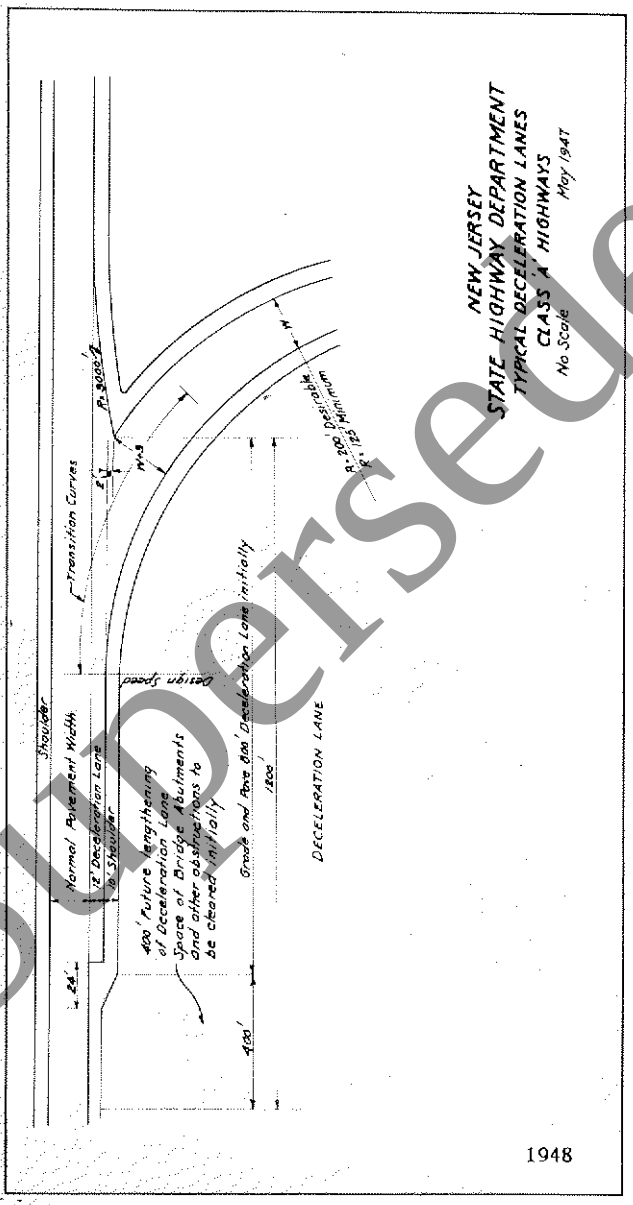
(b) Where the right-of-way is restricted and excessive costs are involved. When preliminary plans are submitted doubtful cases to be noted on prints with factors involved.



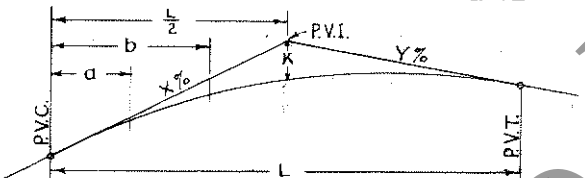
ACCELERATION LANE CLASS A HIGHWAYS



DECELERATION LANES CLASS A HIGHWAYS



VERTICAL CURVE FORMULAE



Formula for K

$$K = \frac{1}{8}(X-Y)\frac{L}{100}$$

$$K = \frac{1}{2}\left\{P.V.I\ Elev. - \left[\frac{P.V.C.\ Elev. + P.V.T.\ Elev.}{2}\right]\right\}$$

Proportioning K

$\left(\frac{a^2}{\left(\frac{L}{2}\right)^2}\right) \times K$: Correction to be applied to any distance from P.V.C. or P.V.T. to P.V.I.

Formula for Constant 'C'

$\frac{(X-Y)}{2L}$ The Algebraic difference of Grades per ft divided by 2 times Length.

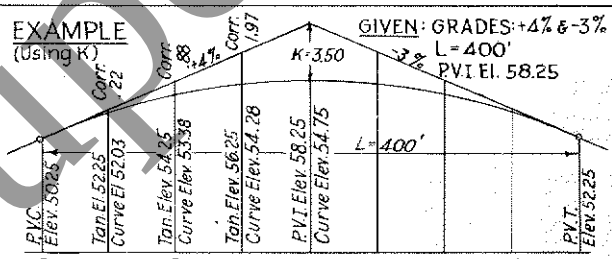
Application of Constant 'C'

$a^2 \times C$ Correction applied to any distance from P.V.C. or P.V.T. to P.V.I.

$\frac{L\,X}{X-Y}$ Distance in feet from P.V.C. to High (or Low) Point on Curve.

EXAMPLE
(Using K)

GIVEN: GRADES: +4% & -3%
L = 400'
P.V.I El. 58.25



Elev. P.V.C. = Elev. P.V.I. $-\left(\frac{L}{2} \times \frac{X}{100}\right)$ = 58.25 − (200 × .04) = 50.25

Elev. P.V.T. = Elev. P.V.I. $-\left(\frac{L}{2} \times \frac{Y}{100}\right)$ = 58.25 − (200 × .03) = 52.25

Find K: $\frac{1}{8}(X-Y)\frac{L}{100} = \frac{1}{8}[+4-(-3)]4 = 3.50$

Find Correction for 50': $\left(\frac{a^2}{\left(\frac{L}{2}\right)^2}\right) \times K = \frac{50^2}{200^2} \times 3.50 = 0.219$

Curve Elev. = Tan. Grade − Corr. ∴ Grade 8+50 = 52.25 − .219 = 52.03

FOR VERTICAL CURVES

FACTOR GIVEN BELOW × SQUARE OF DISTANCE FROM P.V.C. OR P.V.T. × "K" = CORRECTION TO BE APPLIED TO TAN FOR CURVE ELEVATION

Length of Vertical Curve (a)	Factor (b)	Length of Vertical Curve (a)	Factor (b)
100′	.000400	1450′	.00000190
150′	.000178	1500′	.00000177
200′	.000100	1550′	.00000166
250′	.000064	1600′	.00000156
300′	.0000444	1650′	.00000147
350′	.0000327	1700′	.00000138
400′	.0000250	1750′	.00000131
450′	.0000198	1800′	.00000123
500′	.0000160	1850′	.00000117
550′	.0000132	1900′	.00000111
600′	.0000111	1950′	.00000105
650′	.00000947	2000′	.00000100
700′	.00000816	2050′	.00000095
750′	.00000761	2100′	.00000091
800′	.00000625	2150′	.00000087
850′	.00000554	2200′	.00000083
900′	.00000494	2250′	.00000079
950′	.00000443	2300′	.00000076
1000′	.00000400	2350′	.00000072
1050′	.00000363	2400′	.00000069
1100′	.00000330	2450′	.00000067
1150′	.00000302	2500′	.00000064
1200′	.00000278	2550′	.00000062
1250′	.00000256	2600′	.00000059
1300′	.00000237	2650′	.00000057
1350′	.00000219	2700′	.00000055
1400′	.00000204	2750′	.00000053
		2800′	.00000051

DISTANCE "t" SQUARED FOR VERTICAL CURVES

Dist (t)	t^2	Dist (t)	t^2
(c)	(d)	(c)	(d)
25	625	725	525,625
50	2,500	750	562,500
75	5,625	775	600,625
100	10,000	800	640,000
125	15,625	825	680,625
150	22,500	850	722,500
175	30,625	875	765,625
200	40,000	900	810,000
225	50,625	925	855,625
250	62,500	950	902,500
275	75,625	975	950,625
300	90,000	1000	1,000,000
325	105,625	1025	1,050,625
350	122,500	1050	1,102,500
375	140,625	1075	1,155,625
400	160,000	1100	1,210,000
425	180,625	1125	1,265,625
450	202,500	1150	1,322,500
475	225,625	1175	1,380,625
500	250,000	1200	1,440,000
525	275,625	1225	1,500,625
550	302,500	1250	1,562,500
575	330,625	1275	1,625,625
600	360,000	1300	1,690,000
625	390,625	1325	1,755,625
650	422,500	1350	1,822,500
675	455,625	1375	1,890,625
700	490,000	1400	1,960,000

TABLE FOR VERTICAL CURVES UP TO 800 FT.

$C = \frac{\text{Alg. Diff. in Grades}}{\text{Length of Vert. Curve in Sta.}}$ D = Dist. from PVC or PVT

TANGENT OFFSET = C x V

D	V	D	V	D	V	D	V
1	.00005	51	.13005	101	.51005	151	1.14005
2	.00020	52	.13520	102	.52020	152	1.15520
3	.00045	53	.14045	103	.53045	153	1.17045
4	.00080	54	.14580	104	.54080	154	1.18580
5	.00125	55	.15125	105	.55125	155	1.20125
6	.00180	56	.15680	106	.56180	156	1.21680
7	.00245	57	.16245	107	.57245	157	1.23245
8	.00320	58	.16820	108	.58320	158	1.24820
9	.00405	59	.17405	109	.59405	159	1.26405
10	.00500	60	.18000	110	.60500	160	1.28000
11	.00605	61	.18605	111	.61605	161	1.29605
12	.00720	62	.19220	112	.62720	162	1.31220
13	.00845	63	.19845	113	.63845	163	1.32845
14	.00980	64	.20480	114	.64980	164	1.34480
15	.01125	65	.21125	115	.66125	165	1.36125
16	.01280	66	.21780	116	.67280	166	1.37780
17	.01445	67	.22445	117	.68445	167	1.39445
18	.01620	68	.23120	118	.69620	168	1.41120
19	.01805	69	.23805	119	.70805	169	1.42805
20	.02000	70	.24500	120	.72000	170	1.44500
21	.02205	71	.25205	121	.73205	171	1.46205
22	.02420	72	.25920	122	.74420	172	1.47920
23	.02645	73	.26645	123	.75645	173	1.49645
24	.02880	74	.27380	124	.76880	174	1.51380
25	.03125	75	.28125	125	.78125	175	1.53125
26	.03380	76	.28880	126	.79380	176	1.54880
27	.03645	77	.29645	127	.80645	177	1.56645
28	.03920	78	.30420	128	.81920	178	1.58420
29	.04205	79	.31205	129	.83205	179	1.60205
30	.04500	80	.32000	130	.84500	180	1.62000
31	.04805	81	.32805	131	.85805	181	1.63805
32	.05120	82	.33620	132	.87120	182	1.65620
33	.05445	83	.34445	133	.88445	183	1.67445
34	.05780	84	.35280	134	.89780	184	1.69280
35	.06125	85	.36125	135	.91125	185	1.71125
36	.06480	86	.36980	136	.92480	186	1.72980
37	.06845	87	.37845	137	.93845	187	1.74845
38	.07220	88	.38720	138	.95220	188	1.76720
39	.07605	89	.39605	139	.96605	189	1.78605
40	.08000	90	.40500	140	.98000	190	1.80500
41	.08405	91	.41405	141	.99405	191	1.82405
42	.08820	92	.42320	142	1.00820	192	1.84320
43	.09245	93	.43245	143	1.02245	193	1.86245
44	.09680	94	.44180	144	1.03680	194	1.88180
45	.10125	95	.45125	145	1.05125	195	1.90125
46	.10580	96	.46080	146	1.06580	196	1.92080
47	.11045	97	.47045	147	1.08045	197	1.94045
48	.11520	98	.48020	148	1.09520	198	1.96020
49	.12005	99	.49005	149	1.11005	199	1.98005
50	.12500	100	.50000	150	1.12500	200	2.00000

TABLE FOR VERTICAL CURVES UP TO 800 FT.

$C = \frac{\text{Alg. Diff. in Grades}}{\text{Length of Vert. Curve in Sta.}}$ D = Dist. from PVC or PVT

TANGENT OFFSET = C x V

D	V	D	V	D	V	D	V
201	2.02005	251	3.15005	301	4.53005	351	6.16005
202	2.04020	252	3.17520	302	4.56020	352	6.19520
203	2.06045	253	3.20045	303	4.59045	353	6.23045
204	2.08080	254	3.22580	304	4.62080	354	6.26580
205	2.10125	255	3.25125	305	4.65125	355	6.30125
206	2.12180	256	3.27680	306	4.68180	356	6.33680
207	2.14245	257	3.30245	307	4.71245	357	6.37245
208	2.16320	258	3.32820	308	4.74320	358	6.40820
209	2.18405	259	3.35405	309	4.77405	359	6.44405
210	2.20500	260	3.38000	310	4.80500	360	6.48000
211	2.22605	261	3.40605	311	4.83605	361	6.51605
212	2.24720	262	3.43220	312	4.86720	362	6.55220
213	2.26845	263	3.45845	313	4.89845	363	6.58845
214	2.28980	264	3.48480	314	4.92980	364	6.62480
215	2.31125	265	3.51125	315	4.96125	365	6.66125
216	2.33280	266	3.53780	316	4.99280	366	6.69780
217	2.35445	267	3.56445	317	5.02445	367	6.73445
218	2.37620	268	3.59120	318	5.05620	368	6.77120
219	2.39805	269	3.61805	319	5.08805	369	6.80805
220	2.42000	270	3.64500	320	5.12000	370	6.84500
221	2.44205	271	3.67205	321	5.15205	371	6.88205
222	2.46420	272	3.69920	322	5.18420	372	6.91920
223	2.48645	273	3.72645	323	5.21645	373	6.95645
224	2.50880	274	3.75380	324	5.24880	374	6.99380
225	2.53125	275	3.78125	325	5.28125	375	7.03125
226	2.55380	276	3.80880	326	5.31380	376	7.06880
227	2.57645	277	3.83645	327	5.34645	377	7.10645
228	2.59920	278	3.86420	328	5.37920	378	7.14420
229	2.62205	279	3.89205	329	5.41205	379	7.18205
230	2.64500	280	3.92000	330	5.44500	380	7.22000
231	2.66805	281	3.94805	331	5.47805	381	7.25805
232	2.69120	282	3.97620	332	5.51120	382	7.29620
233	2.71445	283	4.00445	333	5.54445	383	7.33445
234	2.73780	284	4.03280	334	5.57780	384	7.37280
235	2.76125	285	4.06125	335	5.61125	385	7.41125
236	2.78480	286	4.08980	336	5.64480	386	7.44980
237	2.80845	287	4.11845	337	5.67845	387	7.48845
238	2.83220	288	4.14720	338	5.71220	388	7.52720
239	2.85605	289	4.17605	339	5.74605	389	7.56605
240	2.88000	290	4.20500	340	5.78000	390	7.60500
241	2.90405	291	4.23405	341	5.81405	391	7.64405
242	2.92820	292	4.26320	342	5.84820	392	7.68320
243	2.95245	293	4.29245	343	5.88245	393	7.72245
244	2.97680	294	4.32180	344	5.91680	394	7.76180
245	3.00125	295	4.35125	345	5.95125	395	7.80125
246	3.02580	296	4.38080	346	5.98580	396	7.84080
247	3.05045	297	4.41045	347	6.02045	397	7.88045
248	3.07520	298	4.44020	348	6.05520	398	7.92020
249	3.10005	299	4.47005	349	6.09005	399	7.96005
250	3.12500	300	4.50000	350	6.12500	400	8.00000

PAYMENT ITEMS FOR CONSTRUCTION CONTRACTS BASED ON 1941 STANDARD SPECIFICATIONS

ROADWAY ITEMS

(*-Payment items not provided in Standard Specifications)

Div. Sec.	Item	Unit
	*MAINTENANCE OF TRAFFIC (Only for very special conditions)	Lump Sum
1.4	*FIELD OFFICE, AREA 432 (or 288) SQ. FT.	Units
1.6	*TRAFFIC DIRECTORS	Man-Hours
2.1	CLEARING SITE (Item to be shown if amount of work warrants)	Lump Sum
	*DEMOLITION OF BUILDINGS	Lump Sum
2.2	STRIPPING (4" to 6" normal or other depth)	Acres
	ROADWAY EXCAVATION, EARTH	Cu. Yd.
	*ROADWAY EXCAVATION, UNCLASSIFIED	Cu. Yd.
	ROADWAY EXCAVATION, ROCK	Cu. Yd.
	*WET EXCAVATION	Cu. Yd.
	*ROADWAY EXCAVATION, UNSUITABLE MATERIAL	Cu. Yd.
	PAVEMENT EXCAVATION	Sq. Yd.
	*BREAKING PAVEMENT	Sq. Yd.
	*PAVEMENT SURFACE REMOVAL (Bit. Conc.)	Sq. Yd.
	*PAVEMENT BASE EXCAVATION	Sq. Yd.
2.3	BORROW EXCAVATION	Cu. Yd.
	*BORROW EXCAVATION, SELECTED MATERIAL	Cu. Yd.
2.4	POROUS FILL (Behind bridge abutments, where required)	Cu. Yd.
	*SAND BLANKET (Sand Fill)	Cu. Yd.
	*VERTICAL SAND DRAINS (size, depth)	Lin. Ft.
2.5	*CHANNEL EXCAVATION, EARTH (For ditches and channels of more than 5'-0" bottom width)	Cu. Yd.
	*CHANNEL EXCAVATION, ROCK	Cu. Yd.
	*DITCH EXCAVATION, EARTH (For ditches and channels up to and including 5'-0" bottom width)	Cu. Yd.
	*DITCH EXCAVATION, ROCK	Cu. Yd.
2.6	*EARTH EXCAVATION FOR TEST PITS	Cu. Yd.
	FOUNDATION EXCAVATION (for Retaining Walls, etc.)	Cu. Yd.

Div. Sec.	Item	Unit
2.7	ROCK EXCAVATION, SUBSURFACE STRUCTURES	Cu. Yd.
	*EARTH EXCAVATION, SUBSURFACE STRUCTURES (Additional Depth)	Cu. Yd.
2.8	SUBBASE	Cu. Yd.
2.9	SUBGRADE (For Concrete Pavement and Concrete Foundation)	Sq. Yd.
2.10	GRAVEL SHOULDER, - " THICK	Sq. Yd.
	*RESURFACED GRAVEL SHOULDERS, -" AVER. THICKNESS	
	STONE SHOULDER, - "THICK	Sq. Yd.
	*PENETRATION GRAVEL SHOULDER	Sq. Yd.
2.11	4" TOPSOILING	Sq. Yd.
	*TOPSOIL	Cu. Yd.
	*PREPARATION OF EXISTING SOIL	Sq. Yd.
	*FERTILIZING & SEEDING	Sq. Yd.
2.12	SODDING	Sq. Yd.
2.13	*PLANTING ITEMS, (Peat Humus, Mulching, etc.)	
2.14	RIP-RAP SLOPE PROTECTION	Sq. Yd.
2.15	CONCRETE BAG SLOPE PROTECTION	Cu. Yd.
3.1	GRAVEL BASE COURSE, -"THICK	Sq. Yd.
	RECONSTRUCTED GRAVEL BASE COURSE	Sq. Yd.
	ROAD GRAVEL (for Base Courses)	Cu. Yd. or Ton
3.2	MACADAM BASE COURSE, -"THICK	Sq. Yd.
	*WATERBOUND MACADAM BASE COURSE	Sq. Yd.
3.3	CONCRETE BASE COURSE, -"THICK	Sq. Yd.
3.4	MODIFIED PENETRATION MACADAM, INTERMEDIATE COURSES, 3" THICK	Sq. Yd.
	BITUMINOUS BINDER, MODIFIED PENETRATION MACADAM	Gal.
	*MACADAM INTERMEDIATE COURSE, -"THICK	Sq. Yd.
	*WATERBOUND MACADAM INTERMEDIATE COURSE	Sq. Yd.
3.5	GRAVEL SURFACE COURSE, -"THICK	Sq. Yd.

Div. Sec.	Item	Unit
	RECONSTRUCTED GRAVEL SURFACE COURSE	Sq. Yd.
	ROAD GRAVEL (For Reconstructed Gravel Surface Course for State Aid Projects)	Cu. Yd. or Ton
3.6	SURFACE TREATMENT, BITUMINOUS MATERIAL	Gal.
	SURFACE TREATMENT, COVER MATERIAL (For all treatments except S.C.O.)	Tons
3.7	LIGNIN TREATMENT	Gal.
3.8	PENETRATION MACADAM SURFACE, HOT APPLICATION, -"THICK	Sq. Yd.
	PENETRATION MACADAM THIRD HOT APPLICATION	Sq. Yd
	BITUMINOUS MATERIAL FIRST AND SECOND HOT APPLICATION (The last 3 items cover payment for Penetration Macadam, Hot Application, on State Aid Projects and F. A. Secondary Projects. For State Highway Projects, Omit last 2 items)	Gal.
	*MODIFIED PENETRATION MACADAM, SURFACE COURSE, -"THICK	Sq. Yd.
3.9	PAVEMENT TYPE CA-BC-1&2, MA-BC-1&2, FA-BC-1&2, SP-1, SP-2, or S.A. -"THICK	Tons
3.10	PAVEMENT TYPE A or T, -"THICK (Type A or T on Plans. Alternative items in Proposal)	Tons
	REPAIR COURSE TYPE A or T (For repairing concrete pavements use Type A or T on Plans. Alternative items in proposal. For repairing bituminous pavements, type will be governed by existing pavement type.)	Tons
3.11	CONCRETE PAVEMENT SURFACE, PLAIN -"THICK	Sq. Yd.
	CONCRETE PAVEMENT SURFACE, REINFORCED -"THICK	Sq. Yd.
	*CONCRETE PAVEMENT SURFACE, REINFORCED, -"AVERAGE THICKNESS	Sq. Yd.
	BRIDGE APPROACH SLABS, REINFORCED, -"THICK	Sq. Yd.

Div. Sec.	Item	Unit
	*DOWEL TYPE TRANSVERSE JOINTS	Lin. Ft.
	*TONGUE & GROOVE TYPE TRANSVERSE JOINTS	Lin. Ft.
	*REINFORCEMENT STEEL	Lbs.
	*EXTRA CEMENT	Bags
3.12	GRANITE BLOCK PAVEMENT	Sq. Yd.
	RESET STONE BLOCKS	Sq. Yd.
	*RAILROAD CROSSING PAVEMENT	Sq. Yd.
3.13	*CALCIUM CHLORIDE	Tons
	*BROKEN STONE OR WASHED GRAVEL	Cu. Yd.
	*BROKEN STONE, ROCK FILL, ETC.	Cu. Yd. or Tons
	*CINDER SURFACE	Cu. Yd.
	*TACK COAT	Gal.
	*PRIME COAT	Gal.
4.1	CLASS C CONCRETE (in Structures, Walls, Steps, etc.)	Cu. Yd.
4.2	STEEL STRUCTURES	
4.3	TIMBER STRUCTURES	M.B.M.
	*TREATED TIMBER CAPS & STRINGERS	M.B.M.
	*WOOD CRADLE, ETC.	M.B.M.
4.4	TEST PILES	Units or Lin. Ft.
	TIMBER PILES, TREATED TIMBER PILES, ETC.	Lin. Ft.
4.5	TIMBER SHEET PILING	Sq. Ft.
5.1	UNDERDRAIN TYPE F,T,S, ETC.	Lin. Ft.
	-*COMBINATION DRAIN (Separate item for each size of pipe)	Lin. Ft.
	-*CLAY PIPE, STANDARD STRENGTH	Lin. Ft.
	-*CLAY PIPE, EXTRA STRENGTH	Lin. Ft.
	-*CLAY PIPE, SANITARY SEWER	Lin. Ft.
5.2	-*REINFORCED CONCRETE CULVERT PIPE, STANDARD STRENGTH	Lin. Ft.
	-*REINFORCED CONCRETE CULVERT PIPE, EXTRA STRENGTH (For drains 12" to 48" diam. inclusive.)	Lin. Ft.
	-*PLAIN CONCRETE CULVERT PIPE	Lin. Ft.
	-*CAST IRON CULVERT PIPE, EXTRA HEAVY	Lin. Ft.

Div. Sec.	Item	Unit
	-"CAST IRON CULVERT PIPE, JACKING METHOD	Lin. Ft.
	-"CAST IRON WATER PIPE CLASS 50,(Laying Conditions B or other as required)	Lin. Ft.
	*-"CAST IRON SOIL PIPE	Lin. Ft.
	-"CORRUGATED METAL CULVERT PIPE, BITUMINOUS COATED	Lin. Ft.
	-"CORRUGATED METAL CULVERT PIPE, BITUMINOUS COATED, PERFORATED ENDS	Lin. Ft.
	-"CORRUGATED METAL PIPE ARCH, BITUMINOUS COATED	Lin. Ft.
	RELAID -" (kind) PIPE (grouped where feasible)	Lin. Ft.
	*FILLING EXISTING DRAIN (with sand, etc.)	Lin. Ft.
	*REMOVAL EXISTING -"to-" (kind) DRAINS	Lin. Ft.
	*CLEANING EXISTING DRAINAGE STRUCTURES	Lump Sum
5.3	MANHOLES	Units
	*MANHOLES, SANITARY SEWER	Units
	*MANHOLES, USING EXISTING CASTINGS	Units
	*RECONSTRUCTED MANHOLES	Units
	NEW MANHOLE HEADS	Units
	INLETS, TYPE-	Units
	*INLETS TYPE-USING EXISTING CASTINGS	Units
	*INLETS CONVERTED TO MANHOLES	Units
	*RECONSTRUCTED INLETS	Units
	NEW INLET HEADS	Units
	CATCH BASINS TYPE-	Units
	*CATCH BASINS, TYPE-USING EXISTING CASTINGS	Units
	*EXTRA DEPTH OF MANHOLES, INLETS, & CATCH BASINS BELOW 8 FEET	Lin. Ft.
	*MASONRY WALLS (Added to Existing Inlets and Manholes)	Lin. Ft.
	RESET MANHOLE INLET & CATCH BASIN HEADS	Units
	*FLUME INLETS	Units
	*RESET SEWER & WATER VENTS	Units
	*REINFORCED CONCRETE MANHOLE CAPS	Units
	*REMOVAL OF TRACK INLETS, ETC.	Units

Div. Sec.	Item	Unit
5.4	CONCRETE GUTTER, -"THICK	Sq. Yd.
	RUBBLE STONE GUTTER	Sq. Yd.
	GROUTED RUBBLE STONE GUTTER	Sq. Yd.
	*CONCRETE APRONS, -"THICK	Sq. Yd.
5.5	*WOOD CURB	Lin. Ft.
	9" x 20" CONCRETE CURB	Lin. Ft.
	*COMBINATION CONCRETE CURB & GUTTER	Lin. Ft.
	GRANITE, BLUESTONE or FLAGSTONE CURB	Lin. Ft.
	*RESET GRANITE, ETC., CURB	Lin. Ft.
5.6	-" x -" WHITE CONCRETE VERTICAL CURB	Lin. Ft.
	*-" x -" WHITE CONCRETE SLOPING CURB	Lin. Ft.
5.7	BITUMINOUS CONCRETE SIDEWALK TYPE-, -"THICK	Tons
	*6" GRAVEL OR MACADAM SIDEWALK BASE	Sq. Yd.
	PENETRATION MACADAM SIDEWALK, -"THICK	Sq. Yd.
	CONCRETE SIDEWALK, -"THICK	Sq. Yd.
	*CINDER SIDEWALK, -"THICK	Sq. Yd.
	*BRICK SIDEWALK	Sq. Yd.
	*RELAID (kind) SIDEWALK	Sq. Yd.
5.8	*WHITE CONCRETE ISLAND PAVEMENT, -"THICK	Sq. Yd.
5.9	DRY RUBBLE WALLS	Cu. Yd.
	MORTAR RUBBLE WALLS	Cu. Yd.
5.10	CONCRETE CRIBBING	Cu. Ft.
	STONE FILL FOR CRIB WALL	Cu. Yd.
5.11	HEADWALLS	Cu. Yd.
	CULVERTS	Cu. Yd.
	*REMOVAL OF EXISTING CULVERTS	Lin. Ft.
5.12	MONUMENTS	Units
	*FEDERAL PROJECT MARKET POSTS	Units
5.13	WIRE ROPE FENCE	Lin. Ft.
	*GUARD FENCE ANCHORAGES	Units
	*BEAM GUARD RAIL	Lin. Ft.
	*RESET WIRE ROPE FENCE USING OLD POSTS	Lin. Ft.
	*RESET WIRE ROPE FENCE USING NEW POSTS	Lin. Ft.
	*GUARD FENCE POSTS	Units
	*WIRE MESH FENCE	Lin. Ft.
	*WOOD BARRICADE	Lin. Ft.
	*RESET WOOD BARRICADE	Lin. Ft.

Div. Sec.	Item	Unit
	*ROUGH CUT TIMBER GUARD RAIL, LOW TYPE	Lin. Ft.
	*ROUGH CUT TIMBER GUARD RAIL, HIGH TYPE	Lin. Ft.
5.14	PIPE RAILING	Lin. Ft.
5.15	WROUGHT IRON PIPE CONDUITS (Electrical)	
	*JUNCTION BOXES (Electrical)	Units

CONVERGENCE OF MERIDIANS FOR NEW JERSEY

To convert bearings from N. J. Plane Coordinate System North to True North use the following Table of Convergence.

Latitude	Per Mile East or West	Per 1000 Ft. East or West
39°	42.1″	7.97″
39½°	42.85″	8.12″
40°	43.6″	8.26″
40½°	44.4″	8.41″
41°	45.2″	8.56″
41½°	46.0″	8.71″

NOTE: North for Plane Coordinate System = True North at 70° 40′ West Longitude.

FORMULA: Convergence of Meridians = (Diff. in Longitude in min.) × Sin of Latitude. If possible use coordinates to determine distance east or west of 70° 40′. The Coordinate for 74° 40′ is 2,000,000 E.

East of 74° 40′—Add corrections to N.E. or S.W. Bearing.
Subtract corrections from N.W. or S.E. Bearing.

West of 74° 40′—Add corrections to N.W. or S.E. Bearing.
Subtract corrections from N.E. or S.W. Bearing.

STANDARD NORTH POINTS

Where bearings are referred to the New Jersey Plane Coordinate System, this Arrow is to be used.

Where bearings are referred to True North, this Arrow is to be used.

Where bearings are referred to Magnetic North, this Arrow is to be used.

North Points to be drawn 6" long on Standard Size sheets.

North Points for sheets of other sizes are to be drawn in proportion.

CONVERGENCE OF MERIDIANS

The distance between meridians for each second of arc is as follows:

Latitude	39°	39½°	40°	40½°	41°	41½°
Length of Arc per Second of Longitude	78.95′	78.39′	77.83′	77.25′	76.68′	76.10′

Example: To find convergence of meridians at 40° latitude with coordinate of 2,005,280 East.

Given: True North is at 74°40′ West Longitude or 2,000,000′ East coordinate.

Coordinate for point of transit is 2,005,280 E. 2,005,280—2,000,000 = 5,280′. Distance point is East of True North meridian.

5,280′ divided by 77.83′ = 67.84 seconds of longitudinal arc.

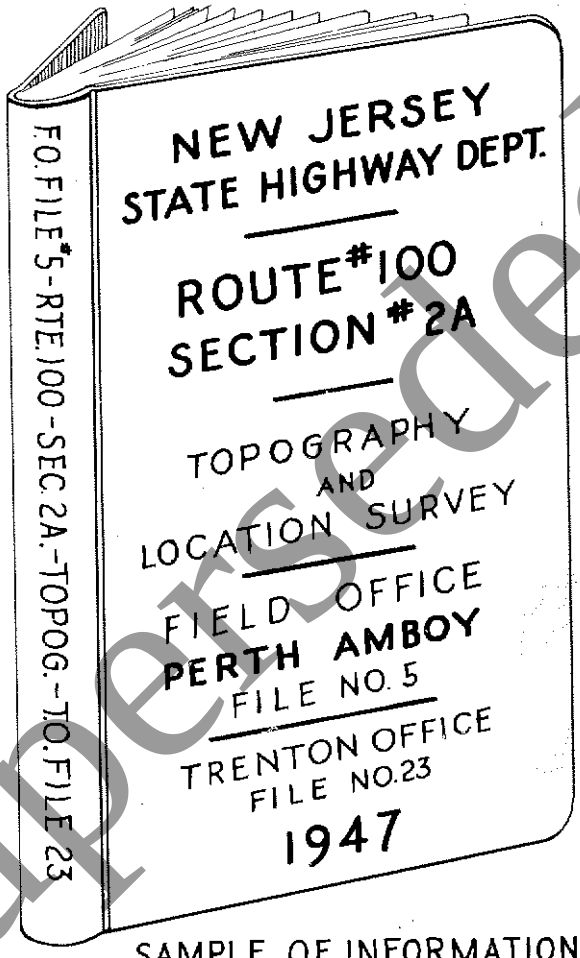
Using Formula: Convergence of meridians (in min. or sec.) = Diff. in longitude in minutes (or seconds) × sin of latitude.

Convergence = 67.84 seconds × sin of 40° = 43.6″. This correction should be added to N.E. and S.W. bearings or subtracted from N.W. and S.E. bearings.

CORRECT HORIZONTAL DISTANCE FOR MEASUREMENTS MADE ON SLOPES

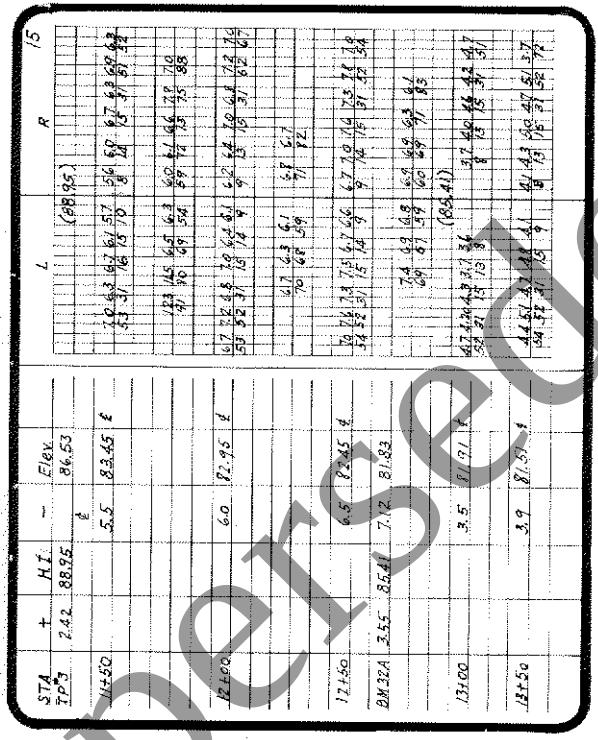
Slope Distance	Vertical Distance	Slope Ratio	Correct Horizontal Distance
100′	0.5′		99.9988′
100′	1.0′	100:1	99.995′
100′	1.2′		99.993′
100′	1.4′		99.990′
100′	1.6′		99.987′
100′	1.8′		99.984′
100′	2.0′	50:1	99.980′
100′	2.2′		99.976′
100′	2.4′		99.971′
100′	2.6′		99.966′
100′	2.8′		99.961′
100′	3.0′		99.955′
100′	3.2′		99.949′
100′	3.4′		99.942′
100′	3.6′		99.935′
100′	3.8′		99.928′
100′	4.0′	25:1	99.920′
100′	4.2′		99.912′
100′	4.4′		99.903′
100′	4.6′		99.894′
100′	4.8′		99.885′
100′	5.0′	20:1	99.875′
100′	5.2′		99.865′
100′	5.4′		99.854′
100′	5.6′		99.843′
100′	5.8′		99.832′
100′	6.0′		99.820′
100′	6.5′		99.788′
100′	7.0′		99.754′
100′	7.5′		99.718′
100′	8.0′		99.679′
100′	8.5′		99.638′
100′	9.0′		99.594′
100′	9.5′		99.548′
100′	10.0′	10:1	99.499′
100′	11.0′		99.393′
100′	12.0′		99.277′
100′	13.0′		99.138′
100′	14.0′		99.015′

Slope Distance	Vertical Distance	Slope Ratio	Correct Horizontal Distance
100′	15.0′		98.868′
100′	16.0′		98.711′
100′	17.0′		98.544′
100′	18.0′		98.367′
100′	19.0′		98.178′
100′	20.0′	5:1	97.980′
100′	25.0′	4:1	96.825′
100′	30.0′		95.394′
100′	33.33′	3:1	94.281′
100′	35.0′		93.675′
100′	40.0′		91.652′
100′	45.0′		89.202′
100′	50.0′	2:1	86.603′
100′	55.0′		83.185′
100′	57.143′	1¾:1	82.065′
100′	60.0′		80.000′
100′	65.0′		75.562′
100′	66.666′	1½:1	74.535′
100′	70.0		71.414′



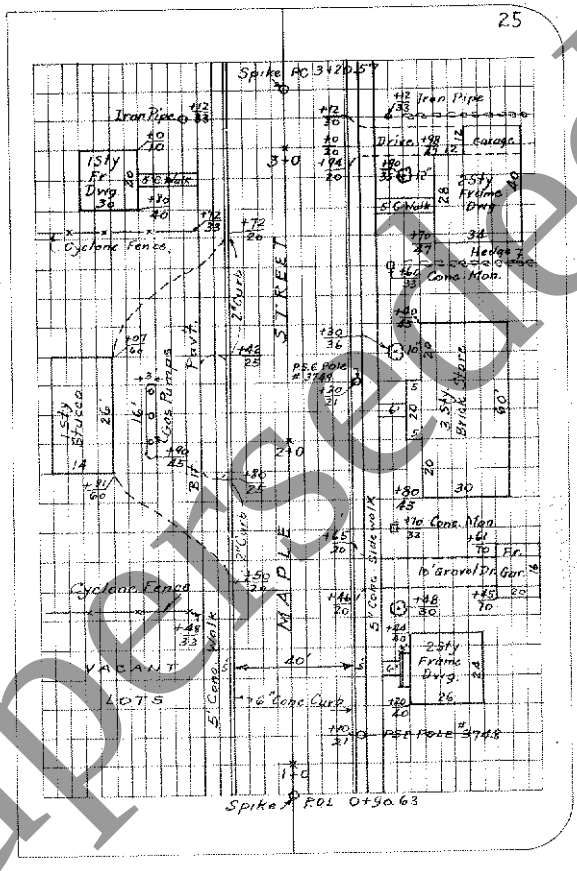
SAMPLE OF INFORMATION
TO BE SHOWN ON FIELD BOOKS

SAMPLE OF CROSS SECTION AND LEVEL NOTES



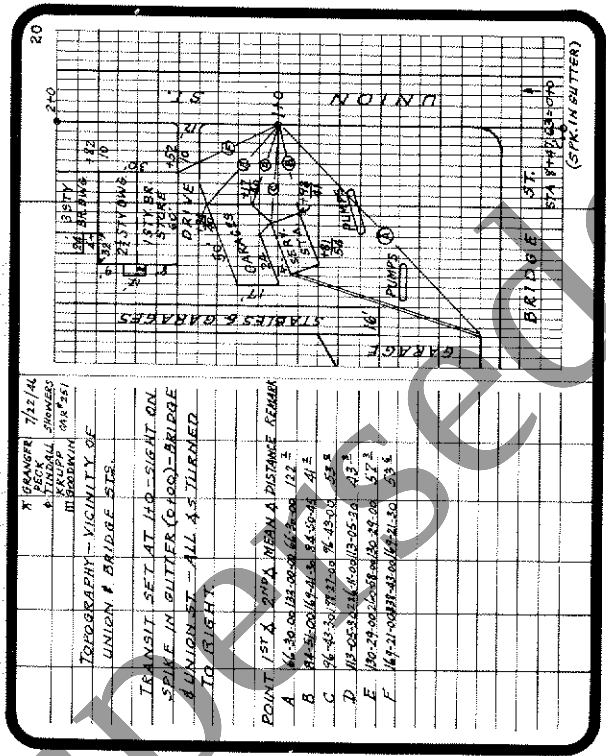
SAMPLE CROSS SECTION
AND
LEVEL NOTES

SAMPLE TOPOGRAPHY NOTES
(PLUS AND OFFSET)



SAMPLE TOPOGRAPHY NOTES

TOPOGRAPHY NOTES
(ANGLE AND DISTANCE)



TEMPERATURE COEFFICIENTS FOR STEEL TAPES

(Correction per foot)

°F		°F	°F		°F	°F	
—		+	—		+	—	
68	.00000000	68	51	.00010965	85	34	.00021930
67	.00000645	69	50	.00011610	86	33	.00022575
66	.00001290	70	49	.00012255	87	32	.00023220
65	.00001935	71	48	.00012900	88	31	.00023865
64	.00002580	72	47	.00013545	89	30	.00024510
63	.00003225	73	46	.00014190	90	29	.00025155
62	.00003870	74	45	.00014835	91	28	.00025800
61	.00004515	75	44	.00015480	92	27	.00026445
60	.00005160	76	43	.00016125	93	26	.00027090
59	.00005805	77	42	.00016770	94	25	.00027735
58	.00006450	78	41	.00017415	95	24	.00028380
57	.00007095	79	40	.00018060	96	23	.00029025
56	.00007740	80	39	.00018705	97	22	.00029670
55	.00008385	81	38	.00019350	98	21	.00030315
54	.00009030	82	37	.00019995	99	20	.00030960
53	.00009675	83	36	.00020640		19	.00031605
52	.00010320	84	35	.00021285		18	.00032250

AREA IN ACRES PER HUNDRED FEET OF LENGTH FOR VARIOUS WIDTHS OF RIGHT OF WAY

Width of New Right of Way	Area In Acres Per 100′	Width of New Right of Way	Area In Acres Per 100′
1′	.00229568	80′	.183655
5′	.011478	100′	.229568
16.5′	.037879	110′	.252525
25′	.057392	120′	.275482
33′	.075758	140′	.321396
49.5′	.113636	144′	.330579
50′	.114784	146′	.335170
60′	.137741	150′	.344353
66′	.151515	154′	.353535
70′	.160698	200′	.459137
75′	.172176	250′	.573921
		300′	.688705

TO USE TABLE: (1) Take area for appropriate width of new right of way from table and multiply by number of 100′ stations. (2) Take area for existing right of way from table and multiply by number of 100′ stations. (3) Subtract (2) from (1) and the result is the area of the parcel.

ALTERNATE TABLE

AREA IN ACRES PER HUNDRED FEET OF LENGTH FOR VARIOUS WIDTHS OF RIGHT OF WAY

Width of New Right of Way	Area In Acres Per 100′	Width of New Right of Way	Area In Acres Per 100′
1′	.00229568	90.5′	.207759
5′	.011478	94.5′	.216942
14′	.032140	96.5′	.221534
16.5′	.037879	100′	.229568
25′		104.5′	.239899
30.5′	.070018	107′	.245638
33′	.075758	110′	.252525
34′	.078053	111′	.254821
44′	.101010	113′	.259412
47′	.107897	120′	.275482
49.5′	.113636	121′	.277778
50.5′	.115932	134′	.307622
54′	.123967	140′	.321396
60′		144′	.330579
60.5′	.138889	146′	.335170
66′	.151515	150′	
67′	.153811	150.5′	.345500
70.5′	.161846	154′	.353535
74′	.169881	167′	.383379
75′		184′	.422406
77′	.176768	200′	.459137
78′	.179063	200.5′	.460285
80′	.183655	217′	.498163
87′	.199725	234′	.537190
88′	.202020	250′	.573921
		250.5′	.575069
		267′	.612948
		300′	.688705

TO USE TABLE: Subtract width of existing righ of way from width of new right of way. Look up area and multiply by number of 100′ stations to get area of parcel.

CHAINS AND LINKS TO FEET

Chains	Feet	Chains	Feet	Chains	Feet	Chains	Feet
1	66	51	3366	101	6666	151	9966
2	132	52	3432	102	6732	152	10032
3	198	53	3498	103	6798	153	10098
4	264	54	3564	104	6864	154	10164
5	330	55	3630	105	6930	155	10230
6	396	56	3696	106	6996	156	10296
7	462	57	3762	107	7062	157	10362
8	528	58	3828	108	7128	158	10428
9	594	59	3894	109	7194	159	10494
10	660	60	3960	110	7260	160	10560
11	726	61	4026	111	7326	161	10626
12	792	62	4092	112	7392	162	10692
13	858	63	4158	113	7458	163	10758
14	924	64	4224	114	7524	164	10824
15	990	65	4290	115	7590	165	10890
16	1056	66	4356	116	7656	166	10956
17	1122	67	4422	117	7722	167	11022
18	1188	68	4488	118	7788	168	11088
19	1254	69	4554	119	7854	169	11154
20	1320	70	4620	120	7920	170	11220
21	1386	71	4686	121	7986	171	11286
22	1452	72	4752	122	8052	172	11352
23	1518	73	4818	123	8118	173	11418
24	1584	74	4884	124	8184	174	11484
25	1650	75	4950	125	8250	175	11550
26	1716	76	5016	126	8316	176	11616
27	1782	77	5082	127	8382	177	11682
28	1848	78	5148	128	8448	178	11748
29	1914	79	5214	129	8514	179	11814
30	1980	80	5280	130	8580	180	11880
31	2046	81	5346	131	8646	181	11946
32	2112	82	5412	132	8712	182	12012
33	2178	83	5478	133	8778	183	12078
34	2244	84	5544	134	8844	184	12144
35	2310	85	5610	135	8910	185	12210
36	2376	86	5676	136	8976	186	12276
37	2442	87	5742	137	9042	187	12342
38	2508	88	5808	138	9108	188	12408
39	2574	89	5874	139	9174	189	12474
40	2640	90	5940	140	9240	190	12540
41	2706	91	6006	141	9306	191	12606
42	2772	92	6072	142	9372	192	12672
43	2838	93	6138	143	9438	193	12738
44	2904	94	6204	144	9504	194	12804
45	2970	95	6270	145	9570	195	12870
46	3036	96	6336	146	9636	196	12936
47	3102	97	6402	147	9702	197	13002
48	3168	98	6468	148	9768	198	13068
49	3234	99	6534	149	9834	199	13134
50	3300	100	6600	150	9900	200	13200

100 Links = 1 Chain. Point off two decimal places if Links are required. Example—1 Chain, 93 Links = 1.93 Chains = 127.38 ft.

CONVERSION OF MINUTES AND SECONDS TO DECIMAL PARTS OF A DEGREE

Minutes		Seconds	
0′	0°000000	0″	0°000000
1	016667	1	00278
2	033333	2	00556
3	050000	3	00833
4	066667	4	01111
5	083333	5	01389
6	100000	6	01667
7	116667	7	01944
8	133333	8	02222
9	150000	9	02500
10	0.166667	10	0.002778
11	183333	11	03056
12	200000	12	03333
13	216667	13	03611
14	233333	14	03889
15	250000	15	04167
16	266667	16	04444
17	283333	17	04722
18	300000	18	05000
19	316667	19	05278
20	0.333333	20	0.005556
21	350000	21	05833
22	366667	22	06111
23	383333	23	06389
24	400000	24	06667
25	416667	25	06944
26	433333	26	07222
27	450000	27	07500
28	466667	28	07778
29	483333	29	08056

CONVERSION OF MINUTES AND SECONDS TO DECIMAL PARTS OF A DEGREE

30	0.500000	30	0.008333
31	516667	31	08611
32	533333	32	08889
33	550000	33	09167
34	566667	34	09444
35	583333	35	09722
36	600000	36	10000
37	616667	37	10278
38	633333	38	10556
39	650000	39	10833
40	0.666667	40	0.011111
41	683333	41	11389
42	700000	42	11667
43	716667	43	11944
44	733333	44	12222
45	750000	45	12500
46	766667	46	12778
47	783333	47	13056
48	800000	48	13333
49	816667	49	13611
50	0.833333	50	0.013889
51	850000	51	14167
52	866667	52	14444
53	883333	53	14722
54	900000	54	15000
55	916667	55	15278
56	933333	56	15556
57	950000	57	15833
58	966667	58	16111
59	983333	59	16389

CONVERSION OF INCHES TO DECIMALS OF A FOOT

In.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	000	005	010	016	021	026	031	036	042	047	052	057	062	068	073	078
1	083	089	094	099	104	109	115	120	125	130	135	141	146	151	156	161
2	167	172	177	182	188	193	198	203	208	214	219	224	229	234	240	245
3	250	255	260	266	271	276	281	286	292	297	302	307	313	318	323	328
4	333	339	344	349	354	359	365	370	375	380	385	391	396	401	406	411
5	417	422	427	432	438	443	448	453	458	464	469	474	479	484	490	495
6	500	505	510	516	521	526	531	536	542	547	552	557	562	568	573	578
7	583	589	594	599	604	609	615	620	625	630	635	641	646	651	656	661
8	667	672	677	682	688	693	698	703	708	714	719	724	729	734	740	745
9	750	755	760	766	771	776	781	786	792	797	802	807	813	818	823	828
10	833	839	844	849	854	859	865	870	875	880	885	891	896	901	906	911
11	917	922	927	932	938	943	948	953	958	964	969	974	979	984	990	995

CURVE DATA TABLES

TABLE OF CONTENTS

EXPLANATIONS AND USE OF TABLES

TABLE NO. 1.—TABLE OF TANGENTS, EXTERNALS AND MIDDLE ORDINATES FOR 10,000 FT. RADIUS CURVE.

Given: ▲ = 16°06′. Radius = 8,000 Ft.
Required: Tangent and external.
Method: From table take length of tangent for 10,000 ft. radius and angle of 16°00′. Take length of tangent for 16°10′. Subtract first figure from second figure. Take 6/10 of difference and add to first figure. The sum is the tangent length for 10,000 ft. radius at 16°06′ delta; the numerical value being 1414.309 feet. To find tangent length for 8,000 ft. radius curve take $\frac{8,000}{10,000}$ of 1414.309 or .8 x 1414.309 = 1131.447 feet.

Externals and middle ordinates are computed by using the same method.

TABLE NO. 2.—TABLE OF ARC LENGTHS TO THE RADIUS 1.

Example:
Given: ▲ = 16°06′, radius = 8,000 Ft.
Required: Length of curve.

From table—length of arc for 16°	= 0.2792527
Add length of arc for 06′	= 0.0017453
Total length for radius 1	= 0.2809980
Multiply by	8000
Length of curve	= 2247.984

TABLE NO. 3.—LENGTH OF CHORD FOR ARCS OF 10′, 25′, 50′, 75′, 100′ and 200′.

Example:
Given: Radius = 300 ft.
Required: Length of chord for 25′, 50′ and 100′ of arc.
From table-opposite radius of 300′ in column for 25′ of arc is shown length of chord to lay off for 25′ of arc.
Thus—For arc of 25 ft., chord = 24.993 ft.
For arc of 50 ft., chord = 49.942 ft.
For arc of 100 ft., chord = 99.538 ft.

When it is necessary to lay off an arc with a length other than any shown in the tables, the correct chord length may be computed by taking the sine of the *deflection angle* for that length of arc and multiplying by two times the radius.

TABLE NO. 4.—TABLE OF DEFLECTIONS PER FOOT OF ARC FOR RADII FROM 25 FEET TO 40,000 FEET.

Example:

Given: P.C. Sta. = 192+40, P. T. Sta. = 214+87.98, Radius = 8,000 feet, $\blacktriangle$ = 16°06′.

Required: Deflections from P.C. to +00 Stations for entire curve.

From table—deflections per foot for 8,000 ft. radius = 0.2149 minutes.

1st arc length = (193−00) − (192+40) = 60 feet.

Deflection = 0.2149 min. × 60 = 12.894 minutes.

Deflection to be added for each 100 ft. of arc = 0.2149 × 100 = 21.49 minutes.

Deflection for arc between 214+00 and 214+87.98 = 0.2149 × 87.98 = 18.9069 minutes.

Deflections for total arc:

1st arc	=	12.894 minutes
2100 ft. of arc = 21 × 21.49	=	451.290 minutes
Last arc	=	18.907 minutes
Total	=	$\frac{483.091}{60}$ = 8°03.091′

The discrepancy of 0.091′ occurs because of the limited number of places in deflection table.

TANGENTS, EXTERNALS AND MIDDLE ORDINATES FOR 10,000 FT. RADIUS CURVE. TABLE I.

Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.	Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.
0°	0.00	0.00	0.00	10°	874.89	38.20	38.05
10′	14.54	0.01	0.01	10′	889.54	39.49	39.33
20′	29.09	0.04	0.04	20′	904.21	40.80	40.63
30′	43.63	0.10	0.10	30′	918.87	42.13	41.95
40′	58.18	0.17	0.17	40′	933.54	43.48	43.29
50′	72.72	0.26	0.26	50′	948.21	44.86	44.66
1°	87.27	0.38	0.38	11°	962.89	46.25	46.04
10′	101.81	0.52	0.52	10′	977.57	47.67	47.44
20′	116.36	0.68	0.68	20′	992.26	49.11	48.87
30′	130.91	0.86	0.86	30′	1,006.95	50.57	50.32
40′	145.45	1.06	1.06	40′	1,021.64	52.05	51.78
50′	160.00	1.28	1.28	50′	1,036.34	53.56	53.27
2°	174.55	1.52	1.52	12°	1,051.04	55.08	54.78
10′	189.10	1.79	1.79	10′	1,065.75	56.63	56.31
20′	203.65	2.07	2.07	20′	1,080.46	58.20	57.86
30′	218.20	2.38	2.38	30′	1,095.18	59.79	59.44
40′	232.75	2.71	2.71	40′	1,109.90	61.41	61.03
50′	247.31	3.06	3.06	50′	1,124.63	63.04	62.65
3°	261.86	3.43	3.43	13°	1,139.36	64.70	64.28
10′	276.41	3.82	3.82	10′	1,154.09	66.38	65.94
20′	290.97	4.23	4.23	20′	1,168.83	68.08	67.62
30′	305.53	4.67	4.66	30′	1,183.58	69.80	69.32
40′	320.09	5.12	5.12	40′	1,198.33	71.54	71.04
50′	334.65	5.60	5.60	50′	1,213.09	73.31	72.78
4°	349.21	6.10	6.09	14°	1,227.85	75.10	74.54
10′	363.77	6.61	6.61	10′	1,242.61	76.91	76.32
20′	378.34	7.15	7.15	20′	1,257.38	78.74	78.13
30′	392.90	7.72	7.71	30′	1,272.16	80.60	79.95
40′	407.47	8.30	8.29	40′	1,286.94	82.47	81.80
50′	422.04	8.90	8.89	50′	1,301.73	84.37	83.66
5°	436.61	9.53	9.52	15°	1,316.53	86.29	85.55
10′	451.18	10.17	10.16	10′	1,331.32	88.23	87.46
20′	465.76	10.84	10.83	20′	1,346.13	90.20	89.39
30′	480.33	11.53	11.52	30′	1,360.94	92.18	91.34
40′	494.91	12.24	12.23	40′	1,375.76	94.19	93.31
50′	509.50	12.97	12.95	50′	1,390.58	96.22	95.31
6°	524.08	13.72	13.71	16°	1,405.41	98.28	97.32
10′	538.66	14.50	14.48	10′	1,420.24	100.35	99.35
20′	553.25	15.29	15.27	20′	1,435.08	102.45	101.41
30′	567.84	16.11	16.08	30′	1,449.93	104.57	103.49
40′	582.43	16.95	16.92	40′	1,464.78	106.71	105.58
50′	597.03	17.81	17.78	50′	1,479.64	108.88	107.70
7°	611.63	18.69	18.65	17°	1,494.51	111.06	109.84
10′	626.23	19.59	19.55	10′	1,509.38	113.27	112.00
20′	640.83	20.51	20.47	20′	1,524.26	115.50	114.18
30′	655.44	21.46	21.41	30′	1,539.15	117.76	116.39
40′	670.04	22.42	22.37	40′	1,554.04	120.03	118.61
50′	684.65	23.41	23.36	50′	1,568.94	122.33	120.85
8°	699.27	24.42	24.36	18°	1,583.84	124.65	123.12
10′	713.89	25.45	25.39	10′	1,598.76	127.00	125.40
20′	728.51	26.50	26.43	20′	1,613.68	129.36	127.71
30′	743.13	27.57	27.50	30′	1,628.60	131.75	130.04
40′	757.76	28.67	28.59	40′	1,643.54	134.16	132.39
50′	772.38	29.79	29.70	50′	1,658.48	136.60	134.75
9°	787.02	30.92	30.83	19°	1,673.43	139.05	137.14
10′	801.65	32.08	31.98	10′	1,688.38	141.53	139.56
20′	816.29	33.26	33.15	20′	1,703.34	144.03	141.99
30′	830.94	34.46	34.35	30′	1,718.31	146.56	144.44
40′	845.58	35.69	35.56	40′	1,733.29	149.10	146.91
50′	860.23	36.93	36.80	50′	1,748.28	151.67	149.41

TANGENTS, EXTERNALS AND MIDDLE ORDINATES FOR 10,000 FT. RADIUS CURVE. TABLE I.

Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.	Cen. Angle Delta	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.
20°	1,763.27	154.27	151.92	30°	2,679.49	352.76	340.74
10′	1,778.27	156.88	154.46	10′	2,695.09	356.81	344.52
20′	1,793.28	159.52	157.02	20′	2,710.69	360.88	348.31
30′	1,808.30	162.18	159.59	30′	2,726.31	364.98	352.13
40′	1,823.32	164.87	162.19	40′	2,741.95	369.10	355.96
50′	1,838.35	167.57	164.81	50′	2,757.59	373.25	359.82
21°	1,853.39	170.30	167.45	31°	2,773.25	377.42	363.70
10′	1,868.44	173.06	170.11	10′	2,788.92	381.62	367.59
20′	1,883.50	175.83	172.79	20′	2,804.60	385.84	371.51
30′	1,898.56	178.63	175.50	30′	2,820.29	390.09	375.45
40′	1,913.63	181.45	178.22	40′	2,836.00	394.37	379.41
50′	1,928.71	184.30	180.96	50′	2,851.72	398.67	383.38
22°	1,943.80	187.17	183.73	32°	2,867.45	402.99	387.38
10′	1,958.90	190.06	186.51	10′	2,883.20	407.35	391.40
20′	1,974.01	192.97	189.32	20′	2,898.96	411.72	395.44
30′	1,989.12	195.91	192.15	30′	2,914.73	416.13	399.50
40′	2,004.25	198.87	195.00	40′	2,930.52	420.55	403.58
50′	2,019.38	201.86	197.86	50′	2,946.32	425.01	407.68
23°	2,034.52	204.87	200.75	33°	2,962.14	429.49	411.80
10′	2,049.67	207.90	203.66	10′	2,977.96	434.00	415.94
20′	2,064.83	210.95	206.59	20′	2,993.80	438.53	420.11
30′	2,080.00	214.03	209.55	30′	3,009.66	443.09	424.29
40′	2,095.18	217.13	212.52	40′	3,025.53	447.67	428.49
50′	2,110.37	220.26	215.51	50′	3,041.41	452.28	432.71
24°	2,125.51	223.41	218.52	34°	3,057.31	456.92	436.95
10′	2,140.77	226.58	221.56	10′	3,073.22	461.58	441.22
20′	2,155.99	229.77	224.61	20′	3,089.14	466.27	445.50
30′	2,171.21	232.99	227.69	30′	3,105.08	470.99	449.80
40′	2,186.45	236.24	230.79	40′	3,121.04	475.73	454.12
50′	2,201.69	239.50	233.90	50′	3,137.01	480.50	458.47
25°	2,216.95	242.80	237.04	35°	3,152.99	485.29	462.85
10′	2,232.21	246.11	240.20	10′	3,168.99	490.11	467.21
20′	2,247.49	249.45	243.38	20′	3,185.00	494.96	471.62
30′	2,262.77	252.81	246.58	30′	3,201.03	499.84	476.04
40′	2,278.06	256.20	249.80	40′	3,217.07	504.74	480.49
50′	2,293.37	259.61	253.04	50′	3,233.13	509.67	484.95
26°	2,308.68	263.04	256.30	36°	3,249.20	514.62	489.44
10′	2,324.01	266.50	259.58	10′	3,265.28	519.61	493.94
20′	2,339.34	269.98	262.88	20′	3,281.39	524.61	498.46
30′	2,354.69	273.49	266.21	30′	3,297.51	529.65	503.01
40′	2,370.04	277.02	269.55	40′	3,313.64	534.71	507.57
50′	2,385.41	280.57	272.92	50′	3,329.79	539.81	512.16
27°	2,400.79	284.15	276.30	37°	3,345.95	544.92	516.76
10′	2,416.18	287.76	279.71	10′	3,362.13	550.07	521.39
20′	2,431.58	291.38	283.13	20′	3,378.33	555.24	526.03
30′	2,446.98	295.03	286.58	30′	3,394.54	560.44	530.70
40′	2,462.41	298.71	290.05	40′	3,410.77	565.67	535.38
50′	2,477.84	302.41	293.53	50′	3,427.02	570.92	540.09
28°	2,493.28	306.14	297.04	38°	3,443.28	576.21	544.81
10′	2,508.73	309.89	300.57	10′	3,459.55	581.52	549.56
20′	2,524.20	313.66	304.12	20′	3,475.85	586.86	554.33
30′	2,539.68	317.46	307.69	30′	3,492.16	592.22	559.11
40′	2,555.17	321.28	311.28	40′	3,508.48	597.62	563.92
50′	2,570.66	325.13	314.89	50′	3,524.83	603.04	568.74
29°	2,586.18	329.00	318.52	39°	3,541.19	608.49	573.59
10′	2,601.70	332.90	322.18	10′	3,557.56	613.97	578.45
20′	2,617.23	336.82	325.85	20′	3,573.96	619.47	583.34
30′	2,632.78	340.77	329.54	30′	3,590.37	625.01	588.24
40′	2,648.34	344.74	333.25	40′	3,606.80	630.57	593.17
50′	2,663.91	348.74	336.99	50′	3,623.24	636.16	598.11

TANGENTS, EXTERNALS AND MIDDLE ORDINATES FOR 10,000 FT. RADIUS CURVE. TABLE I.

Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.	Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.
40°	3,639.70	641.78	603.07	50°	4,663.08	1,033.78	936.92
10′	3,656.18	647.43	608.06	10′	4,680.80	1,041.28	943.08
20′	3,672.68	653.10	613.06	20′	4,698.54	1,048.81	949.25
30′	3,689.20	658.81	618.09	30′	4,716.31	1,056.38	955.45
40′	3,705.73	664.54	623.13	40′	4,734.10	1,063.98	961.66
50′	3,722.28	670.30	628.19	50′	4,751.91	1,071.62	967.90
41°	3,738.85	676.09	633.28	51°	4,769.76	1,079.29	974.15
10′	3,755.43	681.91	638.38	10′	4,787.62	1,086.99	980.42
20′	3,772.04	687.76	643.51	20′	4,805.51	1,094.73	986.71
30′	3,788.66	693.64	648.65	30′	4,823.43	1,102.50	993.02
40′	3,805.30	699.55	653.81	40′	4,841.37	1,110.30	999.35
50′	3,821.96	705.48	658.99	50′	4,859.33	1,118.14	1,005.69
42°	3,838.64	711.45	664.20	52°	4,877.33	1,126.02	1,012.06
10′	3,855.34	717.45	669.42	10′	4,895.34	1,133.93	1,018.45
20′	3,872.05	723.47	674.66	20′	4,913.39	1,141.87	1,024.85
30′	3,888.79	729.52	679.92	30′	4,931.45	1,149.85	1,031.27
40′	3,905.54	735.61	685.20	40′	4,949.55	1,157.87	1,037.72
50′	3,922.31	741.72	690.50	50′	4,967.67	1,165.92	1,044.18
43°	3,939.11	747.86	695.82	53°	4,985.82	1,174.00	1,050.66
10′	3,955.92	754.04	701.17	10′	5,003.99	1,182.12	1,057.16
20′	3,972.75	760.24	706.53	20′	5,022.19	1,190.28	1,063.67
30′	3,989.60	766.47	711.90	30′	5,040.42	1,198.47	1,070.21
40′	4,006.47	772.73	717.30	40′	5,058.67	1,206.70	1,076.77
50′	4,023.35	779.03	722.72	50′	5,076.95	1,214.96	1,083.34
44°	4,040.26	785.35	728.16	54°	5,095.25	1,223.26	1,089.94
10′	4,057.19	791.70	733.62	10′	5,113.59	1,231.60	1,096.55
20′	4,074.14	798.08	739.10	20′	5,131.95	1,239.97	1,103.18
30′	4,091.11	804.50	744.60	30′	5,150.34	1,248.38	1,109.83
40′	4,108.10	810.94	750.11	40′	5,168.76	1,256.82	1,116.50
50′	4,125.11	817.42	755.65	50′	5,187.20	1,265.30	1,123.19
45°	4,142.14	823.92	761.21	55°	5,205.67	1,273.82	1,129.89
10′	4,159.19	830.46	766.78	10′	5,224.17	1,282.37	1,136.62
20′	4,176.26	837.03	772.38	20′	5,242.70	1,290.97	1,143.36
30′	4,193.35	843.62	777.99	30′	5,261.26	1,299.59	1,150.12
40′	4,210.46	850.25	783.63	40′	5,279.84	1,308.26	1,156.91
50′	4,227.59	856.91	789.28	50′	5,298.45	1,316.96	1,163.71
46°	4,244.75	863.60	794.95	56°	5,317.09	1,325.70	1,170.52
10′	4,261.92	870.32	800.64	10′	5,335.77	1,334.48	1,177.36
20′	4,279.12	877.08	806.36	20′	5,354.47	1,343.29	1,184.22
30′	4,296.34	883.87	812.09	30′	5,373.19	1,352.15	1,191.09
40′	4,313.58	890.68	817.84	40′	5,391.95	1,361.04	1,197.99
50′	4,330.84	897.53	823.61	50′	5,410.74	1,369.97	1,204.90
47°	4,348.12	904.41	829.40	57°	5,429.56	1,378.93	1,211.83
10′	4,365.43	911.32	835.21	10′	5,448.40	1,387.94	1,218.78
20′	4,382.76	918.27	841.04	20′	5,467.28	1,396.98	1,225.75
30′	4,400.11	925.24	846.89	30′	5,486.19	1,406.06	1,232.73
40′	4,417.48	932.25	852.75	40′	5,505.13	1,415.18	1,239.74
50′	4,434.87	939.29	858.64	50′	5,524.09	1,424.34	1,246.76
48°	4,452.29	946.36	864.55	58°	5,543.09	1,433.54	1,253.80
10′	4,469.73	953.47	870.47	10′	5,562.12	1,442.78	1,260.86
20′	4,487.19	960.60	876.42	20′	5,581.18	1,452.06	1,267.94
30′	4,504.67	967.77	882.38	30′	5,600.27	1,461.37	1,275.04
40′	4,522.18	974.98	888.36	40′	5,619.39	1,470.73	1,282.16
50′	4,539.71	982.21	894.37	50′	5,638.54	1,480.12	1,289.29
49°	4,557.26	989.48	900.39	59°	5,657.73	1,489.56	1,296.44
10′	4,574.84	996.78	906.43	10′	5,676.94	1,499.03	1,303.61
20′	4,592.44	1,004.11	912.49	20′	5,696.19	1,508.54	1,310.80
30′	4,610.06	1,011.48	918.57	30′	5,715.47	1,518.10	1,318.01
40′	4,627.71	1,018.88	924.67	40′	5,734.78	1,527.69	1,325.24
50′	4,645.38	1,026.31	930.79	50′	5,754.13	1,537.33	1,332.48

TANGENTS, EXTERNALS AND MIDDLE ORDINATES FOR 10,000 FT. RADIUS CURVE. TABLE I.

Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.	Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.
60°	5,773.50	1,547.01	1,339.75	70°	7,002.08	2,207.75	1,808.48
10′	5,792.91	1,556.72	1,347.03	10′	7,023.77	2,220.20	1,816.83
20′	5,812.35	1,566.48	1,354.33	20′	7,045.52	2,232.71	1,825.20
30′	5,831.83	1,576.28	1,361.65	30′	7,067.30	2,245.27	1,833.58
40′	5,851.34	1,586.12	1,368.98	40′	7,089.13	2,257.89	1,841.99
50′	5,870.88	1,596.00	1,376.34	50′	7,111.01	2,270.55	1,850.41
61°	5,890.45	1,605.92	1,383.71	71°	7,132.93	2,283.27	1,858.85
10′	5,910.06	1,615.89	1,391.10	10′	7,154.90	2,296.04	1,867.30
20′	5,929.70	1,625.89	1,398.51	20′	7,176.91	2,308.86	1,875.77
30′	5,949.38	1,635.94	1,405.94	30′	7,198.97	2,321.74	1,884.26
40′	5,969.08	1,646.03	1,413.38	40′	7,221.08	2,334.66	1,892.77
50′	5,988.83	1,656.16	1,420.85	50′	7,243.23	2,347.65	1,901.29
62°	6,008.61	1,666.33	1,428.33	72°	7,265.43	2,360.68	1,909.83
10′	6,028.42	1,676.55	1,435.83	10′	7,287.67	2,373.77	1,918.39
20′	6,048.27	1,686.81	1,443.35	20′	7,309.96	2,386.91	1,926.96
30′	6,068.15	1,697.11	1,450.88	30′	7,332.30	2,400.11	1,935.55
40′	6,088.07	1,707.46	1,458.44	40′	7,354.69	2,413.36	1,944.16
50′	6,108.02	1,717.85	1,466.01	50′	7,377.13	2,426.67	1,952.79
63°	6,128.01	1,728.28	1,473.60	73°	7,399.61	2,440.03	1,961.43
10′	6,148.03	1,738.75	1,481.21	10′	7,422.14	2,453.44	1,970.09
20′	6,168.09	1,749.27	1,488.83	20′	7,444.72	2,466.91	1,978.77
30′	6,188.19	1,759.83	1,496.48	30′	7,467.35	2,480.44	1,987.46
40′	6,208.32	1,770.44	1,504.14	40′	7,490.03	2,494.02	1,996.17
50′	6,228.49	1,781.09	1,511.82	50′	7,512.76	2,507.66	2,004.90
64°	6,248.69	1,791.78	1,519.52	74°	7,535.54	2,521.36	2,013.65
10′	6,268.94	1,802.52	1,527.24	10′	7,558.37	2,535.11	2,022.41
20′	6,289.21	1,813.31	1,534.97	20′	7,581.25	2,548.92	2,031.19
30′	6,309.53	1,824.14	1,542.72	30′	7,604.18	2,562.78	2,039.98
40′	6,329.88	1,835.01	1,550.49	40′	7,627.16	2,576.71	2,048.79
50′	6,350.27	1,845.93	1,558.28	50′	7,650.19	2,590.69	2,057.62
65°	6,370.70	1,856.89	1,566.09	75°	7,673.27	2,604.72	2,066.47
10′	6,391.17	1,867.90	1,573.91	10′	7,696.40	2,618.82	2,075.33
20′	6,411.67	1,878.95	1,581.75	20′	7,719.59	2,632.98	2,084.21
30′	6,432.22	1,890.06	1,589.61	30′	7,742.83	2,647.19	2,093.10
40′	6,452.80	1,901.20	1,597.49	40′	7,766.12	2,661.46	2,102.02
50′	6,473.42	1,912.39	1,605.38	50′	7,789.46	2,675.79	2,110.95
66°	6,494.08	1,923.63	1,613.29	76°	7,812.86	2,690.18	2,119.89
10′	6,514.77	1,934.92	1,621.23	10′	7,836.31	2,704.63	2,128.86
20′	6,535.51	1,946.25	1,629.17	20′	7,859.81	2,719.14	2,137.84
30′	6,556.28	1,957.63	1,637.14	30′	7,883.36	2,733.71	2,146.83
40′	6,577.10	1,969.06	1,645.12	40′	7,906.98	2,748.34	2,155.84
50′	6,597.96	1,980.53	1,653.12	50′	7,930.64	2,763.03	2,164.87
67°	6,618.86	1,992.05	1,661.14	77°	7,954.36	2,777.79	2,173.92
10′	6,639.79	2,003.62	1,669.18	10′	7,978.13	2,792.60	2,182.98
20′	6,660.77	2,015.23	1,677.23	20′	8,001.96	2,807.48	2,192.06
30′	6,681.79	2,026.90	1,685.30	30′	8,025.85	2,822.41	2,201.16
40′	6,702.85	2,038.61	1,693.39	40′	8,049.79	2,837.41	2,210.27
50′	6,723.94	2,050.37	1,701.50	50′	8,073.79	2,852.47	2,219.40
68°	6,745.09	2,062.18	1,709.62	78°	8,097.84	2,867.60	2,228.54
10′	6,766.27	2,074.04	1,717.77	10′	8,121.95	2,882.78	2,237.70
20′	6,787.49	2,085.94	1,725.93	20′	8,146.12	2,898.03	2,246.88
30′	6,808.76	2,097.90	1,734.10	30′	8,170.34	2,913.35	2,256.07
40′	6,830.07	2,109.91	1,742.30	40′	8,194.62	2,928.72	2,265.28
50′	6,851.42	2,121.96	1,750.51	50′	8,218.97	2,944.16	2,274.51
69°	6,872.81	2,134.06	1,758.74	79°	8,243.36	2,959.67	2,283.75
10′	6,894.25	2,146.22	1,766.99	10′	8,267.82	2,975.24	2,293.01
20′	6,915.73	2,158.42	1,775.25	20′	8,292.34	2,990.88	2,302.29
30′	6,937.25	2,170.68	1,783.53	30′	8,316.91	3,006.58	2,311.58
40′	6,958.81	2,182.98	1,791.83	40′	8,341.55	3,022.34	2,320.89
50′	6,980.42	2,195.34	1,800.15	50′	8,366.24	3,038.18	2,330.22

TANGENTS, EXTERNALS AND MIDDLE ORDINATES FOR 10,000 FT. RADIUS CURVE. TABLE I.

Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.	Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.
80°	8,391.00	3,054.07	2,339.56	90°	10,000.00	4,142.14	2,928.93
10′	8,415.81	3,070.04	2,348.91	10′	10,029.13	4,162.75	2,939.22
20′	8,440.69	3,086.07	2,358.29	20′	10,058.35	4,183.45	2,949.53
30′	8,465.63	3,102.17	2,367.68	30′	10,087.65	4,204.25	2,959.85
40′	8,490.62	3,118.33	2,377.08	40′	10,117.04	4,225.13	2,970.19
50′	8,515.68	3,134.57	2,386.50	50′	10,146.51	4,256.11	2,980.54
81°	8,540.81	3,150.87	2,395.94	91°	10,176.07	4,267.18	2,990.91
10′	8,565.99	3,167.24	2,405.39	10′	10,205.72	4,288.35	3,001.29
20′	8,591.24	3,183.68	2,414.86	20′	10,235.46	4,309.60	3,011.69
30′	8,616.55	3,200.19	2,424.35	30′	10,265.29	4,330.95	3,022.10
40′	8,641.93	3,216.77	2,433.85	40′	10,295.20	4,352.39	3,032.52
50′	8,667.37	3,233.41	2,443.37	50′	10,325.21	4,373.93	3,042.96
82°	8,692.87	3,250.13	2,452.90	92°	10,355.30	4,395.57	3,053.42
10′	8,718.44	3,266.92	2,462.45	10′	10,385.49	4,417.30	3,063.89
20′	8,744.07	3,283.78	2,472.02	20′	10,415.77	4,439.12	3,074.37
30′	8,769.77	3,300.71	2,481.60	30′	10,446.14	4,461.04	3,084.87
40′	8,795.53	3,317.71	2,491.20	40′	10,476.60	4,483.06	3,095.38
50′	8,821.36	3,334.78	2,500.81	50′	10,507.15	4,505.18	3,105.91
83°	8,847.25	3,351.92	2,510.44	93°	10,537.80	4,527.40	3,116.45
10′	8,873.22	3,369.14	2,520.09	10′	10,568.54	4,549.71	3,127.01
20′	8,899.24	3,386.43	2,529.75	20′	10,599.38	4,572.13	3,137.58
30′	8,925.34	3,403.80	2,539.43	30′	10,630.31	4,594.64	3,148.17
40′	8,951.51	3,421.23	2,549.12	40′	10,661.34	4,617.26	3,158.77
50′	8,977.74	3,438.74	2,558.83	50′	10,692.47	4,639.97	3,169.39
84°	9,004.04	3,456.33	2,568.55	94°	10,723.69	4,662.79	3,180.02
10′	9,030.41	3,473.99	2,578.29	10′	10,755.01	4,685.71	3,190.66
20′	9,056.85	3,491.72	2,588.05	20′	10,786.42	4,708.74	3,201.32
30′	9,083.36	3,509.53	2,597.82	30′	10,817.94	4,731.86	3,211.99
40′	9,109.94	3,527.42	2,607.61	40′	10,849.55	4,755.10	3,222.68
50′	9,136.59	3,545.38	2,617.41	50′	10,881.27	4,778.43	3,233.38
85°	9,163.31	3,563.42	2,627.23	95°	10,913.09	4,801.87	3,244.10
10′	9,190.10	3,581.53	2,637.06	10′	10,945.00	4,825.42	3,254.83
20′	9,216.97	3,599.73	2,646.91	20′	10,977.02	4,849.07	3,265.57
30′	9,243.91	3,618.00	2,656.78	30′	11,009.14	4,872.83	3,276.33
40′	9,270.91	3,636.34	2,666.66	40′	11,041.37	4,896.70	3,287.11
50′	9,298.00	3,654.77	2,676.55	50′	11,073.69	4,920.68	3,297.89
86°	9,325.15	3,673.28	2,686.46	96°	11,106.13	4,944.77	3,308.69
10′	9,352.38	3,691.86	2,696.39	10′	11,138.66	4,968.96	3,319.51
20′	9,379.68	3,710.52	2,706.33	20′	11,171.31	4,993.27	3,330.34
30′	9,407.06	3,729.27	2,716.29	30′	11,204.05	5,017.68	3,341.18
40′	9,434.51	3,748.09	2,726.26	40′	11,236.91	5,042.21	3,352.04
50′	9,462.04	3,767.00	2,736.25	50′	11,269.87	5,066.85	3,362.91
87°	9,489.65	3,785.99	2,746.26	97°	11,302.94	5,091.61	3,373.80
10′	9,517.33	3,805.05	2,756.28	10′	11,336.12	5,116.47	3,384.70
20′	9,545.08	3,824.20	2,766.31	20′	11,369.41	5,141.45	3,395.61
30′	9,572.92	3,843.44	2,776.36	30′	11,402.82	5,166.56	3,406.54
40′	9,600.83	3,862.75	2,786.43	40′	11,436.33	5,191.76	3,417.48
50′	9,628.82	3,882.15	2,796.51	50′	11,469.95	5,217.09	3,428.44
88°	9,656.89	3,901.64	2,806.60	98°	11,503.68	5,242.53	3,439.41
10′	9,685.04	3,921.20	2,816.71	10′	11,537.53	5,268.09	3,450.39
20′	9,713.26	3,940.86	2,826.84	20′	11,571.50	5,293.77	3,461.39
30′	9,741.57	3,960.59	2,836.98	30′	11,605.57	5,319.57	3,472.40
40′	9,769.96	3,980.42	2,847.14	40′	11,639.76	5,345.49	3,483.43
50′	9,798.42	4,000.33	2,857.31	50′	11,674.07	5,371.53	3,494.47
89°	9,826.97	4,020.32	2,867.50	99°	11,708.50	5,397.69	3,505.52
10′	9,855.60	4,040.40	2,877.70	10′	11,743.04	5,423.97	3,516.59
20′	9,884.32	4,060.57	2,887.91	20′	11,777.70	5,450.38	3,527.67
30′	9,913.11	4,080.83	2,898.15	30′	11,812.48	5,476.91	3,538.76
40′	9,941.99	4,101.18	2,908.39	40′	11,847.38	5,503.56	3,549.87
50′	9,970.95	4,121.61	2,918.66	50′	11,882.40	5,530.34	3,560.99

TANGENTS, EXTERNALS AND MIDDLE ORDINATES FOR 10,000 FT. RADIUS CURVE. TABLE I.

Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.
100°	11,917.54	5,557.24	3,572.12
10′	11,952.80	5,584.27	3,583.27
20′	11,988.18	5,611.42	3,594.43
30′	12,023.69	5,638.71	3,605.61
40′	12,059.33	5,666.12	3,616.80
50′	12,095.09	5,693.66	3,628.00
101°	12,130.97	5,721.34	3,639.22
10′	12,166.98	5,749.14	3,650.45
20′	12,203.12	5,777.08	3,661.69
30′	12,239.39	5,805.15	3,672.95
40′	12,275.79	5,833.35	3,684.22
50′	12,312.31	5,861.69	3,695.50
102°	12,348.97	5,890.16	3,706.80
10′	12,385.76	5,918.77	3,718.11
20′	12,422.69	5,947.51	3,729.43
30′	12,459.74	5,976.39	3,740.77
40′	12,496.93	6,005.42	3,752.12
50′	12,534.26	6,034.58	3,763.48
103°	12,571.72	6,063.88	3,774.85
10′	12,609.32	6,093.32	3,786.24
20′	12,647.06	6,122.91	3,797.65
30′	12,684.94	6,152.64	3,809.06
40′	12,722.96	6,182.51	3,820.49
50′	12,761.12	6,212.53	3,831.93
104°	12,799.42	6,242.69	3,843.39
10′	12,837.86	6,273.00	3,854.85
20′	12,876.45	6,303.46	3,866.33
30′	12,915.18	6,334.07	3,877.83
40′	12,954.06	6,364.83	3,889.33
50′	12,993.08	6,395.74	3,900.85
105°	13,032.25	6,426.80	3,912.39
10′	13,071.58	6,458.01	3,923.93
20′	13,111.05	6,489.38	3,935.49
30′	13,150.67	6,520.90	3,947.06
40′	13,190.44	6,552.58	3,958.64
50′	13,230.37	6,584.41	3,970.24
106°	13,270.45	6,616.40	3,981.85
10′	13,310.68	6,648.55	3,993.47
20′	13,351.08	6,680.86	4,005.11
30′	13,391.62	6,713.34	4,016.75
40′	13,432.33	6,745.97	4,028.41
50′	13,473.20	6,778.77	4,040.09
107°	13,514.22	6,811.73	4,051.77
10′	13,555.41	6,844.86	4,063.47
20′	13,596.76	6,878.15	4,075.18
30′	13,638.28	6,911.61	4,086.90
40′	13,679.96	6,945.24	4,098.64
50′	13,721.81	6,979.04	4,110.39
108°	13,763.82	7,013.02	4,122.15
10′	13,806.00	7,047.16	4,133.92
20′	13,848.35	7,081.48	4,145.71
30′	13,890.88	7,115.97	4,157.50
40′	13,933.57	7,150.64	4,169.31
50′	13,976.44	7,185.48	4,181.14
109°	14,019.48	7,220.51	4,192.97
10′	14,062.70	7,255.71	4,204.82
20′	14,106.10	7,291.10	4,216.68
30′	14,149.67	7,326.66	4,228.55
40′	14,193.43	7,362.41	4,240.43
50′	14,237.36	7,398.35	4,252.33

Cen. Angle (Delta)	Radius = 10,000 Ft. Tan.	Ext.	Mid. Ord.
110°	14,281.48	7,434.47	4,264.24
10′	14,325.78	7,470.78	4,276.16
20′	14,370.27	7,507.27	4,288.09
30′	14,414.94	7,543.96	4,300.03
40′	14,459.80	7,580.84	4,311.99
50′	14,504.85	7,617.91	4,323.96
111°	14,550.09	7,655.17	4,335.94
10′	14,595.52	7,692.63	4,347.93
20′	14,641.15	7,730.29	4,359.93
30′	14,686.97	7,768.15	4,371.95
40′	14,732.98	7,806.20	4,383.98
50′	14,779.20	7,844.46	4,396.02
112°	14,825.61	7,882.92	4,408.07
10′	14,872.22	7,921.58	4,420.14
20′	14,919.04	7,960.45	4,432.21
30′	14,966.06	7,999.52	4,444.30
40′	15,013.28	8,038.81	4,456.40
50′	15,060.71	8,078.30	4,468.51
113°	15,108.35	8,118.01	4,480.63
10′	15,156.20	8,157.93	4,492.76
20′	15,204.26	8,198.07	4,504.91
30′	15,252.54	8,238.42	4,517.07
40′	15,301.02	8,278.99	4,529.24
50′	15,349.73	8,319.77	4,541.42
114°	15,398.65	8,360.79	4,553.61
10′	15,447.79	8,402.02	4,565.81
20′	15,497.16	8,443.48	4,578.03
30′	15,546.74	8,485.16	4,590.26
40′	15,596.55	8,527.07	4,602.49
50′	15,646.59	8,569.22	4,614.74
115°	15,696.86	8,611.59	4,627.00
10′	15,747.35	8,654.20	4,639.28
20′	15,798.08	8,697.04	4,651.56
30′	15,849.04	8,740.12	4,663.86
40′	15,900.24	8,783.44	4,676.16
50′	15,951.67	8,827.00	4,688.48
116°	16,003.35	8,870.80	4,700.81
10′	16,055.26	8,914.85	4,713.15
20′	16,107.42	8,959.14	4,725.50
30′	16,159.82	9,003.68	4,737.86
40′	16,212.47	9,048.47	4,750.23
50′	16,265.37	9,093.51	4,762.62
117°	16,318.52	9,138.81	4,775.01
10′	16,371.92	9,184.36	4,787.42
20′	16,425.58	9,230.17	4,799.84
30′	16,479.49	9,276.24	4,812.27
40′	16,533.66	9,322.58	4,824.71
50′	16,588.10	9,369.18	4,837.16
118°	16,642.80	9,416.04	4,849.62
10′	16,697.76	9,463.17	4,862.09
20′	16,752.99	9,510.58	4,874.58
30′	16,808.49	9,558.25	4,887.07
40′	16,864.26	9,606.21	4,899.57
50′	16,920.31	9,654.44	4,912.09
119°	16,976.63	9,702.94	4,924.62
10′	17,033.23	9,751.74	4,937.15
20′	17,090.12	9,800.81	4,949.70
30′	17,147.28	9,850.17	4,962.26
40′	17,204.74	9,899.82	4,974.83
50′	17,262.48	9,949.76	4,987.41

LENGTH OF CIRCULAR ARCS FOR THE RADIUS 1. TABLE II.

DEGREES									MINUTES			SECONDS		
0°	0.000	0000	60°	1.047	1976	120°	2.094	3951	0′	0.000	0000	0″	0.000	0000
1	0.017	4533	61	1.064	6508	121	2.111	8484	1	0.000	2909	1	0.000	0048
2	0.034	9066	62	1.082	1041	122	2.129	3017	2	0.000	5818	2	0.000	0097
3	0.052	3599	63	1.099	5574	123	2.146	7550	3	0.000	8727	3	0.000	0145
4	0.069	8132	64	1.117	0107	124	2.164	2083	4	0.001	1636	4	0.000	0194
5	0.087	2665	65	1.134	4640	125	2.181	6616	5	0.001	4544	5	0.000	0242
6	0.104	7198	66	1.151	9173	126	2.199	1149	6	0.001	7453	6	0.000	0291
7	0.122	1730	67	1.169	3706	127	2.216	5682	7	0.002	0362	7	0.000	0339
8	0.139	6263	68	1.186	8239	128	2.234	0214	8	0.002	3271	8	0.000	0388
9	0.157	0796	69	1.204	2772	129	2.251	4747	9	0.002	6180	9	0.000	0436
10	0.174	5329	70	1.221	7305	130	2.268	9280	10	0.002	9089	10	0.000	0485
11	0.191	9862	71	1.239	1838	131	2.286	3813	11	0.003	1998	11	0.000	0533
12	0.209	4395	72	1.256	6371	132	2.303	8346	12	0.003	4907	12	0.000	0582
13	0.226	8928	73	1.274	0904	133	2.321	2879	13	0.003	7815	13	0.000	0630
14	0.244	3461	74	1.291	5436	134	2.338	7412	14	0.004	0724	14	0.000	0679
15	0.261	7994	75	1.308	9969	135	2.356	1945	15	0.004	3633	15	0.000	0727
16	0.279	2527	76	1.326	4502	136	2.373	6478	16	0.004	6542	16	0.000	0776
17	0.296	7060	77	1.343	9035	137	2.391	1011	17	0.004	9451	17	0.000	0824
18	0.314	1593	78	1.361	3568	138	2.408	5544	18	0.005	2360	18	0.000	0873
19	0.331	6126	79	1.378	8101	139	2.426	0077	19	0.005	5269	19	0.000	0921
20	0.349	0659	80	1.396	2634	140	2.443	4610	20	0.005	8178	20	0.000	0970
21	0.366	5191	81	1.413	7167	141	2.460	9142	21	0.006	1087	21	0.000	1018
22	0.383	9724	82	1.431	1700	142	2.478	3675	22	0.006	3995	22	0.000	1067
23	0.401	4257	83	1.448	6233	143	2.495	8208	23	0.006	6904	23	0.000	1115
24	0.418	8790	84	1.466	0766	144	2.513	2741	24	0.006	9813	24	0.000	1164
25	0.436	3323	85	1.483	5299	145	2.530	7274	25	0.007	2722	25	0.000	1212
26	0.453	7856	86	1.500	9832	146	2.548	1807	26	0.007	5631	26	0.000	1261
27	0.471	2389	87	1.518	4364	147	2.565	6340	27	0.007	8540	27	0.000	1309
28	0.488	6922	88	1.535	8897	148	2.583	0873	28	0.008	1449	28	0.000	1357
29	0.506	1455	89	1.553	3430	149	2.600	5406	29	0.008	4358	29	0.000	1406
30	0.523	5988	90	1.570	7963	150	2.617	9939	30	0.008	7266	30	0.000	1454

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LENGTH OF CIRCULAR ARCS FOR THE RADIUS 1. TABLE II.

DEGREES									MINUTES			SECONDS		
31°	0.541	0521	91°	1.588	2496	151°	2.635	4472	31	0.009	0175	31"	0.000	1503
32	0.558	5054	92	1.605	7029	152	2.652	9005	32	0.009	3084	32	0.000	1551
33	0.575	9587	93	1.623	1562	153	2.670	3538	33	0.009	5993	33	0.000	1600
34	0.593	4119	94	1.640	6095	154	2.687	8070	34	0.009	8902	34	0.000	1648
35	0.610	8652	95	1.658	0628	155	2.705	2603	35	0.010	1811	35	0.000	1697
36	0.628	3185	96	1.675	5161	156	2.722	7136	36	0.010	4720	36	0.000	1745
37	0.645	7718	97	1.692	9694	157	2.740	1669	37	0.010	7629	37	0.000	1794
38	0.663	2251	98	1.710	4227	158	2.757	6202	38	0.011	0538	38	0.000	1842
39	0.680	6784	99	1.727	8760	159	2.775	0735	39	0.011	3446	39	0.000	1891
40	0.698	1317	100	1.745	3293	160	2.792	5268	40	0.011	6355	40	0.000	1939
41	0.715	5850	101	1.762	7825	161	2.809	9801	41	0.011	9264	41	0.000	1988
42	0.733	0383	102	1.780	2358	162	2.827	4334	42	0.012	2173	42	0.000	2036
43	0.750	4916	103	1.797	6891	163	2.844	8867	43	0.012	5082	43	0.000	2085
44	0.767	9449	104	1.815	1424	164	2.862	3400	44	0.012	7991	44	0.000	2133
45	0.785	3982	105	1.832	5957	165	2.879	7933	45	0.013	0900	45	0.000	2182
46	0.802	8515	106	1.850	0490	166	2.897	2466	46	0.013	3809	46	0.000	2230
47	0.820	3047	107	1.867	5023	167	2.914	6999	47	0.013	6717	47	0.000	2279
48	0.837	7580	108	1.884	9556	168	2.932	1531	48	0.013	9626	48	0.000	2327
49	0.855	2113	109	1.902	4089	169	2.949	6064	49	0.014	2535	49	0.000	2376
50	0.872	6646	110	1.919	8622	170	2.967	0597	50	0.014	5444	50	0.000	2424
51	0.890	1179	111	1.937	3155	171	2.984	5130	51	0.014	8353	51	0.000	2473
52	0.907	5712	112	1.954	7688	172	3.001	9663	52	0.015	1262	52	0.000	2521
53	0.925	0245	113	1.972	2221	173	3.019	4196	53	0.015	4171	53	0.000	2570
54	0.942	4778	114	1.989	6753	174	3.036	8729	54	0.015	7080	54	0.000	2618
55	0.959	9311	115	2.007	1286	175	3.054	3262	55	0.015	9989	55	0.000	2666
56	0.977	3844	116	2.024	5819	176	3.071	7795	56	0.016	2897	56	0.000	2715
57	0.994	8377	117	2.042	0352	177	3.089	2328	57	0.016	5806	57	0.000	2762
58	1.012	2910	118	2.059	4885	178	3.106	6861	58	0.016	8715	58	0.000	2812
59	1.029	7443	119	2.076	9418	179	3.124	1394	59	0.017	1624	59	0.000	2860
60	1.047	1976	120	2.094	3951	180	3.141	5927	60	0.017	4533	60	0.000	2909

LENGTH OF CHORD FOR ARCS OF 10′, 25′, 50′, 75′, 100′, AND 200′. TABLE III.

Radius	Arc=10′ Chord=	Arc=25′ Chord=	Arc=50′ Chord=	Arc=75′ Chord=	Arc=100′ Chord=	Arc=200′ Chord=
25′	9.934	23.971	42.074	49.875		
30′	9.954	24.283	44.411	56.939		
35′	9.966	24.472	45.856	61.452	69.293	
40′	9.974	24.595	46.808	64.487	75.919	
45′	9.979	24.680	47.467	66.616	80.657	
50′	9.983	24.741	47.944	68.164	84.147	
55′	9.986	24.786	48.296	69.323	86.785	
60′	9.988	24.820	48.566	70.212	88.821	
65′	9.990	24.847	48.777	70.908	90.427	129.932
70′	9.992	24.867	48.944	71.464	91.711	138.586
75′	9.993	24.884	49.079	71.914	92.755	145.792
80′	9.994	24.898	49.190	72.283	93.616	151.838
85′	9.994	24.910	49.282	72.591	94.332	156.953
90′	9.995	24.920	49.360	72.849	94.935	161.315
95′	9.995	24.928	49.425	73.067	95.447	165.059
100′	9.996	24.935	49.481	73.255	95.885	168.294
110′	9.997	24.946	49.571	73.556	96.592	173.569
120′	9.997	24.955	49.639	73.785	97.132	177.642
130′	9.998	24.962	49.693	73.965	97.553	180.852
140′	9.998	24.967	49.735	74.107	97.887	183.422
150′	9.998	24.971	49.769	74.221	98.159	185.512

Continued Below

Radius	Arc=50′ Chord=	Arc=75′ Chord=	Arc=100′ Chord=	Arc=200′ Chord=
700′	49.990	74.964	99.916	199.322
750′	49.991	74.969	99.927	199.410
800′	49.992	74.973	99.935	199.479
850′	49.993	74.976	99.942	199.539
900′	49.993	74.979	99.948	199.588
950′	49.994	74.981	99.954	199.632
1,000′	49.995	74.982	99.960	199.670
1,100′	49.996	74.985	99.966	199.726
1,200′	49.997	74.988	99.972	199.769
1,300′	49.997		99.976	199.804
1,400′	49.998		99.980	199.830
1,500′	49.998	74.993	99.982	199.852
1,600′	49.998		99.984	199.870
1,700′	49.998		99.985	199.884
1,800′	49.998	74.995	99.987	199.898
1,900′	49.999		99.989	199.908
2,000′	49.999		99.990	199.918
2,100′		74.996	99.991	199.924
2,200′			99.993	199.933
2,300′				199.938
2,400′		74.997	99.994	199.943

Continued Below

LENGTH OF CHORD FOR ARCS OF 10′, 25′, 50′, 75′, 100′, AND 200′. TABLE III.

Radius	Arc=10′ Chord=	Arc=25′ Chord=	Arc=50′ Chord=	Chord= Arc=75′	Arc=100′ Chord=	Arc=200′ Chord=	Radius	Arc=50′ Chord=	Arc=75′ Chord=	Arc=100′ Chord=	Arc=200′ Chord=
160′	9.998	24.975	49.797	74.316	98.380	187.231	2,500′				199.947
170′	9.999	24.977	49.820	74.393	98.564	188.664	2,600′			99.994	199.952
180′	9.999	24.980	49.839	74.459	98.719	189.870	2,700′		74.998		199.955
190′	9.999	24.982	49.856	74.514	98.850	190.893	2,800′			99.995	199.957
200′	9.999	24.984	49.870	74.562	98.962	191.771	2,900′				
225′		24.987	49.898	74.654	99.180	193.482	3,000′		74.998	99.996	199.964
250′		24.990	49.917	74.719	99.335	194.709	3,100′				199.967
275′		24.992	49.932	74.768	99.451	195.623	3,200′			99.996	199.968
300′		24.993	49.942	74.805	99.538	196.317	3,300′		74.999		
325′		24.994	49.951	74.835	99.607	196.861	3,400′			99.996	199.970
350′		24.995	49.958	74.857	99.661	197.291	3,500′				
375′		24.996	49.963	74.876	99.705	197.640	3,600′			99.997	199.974
400′		24.996	49.968	74.890	99.740	197.923	3,700′				199.976
425′		24.996	49.971	74.903	99.769	198.159	3,800′			99.997	199.978
450′		24.997	49.974	74.913	99.794	198.358	3,900′				
475′		24.997	49.977	74.923	99.816	198.527	4,000′			99.998	199.980
500′		24.998	49.980	74.931	99.835	198.673	5,000′				199.987
550′		24.998	49.983	74.943	99.863	198.901	6,000′				199.992
600′		24.999	49.986	74.951	99.884	199.075	8,000′				199.995
650′		24.999	49.988	74.958	99.902	199.214	10,000′				199.997

DEFLECTIONS PER FOOT OF ARC FOR RADII FROM 25 FT. TO 40,000 FT. TABLE IV.

Radius of Curve	Defl. in Min. Per Ft.	Radius of Curve	Defl. in Min. Per Ft.	Radius of Curve	Defl. in Min. Per Ft.	Radius of Curve	Defl. in Min. Per Ft.
25′	68.7549	600′	2.8648	4,000′	0.4297	12,000′	0.1432
30′	57.2958	650′	2.6445	4,100′	0.4192	12,500′	0.1375
35′	49.1107	700′	2.4555	4,200′	0.4093	13,000′	0.1322
40′	42.9718	750′	2.2918	4,300′	0.3997	13,500′	0.1273
45′	38.1972	800′	2.1486	4,400′	0.3907	14,000′	0.1228
50′	34.3775	850′	2.0222	4,500′	0.3820	14,500′	0.1185
55′	31.2522	900	1.9099	4,600′	0.3737	15,000′	0.1146
60′	28.6479	950′	1.8093	4,700′	0.3657	16,000′	0.1074
65′	26.4442	1,000′	1.7189	4,800′	0.3581	17,000′	0.1011
70′	24.5553	1,100′	1.5626	4,900′	0.3508	18,000′	0.0955
75′	22.9183	1,200′	1.4324	5,000′	0.3438	19,000′	0.0905
80′	21.4859	1,300′	1.3222	5,200′	0.3306	20,000′	0.0859
85′	20.2220	1,400′	1.2278	5,400′	0.3183	21,000′	0.0819
90′	19.0986	1,500′	1.1459	5,600′	0.3069	22,000′	0.0781
95′	18.0934	1,600′	1.0743	5,800′	0.2964	23,000′	0.0747
100′	17.1887	1,700′	1.0111	6,000′	0.2865	24,000′	0.0716
110′	15.6262	1,800′	0.9549	6,200′	0.2772	25,000′	0.0688
120′	14.3240	1,900′	0.9047	6,400′	0.2686	26,000′	0.0661
130′	13.2221	2,000′	0.8594	6,600′	0.2604	27,000′	0.0637
140′	12.2777	2,100′	0.8185	6,800′	0.2528	28,000′	0.0614
150′	11.4592	2,200′	0.7813	7,000′	0.2456	29,000′	0.0593
160′	10.7430	2,300′	0.7473	7,200′	0.2387	30,000′	0.0573
170′	10.1110	2,400′	0.7162	7,400′	0.2323	31,000′	0.0555
180′	9.5493	2,500′	0.6875	7,600′	0.2262	32,000′	0.0537
190′	9.0467	2,600′	0.6611	7,800′	0.2204	33,000′	0.0521
200′	8.5944	2,700′	0.6366	8,000′	0.2149	34,000′	0.0506
225′	7.6395	2,800′	0.6139	8,200′	0.2096	35,000′	0.0491
250′	6.8755	2,900′	0.5927	8,400′	0.2046	36,000′	0.0478
275′	6.2505	3,000′	0.5730	8,600′	0.1999	37,000′	0.0465
300′	5.7296	3,100′	0.5545	8,800′	0.1953	38,000′	0.0452
325′	5.2889	3,200′	0.5371	9,000′	0.1910	39,000′	0.0441
350′	4.9111	3,300′	0.5209	9,200′	0.1868	40,000′	0.0430
375′	4.5837	3,400′	0.5056	9,400′	0.1829		
400′	4.2972	3,500′	0.4911	9,600′	0.1790		
425′	4.0444	3,600′	0.4775	9,800′	0.1754		
450′	3.8197	3,700′	0.4646	10,000′	0.1719		
475	3.6187	3,800′	0.4523	10,500′	0.1637		
500′	3.4378	3,900′	0.4407	11,000′	0.1563		
550′	3.1253	4,000′	0.4297	11,500′	0.1495		
600′	2.8648			12,000′	0.1432		

ENGINEERING CONSTANTS

0 deg. C. (32° F.) = freezing point of water

100 deg. C. (212° F.) = boiling point of water at atmospheric pressure

1.8 Fahrenheit degrees = 1 Centigrade degree

—270 deg. C. = absolute zero

33,000 ft. Lb. per min. = 1 horsepower (hp.)

550 ft. Lb. per second = 1 hp.

1.3410 hp. = 1 kilowatt (kw.)

745.7 watts = 1 hp.

777.5 ft. Lbs. = 1 B.t.u.

2,545 (2,547) B.t.u. per hr. = 1 hp.

3.1416 = π (Greek letter "pi") = ratio circumference of circle to diameter = ratio area of circle to square of radius.

2.54 cm. = 1 inch.

39.37 in. = 1 meter = 100 cm.

10.764 sq. ft. = 1 sq. meter

3.785 liters = 1 gal.

0.62137 miles = 1 kilometer

SURVEYOR'S MEASURE EQUIVALENTS

7.92 inches = 1 link
25.0 links = 1 rod
4.0 rods = 1 chain
10.0 chains or 220 yards = 1 furlong
8 furlongs (80 ch.) = 1 mile
10 square chains = 1 acre
640 acres = 1 square mile

LINEAR MEASURE EQUIVALENTS

Inches	Feet	Yards	Rods	Furlongs	Miles
1	0.0833	0.0278	0.00505	0.000126	0.0000158
12	1.0	0.3333	0.06061	0.001515	0.0001894
36	3.0	1.0	0.18182	0.004545	0.0005682
198	16.5	5.5	1.0	0.025	0.003125
7920	660.0	220.0	40.0	1.0	0.125
63360	5280.0	1760.0	320.0	8.0	1.0

1 nautical mile = 1/60 of 1° of latitude at the equator = 1.1516 statute miles = 6080.27 ft.

1 acre = 208.71 ft. on one side of square.

METRIC UNITS AN EQUIVALENTS

10 millimeters (mm.) = 1 centimeter (cm.)
10 cm. = 1 decimeter (dm.)
10 dm. = 1 meter (m.)
1000 m. = 1 kilometer (km.) (about 5/8 mi.)

1 inch = 2.5400 centimeters
1 foot = 0.3048 meters
1 statute mi. = 1.60935 kilometers
1 centimeter = 0.3937 inches
1 meter = 3.28 feet
1 kilometer = 3280.83 feet = 0.62137 mile
1 sq. cm. = 0.155 sq. in.
1 sq. meter = 10.76 sq. ft. = 1.196 sq. yds.
1 hectare = 2.47 acres
1 sq. km. = 0.386 sq. mi.

FULLER'S RULE

C = Cement in Bbls. for one Cubic Yard of Concrete

S = Sand in Cu. Yds. for one Cubic Yard of Concrete

G = Gravel in Cu. Yds. for one Cu. Yd. of Concrete

$$C = \frac{11}{c+s+g} \qquad S = \frac{3.8\ C\ s}{27} \qquad G = \frac{3.8\ C\ g}{27}$$

AREA OF ONE FOOT OF PAVEMENT IN THE FOLLOWING WIDTHS

Width	Sq. Yds.	Width	Sq. Yds.
10	1.11	30	3.33
11	1.22	32	3.555
12	1.33	33	3.67
13	1.44	35	3.89
20	2.22	40	4.44
22	2.44	50	5.55
24	2.67	60	6.67
25	2.78		

SQUARE MEASURE EQUIVALENTS

Square Inches	Square Feet	Square Yards	Square Rods	Acres	Square Miles
1	0.00694	0.00077			
144	1.0	0.11111			
1296	9.0	1.0	0.03306	0.000207	
39204	272.25	30.25	1.0	0.00625	0.00000977
	43560.0	4840.0	160.0	1.0	0.0015625
				640.0	1.0

CUBIC MEASURE EQUIVALENTS

Cubic Inches	Cubic Feet	Cubic Yards	Cord	Perch
1	0.0005787	0.000021433		
1728	1.0	0.03703704		
46656	27.0	1.0		
221184	128.0	4.074074	1.0	
42768	24.75	0.916666		1.0

231 cu. inches = 1 gallon
1 cu. ft. = 7.4805 gallons
1 cu. ft. (water at 60° F.) = 62.37 lbs.
1 gal. (water at 60° F.) = 8.3374 lbs.
32.5 gal. = 1 barrel
35.314 cu. ft. = 1 cu. meter
61.023 cu. inches = 1 liter

NUMBERS, SQUARES AND CUBES

No.	Square	Cube	Sq. rt.	Cu. rt.
1	1	1	1.	1.
2	4	8	1.4142	1.2599
3	9	27	1.7321	1.4422
4	16	64	2.0000	1.5874
5	25	125	2.2361	1.7100
6	36	216	2.4495	1.8171
7	49	343	2.6458	1.9129
8	64	512	2.8284	2.0000
9	81	729	3.0000	2.0801
10	100	1000	3.1623	2.1544
11	121	1331	3.3166	2.2240
12	144	1728	3.4641	2.2894
13	169	2197	3.6056	2.3513
14	196	2744	3.7417	2.4101
15	225	3375	3.8730	2.4662
16	256	4096	4.	2.5198
17	289	4913	4.1231	2.5713
18	324	5832	4.2426	2.6207
19	361	6859	4.3589	2.6684
20	400	8000	4.4721	2.7144
21	441	9261	4.5826	2.7589
22	484	10648	4.6904	2.8020
23	529	12167	4.7958	2.8439
24	576	13824	4.8990	2.8845
25	625	15625	5.	2.9240
26	676	17576	5.0990	2.9625
27	729	19683	5.1962	3.0000
28	784	21952	5.2915	3.0366
29	841	24389	5.3852	3.0723
30	900	27000	5.4772	3.1072
31	961	29791	5.5678	3.1414
32	1024	32768	5.6569	3.1748
33	1089	35937	5.7446	3.2075
34	1156	39304	5.8310	3.2396
35	1225	42875	5.9161	3.2711
36	1296	46656	6.	3.3019
37	1369	50653	6.0828	3.3322
38	1444	54872	6.1644	3.3620
39	1521	59319	6.2450	3.3912
40	1600	64000	6.3246	3.4200

No.	Square	Cube	Sq. rt.	Cu. rt.
41	1681	68921	6.4031	3.4482
42	1764	74088	6.4807	3.4760
43	1849	79507	6.5574	3.5034
44	1936	85184	6.6332	3.5303
45	2025	91125	6.7082	3.5569
46	2116	97336	6.7823	3.5830
47	2209	103823	6.8557	3.6088
48	2304	110592	6.9282	3.6342
49	2401	117649	7.	3.6593
50	2500	125000	7.0711	3.6840
51	2601	132651	7.1414	3.7084
52	2704	140608	7.2111	3.7325
53	2809	148877	7.2801	3.7563
54	2916	157464	7.3485	3.7798
55	3025	166375	7.4162	3.8030
56	3136	175616	7.4833	3.8259
57	3249	185193	7.5498	3.8485
58	3364	195112	7.6158	3.8709
59	3481	205379	7.6811	3.8930
60	3600	216000	7.7460	3.9149
61	3721	226981	7.8102	3.9365
62	3844	238328	7.8740	3.9579
63	3969	250047	7.9373	3.9791
64	4096	262144	8.	4.
65	4225	274625	8.0623	4.0207
66	4356	287496	8.1240	4.0412
67	4489	300763	8.1854	4.0615
68	4624	314432	8.2462	4.0817
69	4761	328509	8.3066	4.1016
70	4900	343000	8.3666	4.1213
71	5041	357911	8.4261	4.1408
72	5184	373248	8.4853	4.1602
73	5329	389017	8.5440	4.1793
74	5476	405224	8.6023	4.1983
75	5625	421875	8.6603	4.2172
76	5776	438976	8.7178	4.2358
77	5929	456533	8.7750	4.2543
78	6084	474552	8.8318	4.2727
79	6241	493039	8.8882	4.2908
80	6400	512000	8.9443	4.3089

No.	Square	Cube	Sq. rt.	Cu. rt
81	6561	531441	9.	4. 3267
82	6724	551368	9. 0554	4. 3445
83	6889	571787	9. 1104	4. 3621
84	7056	592704	9. 1652	4. 3795
85	7225	614125	9. 2195	4. 3968
86	7396	636056	9. 2736	4. 4140
87	7569	658503	9. 3274	4. 4310
88	7744	681472	9. 3808	4. 4480
89	7921	704969	9. 4340	4. 4647
90	8100	729000	9. 4868	4. 4814
91	8281	753571	9. 5394	4. 4979
92	8464	778688	9. 5917	4. 5144
93	8649	804357	9. 6437	4. 5307
94	8836	830584	9. 6954	4. 5468
95	9025	857375	9. 7468	4. 5629
96	9216	884736	9. 7980	4. 5789
97	9409	912673	9. 8489	4. 5947
98	9604	941192	9. 8995	4. 6104
99	9801	970299	9. 9499	4. 6261
100	10000	1000000	10.	4. 6416
101	10201	1030301	10. 0499	4. 6570
102	10404	1061208	10. 0995	4. 6723
103	10600	1092727	10. 1489	4. 6875
104	10816	1124864	10. 1980	4. 7027
105	11025	1157625	10. 2470	4. 7177
106	11236	1191016	10. 2956	4. 7326
107	11449	1225043	10. 3441	4. 7475
108	11664	1259712	10. 3923	4. 7622
109	11881	1295029	10. 4403	4. 7769
110	12100	1331000	10. 4881	4. 7914
111	12321	1367631	10. 5357	4. 8059
112	12544	1404928	10. 5830	4. 8203
113	12769	1442897	10. 6301	4. 8346
114	12996	1481544	10. 6771	4. 8488
115	13225	1520875	10. 7238	4. 8629
116	13456	1560896	10. 7703	4. 8770
117	13689	1601613	10. 8167	4. 8910
118	13924	1643032	10. 8628	4. 9049
119	14161	1685159	10. 9087	4. 9187
120	14400	1728000	10. 9545	4. 9324

No.	Square	Cube	Sq. rt.	Cu. rt.
121	14641	1771561	11.0000	4.9461
122	14884	1815848	11.0454	4.9597
123	15129	1860867	11.0905	4.9732
124	15376	1906624	11.1355	4.9866
125	15625	1953125	11.1803	5.
126	15876	2000376	11.2250	5.0133
127	16129	2048383	11.2694	5.0265
128	16384	2097152	11.3137	5.0397
129	16641	2146689	11.3578	5.0528
130	16900	2197000	11.4018	5.0658
131	17161	2248091	11.4455	5.0788
132	17424	2299968	11.4891	5.0916
133	17689	2352637	11.5326	5.1045
134	17956	2406104	11.5758	5.1172
135	18225	2460375	11.6190	5.1299
136	18496	2515456	11.6619	5.1426
137	18769	2571353	11.7047	5.1551
138	19044	2628072	11.7473	5.1676
139	19321	2685619	11.7898	5.1801
140	19600	2744000	11.8322	5.1925
141	19881	2803221	11.8743	5.2048
142	20164	2863288	11.9164	5.2171
143	20449	2924207	11.9583	5.2293
144	20736	2985984	12.	5.2415
145	21025	3048625	12.0416	5.2536
146	21316	3112136	12.0830	5.2656
147	21609	3176523	12.1244	5.2776
148	21904	3241792	12.1655	5.2896
149	22201	3307949	12.2066	5.3015
150	22500	3375000	12.2474	5.3133
151	22801	3442951	12.2882	5.3251
152	23104	3511808	12.3288	5.3368
153	23409	3581577	12.3693	5.3485
154	23716	3652264	12.4097	5.3601
155	24025	3723875	12.4499	5.3717
156	24336	3796416	12.4900	5.3832
157	24649	3869893	12.5300	5.3947
158	24964	3944312	12.5698	5.4061
159	25281	4019679	12.6095	5.4175
160	25600	4096009	12.6491	5.4288

No.	Square	Cube	Sq. rt.	Cu. rt.
161	25921	4173281	12.6886	5.4401
162	26244	4251528	12.7279	5.4514
163	26569	4330747	12.7671	5.4626
164	26896	4410944	12.8062	5.4737
165	27225	4492125	12.8452	5.4848
166	27556	4574296	12.8841	5.4959
167	27889	4657463	12.9228	5.5069
168	28224	4741632	12.9615	5.5178
169	28561	4826809	13.	5.5288
170	28900	4913000	13.0384	5.5397
171	29241	5000211	13.0767	5.5505
172	29584	5088448	13.1149	5.5613
173	29929	5177717	13.1529	5.5721
174	30276	5268024	13.1909	5.5828
175	30625	5359375	13.2288	5.5934
176	30976	5451776	13.2665	5.6041
177	31329	5545233	13.3041	5.6147
178	31684	5639752	13.3417	5.6252
179	32041	5735339	13.3791	5.6357
180	32400	5832000	13.4164	5.6462
181	32761	5929741	13.4536	5.6567
182	33124	6028568	13.4907	5.6671
183	33489	6128487	13.5277	5.6774
184	33856	6229504	13.5647	5.6877
185	34225	6331625	13.6015	5.6980
186	34596	6434856	13.6382	5.7083
187	34969	6539203	13.6748	5.7185
188	35344	6644672	13.7113	5.7287
189	35721	6751269	13.7477	5.7388
190	36100	6859000	13.7840	5.7489
191	36481	6967871	13.8203	5.7590
192	36864	7077888	13.8564	5.7690
193	37249	7189057	13.8924	5.7790
194	37636	7301384	13.9284	5.7890
195	38025	7414875	13.9642	5.7989
196	38416	7529536	14.	5.8088
197	38809	7645373	14.0357	5.8186
198	39204	7762392	14.0712	5.8285
199	39601	7880599	14.1067	5.8383
200	40000	8000000	14.1421	5.8480

No.	Square	Cube	Sq. rt.	Cu. rt.
201	40401	8120601	14. 1774	5. 8578
202	40804	8242408	14. 2127	5. 8675
203	41209	8365427	14. 2478	5. 8771
204	41616	8489664	14. 2829	5. 8868
205	42025	8615125	14. 3178	5. 8964
206	42436	8741816	14. 3527	5. 9059
207	42849	8869743	14. 3875	5. 9155
208	43264	8998912	14. 4222	5. 9250
209	43681	9129329	14. 4568	5. 9345
210	44100	9261000	14. 4914	5. 9439
211	44521	9393931	14. 5258	5. 9533
212	44944	9528128	14. 5602	5. 9627
213	45369	9663597	14. 5945	5. 9721
214	45796	9800344	14. 6287	5. 9814
215	46225	9938375	14. 6629	5. 9907
216	46656	10077696	14. 6969	6.
217	47089	10218313	14. 7309	6. 0092
218	47524	10360232	14. 7648	6. 0185
219	47961	10503459	14. 7986	6. 0277
220	48400	10648000	14. 8324	6. 0368
221	48841	10793891	14. 8661	6. 0459
222	49284	10941048	14. 8997	6. 0550
223	49729	11089567	14. 9332	6. 0641
224	50176	11239424	14. 9666	6. 0732
225	50625	11390625	15.	6. 0822
226	51076	11543176	15. 0333	6. 0912
227	51529	11697083	15. 0665	6. 1002
228	51984	11852352	15. 0997	6. 1091
229	52441	12008989	15. 1327	6. 1180
230	52900	12167000	15. 1658	6. 1269
231	53361	12326391	15. 1987	6. 1358
232	53824	12487168	15. 2315	6. 1446
233	54289	12649337	15. 2643	6. 1534
234	54756	12812904	15. 2971	6. 1622
235	55225	12977875	15. 3297	6. 1710
236	55696	13144256	15. 3623	6. 1797
237	56169	13312053	15. 3948	6. 1885
238	56644	13481272	15. 4272	6. 1972
239	57121	13651919	15. 4596	6. 2058
240	57600	13824000	15. 4919	6. 2145

No.	Square	Cube	Sq. rt.	Cu. rt.
241	58081	13997521	15. 5242	6. 2231
242	58564	14172488	15. 5563	6. 2317
243	59049	14348907	15. 5885	6. 2403
244	59536	14526784	15. 6205	6. 2488
245	60025	14706125	15. 6525	6. 2573
246	60516	14886936	15. 6844	6. 2658
247	61009	15069223	15. 7162	6. 2743
248	61504	15252992	15. 7480	6. 2828
249	62001	15438249	15. 7797	6. 2912
250	62500	15625000	15. 8114	6. 2996
251	63001	15813251	15. 8430	6. 3080
252	63504	16003008	15. 8745	6. 3164
253	64009	16194277	15. 9060	6. 3247
254	64516	16387064	15. 9374	6. 3330
255	65025	16581375	15. 9687	6. 3413
256	65536	16777216	16	6. 3496
257	66049	16974593	16. 0312	6. 3579
258	66564	17173512	16. 0624	6. 3661
259	67081	17373979	16. 0935	6. 3743
260	67600	17576000	16. 1245	6. 3825
261	68121	17779581	16. 1555	6. 3907
262	68644	17984728	16. 1864	6. 3988
263	69169	18191447	16. 2173	6. 4070
264	69696	18399744	16. 2481	6. 4151
265	70225	18609625	16. 2788	6. 4232
266	70756	18821096	16. 3095	6. 4312
267	71289	19034163	16. 3401	6. 4393
268	71824	19248832	16. 3707	6. 4473
269	72361	19465109	16. 4012	6. 4553
270	72900	19683000	16. 4317	6. 4633
271	73441	19902511	16. 4621	6. 4713
272	73984	20123648	16. 4924	6. 4792
273	74529	20346417	16. 5227	6. 4872
274	75076	20570824	16. 5529	6. 4951
275	75625	20796875	16. 5831	6. 5030
276	76176	21024576	16. 6132	6. 5108
277	76729	21253933	16. 6433	6. 5187
278	77284	21484952	16. 6733	6. 5265
279	77841	21717639	16. 7033	6. 5343
280	78400	21952000	16. 7332	6. 5421

No.	Square	Cube	Sq. rt.	Cu. rt.
281	78961	22188041	16.7631	6.5499
282	79524	22425768	16.7929	6.5577
283	80089	22665187	16.8226	6.5654
284	80656	22906304	16.8523	6.5731
285	81225	23149125	16.8819	6.5808
286	81796	23393656	16.9115	6.5885
287	82369	23639903	16.9411	6.5962
288	82944	23887872	16.9706	6.6039
289	83521	24137569	17.	6.6115
290	84100	24389000	17.0294	6.6191
291	84681	24642171	17.0587	6.6267
292	85264	24897088	17.0880	6.6343
293	85849	25153757	17.1172	6.6419
294	86436	25412184	17.1464	6.6494
295	87025	25572375	17.1756	6.6569
296	87616	25934336	17.2047	6.6644
297	88209	26198073	17.2337	6.6719
298	88804	26463592	17.2627	6.6794
299	89401	26730899	17.2916	6.6869
300	90000	27000000	17.3205	6.6943
301	90601	27270901	17.3494	6.7018
302	91204	27543608	17.3781	6.7092
303	91809	27818127	17.4069	6.7166
304	92416	28094464	17.4356	6.7240
305	93025	28372625	17.4642	6.7313
306	93636	28652616	17.4929	6.7387
307	94249	28934443	17.5214	6.7460
308	94864	29218112	17.5499	6.7533
309	95481	29503629	17.5784	6.7606
310	96100	29791000	17.6068	6.7679
311	96721	30080231	17.6352	6.7752
312	97344	30371328	17.6635	6.7824
313	97969	30664297	17.6918	6.7897
314	98596	30959144	17.7200	6.7969
315	99225	31255875	17.7482	6.8041
316	99856	31554496	17.7764	6.8113
317	100489	31855013	17.8045	6.8185
318	101124	32157432	17.8326	6.8256
319	101761	32461759	17.8606	6.8328
320	102400	32768000	17.8885	6.8399

No.	Square	Cube	Sq. rt.	Cu. rt.
321	103041	33076161	17.9165	6.8470
322	103684	33386248	17.9444	6.8541
323	104329	33698267	17.9722	6.8612
324	104976	34012224	18.	6.8683
325	105625	34328125	18.0278	6.8753
326	106276	34645976	18.0555	6.8824
327	106929	34965783	18.0831	6.8894
328	107584	35287552	18.1108	6.8964
329	108241	35611289	18.1384	6.9034
330	108900	35937000	18.1659	6.9104
331	109561	36264691	18.1934	6.9174
332	110224	36594368	18.2209	6.9244
333	110889	36926037	18.2483	6.9313
334	111556	37259704	18.2757	6.9382
335	112225	37595375	18.3030	6.9451
336	112896	37933056	18.3303	6.9521
337	113569	38272753	18.3576	6.9589
338	114244	38614472	18.3848	6.9658
339	114921	38958219	18.4120	6.9727
340	115600	39304000	18.4391	6.9795
341	116281	39651821	18.4662	6.9864
342	116964	40001688	18.4932	6.9932
343	117649	40353607	18.5203	7.
344	118336	40707584	18.5472	7.0068
345	119025	41063625	18.5742	7.0136
346	119716	41421736	18.6011	7.0203
347	120409	41781923	18.6279	7.0271
348	121104	42144192	18.6548	7.0338
349	121801	42508549	18.6815	7.0406
350	122500	42875000	18.7083	7.0473
351	123201	43243551	18.7350	7.0540
352	123904	43614208	18.7617	7.0607
353	124609	43986977	18.7883	7.0674
354	125316	44361864	18.8149	7.0740
355	126025	44738875	18.8414	7.0807
356	126736	45118016	18.8680	7.0873
357	127449	45499293	18.8944	7.0940
358	128164	45882712	18.9209	7.1006
359	128881	46268279	18.9473	7.1072
360	129600	46656000	18.9737	7.1138

No.	Square	Cube	Sq. rt.	Cu. rt.
361	130321	47045881	19.	7.1204
362	131044	47437928	19.0263	7.1269
363	131769	47832147	19.0526	7.1335
364	132496	48228544	19.0788	7.1400
365	133225	48627125	19.1050	7.1466
366	133956	49027896	19.1311	7.1531
367	134689	49430863	19.1572	7.1596
368	135424	49836032	19.1833	7.1661
369	136161	50243409	19.2094	7.1726
370	136900	50653000	19.2354	7.1791
371	137641	51064811	19.2614	7.1855
372	138384	51478848	19.2873	7.1920
373	139129	51895117	19.3132	7.1984
374	139876	52313624	19.3391	7.2048
375	140625	52734375	19.3649	7.2112
376	141376	53157376	19.3907	7.2177
377	142129	53582633	19.4165	7.2240
378	142884	54010152	19.4422	7.2304
379	143641	54439939	19.4679	7.2368
380	144400	54872000	19.4936	7.2432
381	145161	55306341	19.5192	7.2495
382	145924	55742968	19.5448	7.2558
383	146689	56181887	19.5704	7.2622
384	147456	56623104	19.5959	7.2685
385	148225	57066625	19.6214	7.2748
386	148996	57512456	19.6469	7.2811
387	149769	57960603	19.6723	7.2874
388	150544	58411072	19.6977	7.2936
389	151321	58863869	19.7231	7.2999
390	152100	59319000	19.7484	7.3061
391	152881	59776471	19.7737	7.3124
392	153664	60236288	19.7990	7.3186
393	154449	60698457	19.8242	7.3248
394	155236	61162984	19.8494	7.3310
395	156025	61629875	19.8746	7.3372
396	156816	62099136	19.8997	7.3434
397	157609	62570773	19.9249	7.3496
398	158404	63044792	19.9499	7.3558
399	159201	63521199	19.9750	7.3619
400	160000	64000000	20.	7.3681

No.	Square	Cube	Sq. rt.	Cu. rt.
401	160801	64481201	20.0250	7.3742
402	161604	64964808	20.0499	7.3803
403	162409	65450827	20.0749	7.3864
404	163216	65939264	20.0998	7.3925
405	164025	66430125	20.1246	7.3986
406	164836	66923416	20.1494	7.4047
407	165649	67419143	20.1742	7.4108
408	166464	67917312	20.1990	7.4169
409	167281	68417929	20.2237	7.4229
410	168100	68921000	20.2485	7.4290
411	168921	69426531	20.2731	7.4350
412	169744	69934528	20.2978	7.4410
413	170569	70444997	20.3224	7.4470
414	171396	70957944	20.3470	7.4530
415	172225	71473375	20.3715	7.4590
416	173056	71991296	20.3961	7.4650
417	173889	72511713	20.4206	7.4710
418	174724	73034632	20.4450	7.4770
419	175561	73560059	20.4695	7.4829
420	176400	74088000	20.4939	7.4889
421	177241	74618461	20.5183	7.4948
422	178084	75151448	20.5426	7.5007
423	178929	75686967	20.5670	7.5067
424	179776	76225024	20.5913	7.5126
425	180625	76765625	20.6155	7.5185
426	181476	77308776	20.6398	7.5244
427	182329	77854483	20.6640	7.5302
428	183184	78402752	20.6882	7.5361
429	184041	78953589	20.7123	7.5420
430	184900	79507000	20.7364	7.5478
431	185761	80062991	20.7605	7.5537
432	180624	80621568	20.7846	7.5595
433	187489	81182737	20.8087	7.5654
434	188356	81746504	20.8327	7.5712
435	189225	82312875	20.8567	7.5770
436	190096	82881856	20.8806	7.5828
437	190969	83453453	20.9045	7.5886
438	191844	84027672	20.9284	7.5944
439	192721	84604519	20.9523	7.6001
440	193600	85184000	20.9762	7.6059

No.	Square	Cube	Sq. rt.	Cu. rt.
441	194481	85766121	21.	7.6117
442	195364	86350888	21.0238	7.6174
443	196249	86938307	21.0476	7.6232
444	197136	87528384	21.0713	7.6289
445	198025	88121125	21.0950	7.6346
446	198916	88716536	21.1187	7.6403
447	199809	89314623	21.1424	7.6460
448	200704	89915392	21.1660	7.6517
449	201601	90518849	21.1896	7.6574
450	202500	91125000	21.2132	7.6631
451	203401	91733851	21.2368	7.6688
452	204304	92345408	21.2603	7.6744
453	205209	92959677	21.2838	7.6801
454	206116	93576664	21.3073	7.6857
455	207025	94196375	21.3307	7.6914
456	207936	94818816	21.3542	7.6970
457	208849	95443993	21.3776	7.7026
458	209764	96071912	21.4009	7.7082
459	210681	96702579	21.4243	7.7138
460	211600	97336000	21.4476	7.7194
461	212521	97972181	21.4709	7.7250
462	213444	98611128	21.4942	7.7306
463	214369	99252847	21.5174	7.7362
464	215296	99897344	21.5407	7.7418
465	216225	100544625	21.5639	7.7473
466	217156	101194696	21.5870	7.7529
467	218089	101847563	21.6102	7.7584
468	219024	102503232	21.6333	7.7639
469	219961	103161709	21.6564	7.7695
470	220900	103823000	21.6795	7.7750
471	221841	104487111	21.7025	7.7805
472	222784	105154048	21.7256	7.7860
473	223729	105823817	21.7486	7.7915
474	224676	106496424	21.7715	7.7970
475	225625	107171875	21.7945	7.8025
476	226576	107850176	21.8174	7.8079
477	227529	108531333	21.8403	7.8134
478	228484	109215352	21.8632	7.8188
479	229441	109902239	21.8861	7.8243
480	230400	110592000	21.9089	7.8297

No.	Square	Cube	Sq. rt.	Cu. rt.
481	23136	111284641	21.9317	7.8352
482	23232	111980168	21.9545	7.8406
483	23328	112678587	21.9773	7.8460
484	234256	113379904	22.	7.8514
485	235225	114084125	22.0227	7.8568
486	236196	114791256	22.0454	7.8622
487	237169	115501303	22.0681	7.8676
488	238144	116214272	22.0907	7.8730
489	239121	116930169	22.1133	7.8784
490	240100	117649000	22.1359	7.8837
491	241081	118370771	22.1585	7.8891
492	242064	119095488	22.1811	7.8944
493	243049	119823157	22.2036	7.8998
494	244036	120553784	22.2261	7.9051
495	245025	121287375	22.2486	7.9105
496	246016	122023936	22.2711	7.9158
497	247009	122763473	22.2935	7.9211
498	248004	123505992	22.3159	7.9264
499	249001	124251499	22.3383	7.9317
500	250000	125000000	22.3607	7.9370
501	251001	125751501	22.3830	7.9423
502	252004	126506008	22.4054	7.9476
503	253009	127263527	22.4277	7.9528
504	254016	128024064	22.4499	7.9581
505	255025	128787625	22.4722	7.9634
506	256036	129554216	22.4944	7.9686
507	257049	130323843	22.5167	7.9739
508	258064	131096512	22.5389	7.9791
509	259081	131872229	22.5610	7.9843
510	260100	132651000	22.5832	7.9896
511	261121	133432831	22.6053	7.9948
512	262144	134217728	22.6274	8.
513	263169	135005697	22.6495	8.0052
514	264196	135796744	22.6716	8.0104
515	265225	136590875	22.6936	8.0156
516	266256	137388096	22.7156	8.0208
517	267289	138188413	22.7376	8.0260
518	268324	138991832	22.7596	8.0311
519	269361	139798359	22.7816	8.0363
520	270400	140608000	22.8035	8.0415

No.	Square	Cube	Sq. rt.	Cu. rt.
521	271441	141420761	22.8254	8.0466
522	272484	142236648	22.8473	8.0517
523	273529	143055667	22.8692	8.0569
524	274576	143877824	22.8910	8.0620
525	275625	144703125	22.9129	8.0671
526	276676	145531576	22.9347	8.0723
527	277729	146363183	22.9565	8.0774
528	278784	147197952	22.9783	8.0825
529	279841	148035889	23.	8.0876
530	280900	148877000	23.0217	8.0927
531	281961	149721291	23.0434	8.0978
532	283024	150568768	23.0651	8.1028
533	284089	151419437	23.0868	8.1079
534	285156	152273304	23.1084	8.1130
535	286225	153130375	23.1301	8.1180
536	287296	153990656	23.1517	8.1231
537	288369	154854153	23.1733	8.1281
538	289444	155720872	23.1948	8.1332
539	290521	156590819	23.2164	8.1382
540	291600	157464000	23.2379	8.1433
541	292681	158340421	23.2594	8.1483
542	293764	159220088	23.2809	8.1533
543	294849	160103007	23.3024	8.1583
544	295936	160989184	23.3238	8.1633
545	297025	161878625	23.3452	8.1683
546	298116	162771336	23.3666	8.1733
547	299209	163667323	23.3880	8.1783
548	300304	164566592	23.4094	8.1833
549	301401	165469149	23.4307	8.1882
550	302500	166375000	23.4521	8.1932
551	303601	167284151	23.4734	8.1982
552	304704	168196608	23.4947	8.2031
553	305809	169112377	23.5160	8.2081
554	306916	170031464	23.5372	8.2130
555	308025	170953875	23.5584	8.2180
556	309136	171879616	23.5797	8.2229
557	310249	172808693	23.6008	8.2278
558	311364	173741112	23.6220	8.2327
559	312481	174676879	23.6432	8.2377
560	313600	175616000	23.6643	8.2426

No.	Square	Cube	Sq. rt.	Cu. rt.
561	314721	176558481	23.6854	8.2475
562	315844	177504328	23.7065	8.2524
563	316969	178453547	23.7276	8.2573
564	318096	179406144	23.7487	8.2621
565	319225	180362125	23.7697	8.2670
566	320356	181321496	23.7908	8.2719
567	321489	182284263	23.8118	8.2768
568	322624	183250432	23.8328	8.2816
569	323761	184220009	23.8537	8.2865
570	324900	185193000	23.8747	8.2913
571	326041	186169411	23.8956	8.2962
572	327184	187149248	23.9165	8.3010
573	328329	188132517	23.9374	8.3059
574	329476	189119224	23.9583	8.3107
575	330625	190109375	23.9792	8.3155
576	331776	191102976	24.	8.3203
577	332929	192100033	24.0208	8.3251
578	334084	193100552	24.0416	8.3300
579	335241	194104539	24.0624	8.3348
580	336400	195112000	24.0832	8.3396
581	337561	196122941	24.1039	8.3443
582	338724	197137368	24.1247	8.3491
583	339889	198155287	24.1454	8.3539
584	341056	199176704	24.1661	8.3587
585	342225	200201625	24.1868	8.3634
586	343396	201230056	24.2074	8.3682
587	344569	202262003	24.2281	8.3730
588	345744	203297472	24.2487	8.3777
589	346921	204336469	24.2693	8.3825
590	348100	205379000	24.2899	8.3872
591	349281	206425071	24.3105	8.3919
592	350464	207474688	24.3311	8.3967
593	351649	208527857	24.3516	8.4014
594	352836	209584584	24.3721	8.4061
595	354025	210644875	24.3926	8.4108
596	355216	211708736	24.4131	8.4155
597	356409	212776173	24.4336	8.4202
598	357604	213847192	24.4540	8.4249
599	358801	214921799	24.4745	8.4296
600	360000	216000000	24.4949	8.4343

No.	Square	Cube	Sq. rt.	Cu. rt.
601	361201	217081801	24. 5153	8. 4390
602	362404	218167208	24. 5357	8. 4437
603	363609	219256227	24. 5561	8. 4484
604	364816	220348864	24. 5764	8. 4530
605	366025	221445125	24. 5967	8. 4577
606	367236	222545016	24. 6171	8. 4623
607	368449	223648543	24. 6374	8. 4670
608	369664	224755712	24. 6577	8. 4716
609	370881	225866529	24. 6779	8. 4763
610	372100	226981000	24. 6982	8. 4809
611	373321	228099131	24. 7184	8. 4856
612	374544	229220928	24. 7386	8. 4902
613	375769	230346397	24. 7588	8. 4948
614	376996	231475544	24. 7790	8. 4994
615	378225	232608375	24. 7992	8. 5040
616	379456	233744896	24. 8193	8. 5086
617	380689	234885113	24. 8395	8. 5132
618	381924	236029032	24. 8596	8. 5178
619	383161	237176659	24. 8797	8. 5224
620	384400	238328000	24. 8998	8. 5270
621	385641	239483061	24. 9199	8. 5316
622	386884	240641848	24. 9399	8. 5362
623	388129	241804367	24. 9600	8. 5408
624	389376	242970624	24. 9800	8. 5453
625	390625	244140625	25.	8. 5499
626	391876	245314376	25. 0200	8. 5544
627	393129	246491883	25. 0400	8. 5590
628	394384	247673152	25. 0599	8. 5635
629	395641	248858189	25. 0799	8. 5681
630	396900	250047000	25. 0998	8. 5726
631	398161	251239591	25. 1197	8. 5772
632	399424	252435968	25. 1396	8. 5817
633	400689	253636137	25. 1595	8. 5862
634	401956	254840104	25. 1794	8. 5907
635	403225	256047875	25. 1992	8. 5952
636	404496	257259456	25. 2190	8. 5997
637	405769	258474853	25. 2389	8. 6043
638	407044	259694072	25. 2587	8. 6088
639	408321	260917119	25. 2784	8. 6132
640	409600	262144000	25. 2982	8. 6177

No.	Square	Cube	Sq. rt.	Cu. rt.
641	410881	263374721	25.3180	8.6222
642	412164	264609288	25.3377	8.6267
643	413449	265847707	25.3574	8.6312
644	414736	267089984	25.3772	8.6357
645	416025	268336125	25.3969	8.6401
646	417316	269586136	25.4165	8.6446
647	418609	270840023	25.4362	8.6490
648	419904	272097792	25.4558	8.6535
649	421201	273359449	25.4755	8.6579
650	422500	274625000	25.4951	8.6624
651	423801	275894451	25.5147	8.6668
652	425104	277167808	25.5343	8.6713
653	426409	278445077	25.5539	8.6757
654	427716	279726264	25.5734	8.6801
655	429025	281011375	25.5930	8.6845
656	430336	282300416	25.6125	8.6890
657	431649	283593393	25.6320	8.6934
658	432964	284890312	25.6515	8.6978
659	434281	286191179	25.6710	8.7022
660	435600	287496000	25.6905	8.7066
661	436921	288804781	25.7099	8.7110
662	438244	290117528	25.7294	8.7154
663	439569	291434247	25.7488	8.7198
664	440896	292754944	25.7682	8.7241
665	442225	294079625	25.7876	8.7285
666	443556	295408296	25.8070	8.7329
667	444889	296740963	25.8263	8.7373
668	446224	298077632	25.8457	8.7416
669	447561	299418309	25.8650	8.7460
670	448900	300763000	25.8844	8.7503
671	450241	302111711	25.9037	8.7547
672	451584	303464448	25.9230	8.7590
673	452929	304821217	25.9422	8.7634
674	454276	306182024	25.9615	8.7677
675	455625	307546875	25.9808	8.7721
676	456976	308915776	26.	8.7764
677	458329	310288733	26.0192	8.7807
678	459684	311665752	26.0384	8.7850
679	461041	313046839	26.0576	8.7893
680	462400	314432000	26.0768	8.7937

No.	Square	Cube	Sq. rt.	Cu. rt.
681	463761	315821241	26. 0960	8. 7980
682	465124	317214568	26. 1151	8. 8023
683	466489	318611987	26. 1343	8. 8066
684	467856	320013504	26. 1534	8. 8109
685	469225	321419125	26. 1725	8. 8152
686	470596	322828856	26. 1916	8. 8194
687	471969	324242703	26. 2107	8. 8237
688	473344	325660672	26. 2298	8. 8280
689	474721	327082769	26. 2488	8. 8323
690	476100	328509000	26. 2679	8. 8366
691	477481	329939371	26. 2869	8. 8408
692	478864	331373888	26. 3059	8. 8451
693	480249	332812557	26. 3249	8. 8493
694	481636	334255384	26. 3439	8. 8536
695	483025	335702375	26. 3629	8. 8578
696	484416	337153536	26. 3818	8. 8621
697	485809	338608873	26. 4008	8. 8663
698	487204	340068392	26. 4197	8. 8706
699	488601	341532099	26. 4386	8. 8748
700	490000	343000000	26. 4575	8. 8790
701	491401	344472101	26. 4764	8. 8833
702	492804	345948408	26. 4953	8. 8875
703	494209	347428927	26. 5141	8. 8917
704	495616	348913664	26. 5330	8. 8959
705	497025	350402625	26. 5518	8. 9001
706	498436	351895816	26. 5707	8 9043
707	499849	353393243	26. 5895	8. 9085
708	501264	354894912	26. 6083	8. 9127
709	502681	356400829	26. 6271	8. 9169
710	504100	357911000	26. 6458	8. 9211
711	505521	359425431	26. 6646	8. 9253
712	506944	360944128	26. 6833	8. 9295
713	508369	362467097	26. 7021	8. 9337
714	509796	363994344	26. 7208	8. 9378
715	511225	365525875	26. 7395	8. 9420
716	512656	367061696	26. 7582	8. 9462
717	514089	368601813	26. 7769	8. 9503
718	515524	370146232	26. 7955	8. 9545
719	516961	371694959	26. 8142	8. 9587
720	518400	373248000	26. 8328	8. 9628

No.	Square	Cube	Sq. rt.	Cu. rt.
721	519841	374805361	26.8514	8.9670
722	521284	376367048	26.8701	8.9711
723	522729	377933067	26.8887	8.9752
724	524176	379503424	26.9072	8.9794
725	525625	381078125	26.9258	8.9835
726	527076	382657176	26.9444	8.9876
727	528529	384240583	26.9629	8.9918
728	529984	385828352	26.9815	8.9959
729	531441	387420489	27.	9.
730	532900	389017000	27.0185	9.0041
731	534361	390617891	27.0370	9.0082
732	535824	392223168	27.0555	9.0123
733	537289	393832837	27.0740	9.0164
734	538756	395446904	27.0924	9.0205
735	540225	397065375	27.1109	9.0246
736	541696	398688256	27.1293	9.0287
737	543169	400315553	27.1477	9.0328
738	544644	401947272	27.1662	9.0369
739	546121	403583419	27.1846	9.0410
740	547600	405224000	27.2029	9.0450
741	549081	406869021	27.2213	9.0491
742	550564	408518488	27.2397	9.0532
743	552049	410172407	27.2580	9.0572
744	553536	411830784	27.2764	9.0613
745	555025	413493625	27.2947	9.0654
746	556516	415160936	27.3130	9.0694
747	558009	416832723	27.3313	9.0735
748	559504	418508992	27.3496	9.0775
749	561001	420189749	27.3679	9.0816
750	562500	421875000	27.3861	9.0856
751	564001	423564751	27.4044	9.0896
752	565504	425259008	27.4226	9.0937
753	567009	426957777	27.4408	9.0977
754	568516	428661064	27.4591	9.1017
755	570025	430368875	27.4773	9.1057
756	571536	432081216	27.4955	9.1098
757	573049	433798093	27.5136	9.1138
758	574564	435519512	27.5318	9.1178
759	576081	437245479	27.5500	9.1218
760	577600	438976000	27.5681	9.1258

No.	Square	Cube	Sq. rt.	Cu. rt.
761	579121	440711081	27. 5862	9. 1298
762	580644	442450728	27. 6043	9. 1338
763	582169	444194947	27. 6225	9. 1378
764	583696	445943744	27. 6405	9. 1418
765	585225	447697125	27. 6586	9. 1458
766	586756	449455096	27. 6767	9. 1498
767	588289	451217663	27. 6948	9. 1537
768	589824	452984832	27. 7128	9. 1577
769	591361	454756609	27. 7308	9. 1617
770	592900	456533000	27. 7489	9. 1657
771	594441	458314011	27. 7669	9. 1696
772	595984	460099648	27. 7849	9. 1736
773	597529	461889917	27. 8029	9. 1775
774	599076	463684824	27. 8209	9. 1815
775	600625	465484375	27. 8388	9. 1855
776	602176	467288576	27. 8568	9. 1894
777	603729	469097433	27. 8747	9. 1933
778	605284	470910952	27. 8927	9. 1973
779	606841	472729139	27. 9106	9. 2012
780	608400	474552000	27. 9285	9. 2052
781	609961	476379541	27. 9464	9. 2091
782	611524	478211768	27. 9643	9. 2130
783	613089	480048687	27. 9821	9. 2170
784	614656	481890304	28.	9. 2209
785	616225	483736625	28. 0179	9. 2248
786	617796	485587656	28. 0357	9. 2287
787	619369	487443403	28. 0535	9. 2326
788	620944	489303872	28. 0713	9. 2365
789	622521	491169069	28. 0891	9. 2404
790	624100	493039000	28. 1069	9. 2443
791	625681	494913671	28. 1247	9. 2482
792	627264	496793088	28. 1425	9. 2521
793	628849	498677257	28. 1603	9. 2560
794	630436	500566184	28. 1780	9. 2599
795	632025	502459875	28. 1957	9. 2638
796	633616	504358336	28. 2135	9. 2677
797	635209	506261573	28. 2312	9. 2716
798	636804	508169592	28. 2489	9. 2754
799	638401	510082399	28. 2666	9. 2793
800	640000	512000000	28. 2843	9. 2832

No.	Square	Cube	Sq. rt.	Cu. rt.
801	641601	513922401	28. 3019	9. 2870
802	643204	515849608	28. 3196	9. 2909
803	644809	517781627	28. 3373	9 2948
804	646416	519718464	28. 3549	9. 2986
805	648025	521660125	28. 3725	9. 3025
806	649636	523606616	28. 3901	9. 2063
807	651249	525557943	28. 4077	9. 3102
808	652864	527514112	28. 4253	9. 3140
809	654481	529475129	28. 4429	9. 3179
810	656100	531441000	28. 4605	9. 3217
811	657721	533411731	28. 4781	9. 3255
812	659344	535387328	28. 4956	9. 3294
813	660969	537367797	28. 5132	9. 3332
814	662596	539353144	28. 5307	9. 3370
815	664225	541343375	28. 5482	9. 3408
816	665856	543338496	28. 5657	9. 3447
817	667489	545338513	28. 5832	9. 3485
818	669124	547343432	28. 6007	9. 3523
819	670761	549353259	28. 6182	9. 3561
820	672400	551368000	28. 6653	9. 3599
821	674041	553387661	28. 6531	9. 3637
822	675684	555412248	28. 6705	9. 3675
823	677329	557441767	28. 6880	9. 3713
824	678976	559476224	28. 7054	9. 3751
825	680625	561515625	28. 7228	9. 3789
826	682276	563559976	28. 7402	9. 3827
827	683929	565609283	28. 7576	9. 3865
828	685584	567663552	28. 7750	9. 3902
829	687241	569722789	28. 7924	9. 3940
830	688900	571787000	28. 8097	9. 3978
831	690561	573856191	28. 8271	9. 4016
832	692224	575930368	28. 8444	9. 4053
833	693889	578009537	28. 8617	9. 4091
834	695556	580093704	28. 8791	9. 4129
835	697225	582182875	28. 8964	9. 4166
836	698896	584277056	28. 9137	9. 4204
837	700569	586376253	28. 9310	9. 4241
838	702244	588480472	28. 9482	9. 4279
839	703921	590589719	28. 9655	9. 4316
840	705600	592704000	28. 9828	9. 4354

No.	Square	Cube	Sq. rt.	Cu. rt.
841	707281	594823321	29.	9. 4391
842	708964	596947688	29. 0172	9. 4429
843	710649	599077107	29. 0345	9. 4466
844	712336	601211584	29. 0517	9. 4503
845	714025	603351125	29. 0689	9. 4541
846	715716	605495736	29. 0861	9. 4578
847	717409	607645423	29. 1033	9. 4615
848	719104	609800192	29. 1204	9. 4652
849	720801	611960049	29. 1376	9. 4690
850	722500	614125000	29. 1548	9. 4727
851	724201	616295051	29. 1719	9. 4764
852	725904	618470208	29. 1890	9. 4801
853	727609	620650477	29. 2062	9. 4838
854	729316	622835864	29. 2233	9. 4875
855	731025	625026375	29. 2204	9. 4912
856	732736	627222016	29. 2575	9. 4949
857	734449	629422793	29. 2746	9. 4986
858	736164	631628712	29. 2916	9. 5023
859	737881	633839779	29. 3087	9. 5060
860	739600	636056000	29. 3258	9. 5097
861	741321	638277381	29. 3428	9. 5134
862	743044	640503928	29. 3598	9. 5171
863	744769	642735647	29. 3769	9. 5207
864	746496	644972544	29. 3939	9. 5244
865	748225	647214625	29. 4109	9. 5281
866	749956	649461896	29. 4279	9. 5317
867	751689	651714363	29. 4449	9. 5354
868	753424	653972032	29. 4618	9. 5391
869	755161	656234909	29. 4788	9. 5427
870	756900	658503000	29. 4958	9. 5464
871	758641	660776311	29. 5127	9. 5501
872	760384	663054848	29. 5296	9. 5537
873	762129	665338617	29. 5466	9. 5574
874	763876	667627624	29. 5635	9. 5610
875	765625	669921875	29. 5804	9. 5647
876	767376	672221376	29. 5973	9. 5683
877	769129	674526133	29. 6142	9. 5719
878	770884	676836152	29. 6311	9. 5756
879	772641	679151439	29. 6479	9. 5792
880	774400	681472000	29. 6648	9. 5828

No.	Square	Cube	Sq. rt.	Cu. rt.
881	776161	683797841	29. 6816	9. 5865
882	777924	686128968	29. 6985	9. 5901
883	779689	688465387	29. 7152	9. 5937
884	781456	690807104	29. 7321	9. 5973
885	783225	693154125	29. 7489	9. 6010
886	784996	695506456	29. 7658	9. 6046
887	786769	697864103	29. 7825	9. 6082
888	788544	700227072	29. 7993	9. 6118
889	790321	702595369	29. 8161	9. 6154
890	792100	704969000	29. 8329	9. 6190
891	793881	707347971	29. 8496	9. 6226
892	795664	709732288	29. 8664	9. 6262
893	797449	712121957	29. 8831	9. 6298
894	799236	714516984	29. 8998	9. 6334
895	801025	716917375	29. 9166	9. 6370
896	802816	719323136	29. 9333	9. 6406
897	804609	721734273	29. 9500	9. 6442
898	806404	724150792	29. 9666	9. 6477
899	808201	726572699	29. 9833	9. 6513
900	810000	729000000	30.	9. 6549
901	811801	731432701	30. 0167	9. 6585
902	813604	733870808	30. 0333	9. 6620
903	815409	736314327	30. 0500	9. 6656
904	817216	738763264	30. 0666	9. 6692
905	819025	741217625	30. 0832	9. 6727
906	820836	743677416	30. 0998	9. 6763
907	822649	746142643	30. 1164	9. 6799
908	824464	748613312	30. 1330	9. 6834
909	826281	751089429	30. 1496	9. 6870
910	828100	753571000	30. 1662	9. 6905
911	829921	756058031	30. 1828	9. 6941
912	831744	758550528	30. 1993	9. 6976
913	833569	761048497	30. 2159	9. 7012
914	835396	763551944	30. 2324	9. 7047
915	837225	766060875	30. 2490	9. 7082
916	839056	768575296	30. 2655	9. 7118
917	840889	771095213	30. 2820	9. 7153
918	842724	773620632	30. 2985	9. 7188
919	844561	776151559	30. 3150	9. 7224
920	846400	778688000	30. 3315	9. 7259

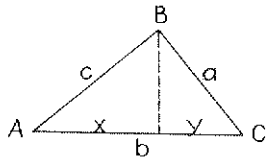
No.	Square	Cube	Sq. rt.	Cu. rt.
921	848241	781229961	30. 3480	9. 7294
922	850084	783777448	30. 3645	9. 7329
923	851929	786330467	30. 3809	9. 7364
924	853776	788889024	30. 3974	9. 7400
925	855625	791453125	30. 4138	9. 7435
926	857476	794022776	30. 4302	9. 7470
927	859329	796597983	30. 4467	9. 7505
928	861184	799178752	30. 4631	9. 7540
929	863041	801765089	30. 4795	9. 7575
930	864900	804357000	30. 4959	9. 7610
931	866761	806954491	30. 5123	9. 7645
932	868624	809557568	30. 5287	9. 7680
933	870489	812166237	30. 5450	9. 7715
934	872356	814780504	30. 5614	9. 7750
935	874225	817400375	30. 5778	9. 7785
936	876096	820025856	30. 5941	9. 7819
937	877969	822656953	30. 6105	9. 7854
938	879844	825293672	30. 6268	9. 7889
939	881721	827936019	30. 6431	9. 7924
940	883600	830584000	30. 6594	9. 7959
941	885481	833237621	30. 6757	9. 7993
942	887364	835896888	30. 6920	9. 8028
943	889249	838561807	30. 7083	9. 8063
944	891136	841232384	30. 7246	9. 8097
945	893025	843908625	30. 7409	9. 8132
946	894916	846590536	30. 7571	9. 8167
947	896809	849278123	30. 7734	9. 8201
948	898704	851971392	30. 7896	9. 8236
949	900601	854670349	30. 8058	9. 8270
950	902500	857375000	30. 8221	9. 8305
951	904401	860085351	30. 8383	9. 8339
952	906304	862801408	30. 8545	9. 8374
953	908209	865523177	30. 8707	9. 8408
954	910116	868250664	30. 8869	9. 8443
955	912025	870983875	30. 9031	9. 8477
956	913936	873722816	30. 9192	9. 8511
957	915849	876467493	30. 9354	9. 8546
958	917764	879217912	30. 9516	9. 8580
959	919681	881974079	30. 9677	9. 8614
960	921600	884736000	30. 9839	9. 8648

No.	Square	Cube	Sq. rt.	Cu. rt.
961	923521	887503681	31.	9. 8683
962	925444	890277128	31. 0161	9. 8717
963	927369	893056347	31. 0322	9. 8751
964	929296	895841344	31. 0483	9. 8785
965	931225	898632125	31. 0644	9. 8819
966	933156	901428696	31. 0805	9. 8854
967	935089	904231063	31. 0966	9. 8888
968	937024	907039232	31. 1127	9. 8922
969	938961	909853209	31. 1288	9. 8956
970	940900	912673000	31. 1448	9. 8990
971	942841	915498611	31. 1609	9. 9024
972	944784	918330048	31. 1769	9. 9058
973	946729	921167317	31. 1929	9. 9092
974	948676	924010424	31. 2090	9. 9126
975	950625	926859375	31. 2250	9. 9160
976	952576	929714176	31. 2410	9. 9194
977	954529	932574833	31. 2570	9. 9227
978	956484	935441352	31. 2730	9. 9261
979	958441	938313739	31. 2890	9. 9295
980	960400	941192000	31. 3050	9. 9329
981	962361	944076141	31. 3209	9. 9363
982	964324	946966168	31. 3369	9. 9396
983	966289	949862087	31. 3528	9. 9430
984	968256	952763904	31. 3688	9. 9464
985	970225	955671625	31. 3847	9. 9497
986	972196	958585256	31. 4006	9. 9531
977	974169	961504803	31. 4166	9. 9565
988	976144	964430272	31. 4325	9. 9598
989	978121	967361669	31. 4484	9. 9632
990	980100	970299000	31. 4643	9. 9666
991	982081	973242271	31. 4802	9. 9699
992	984064	976191488	31. 4960	9. 9733
993	986049	979146657	31. 5119	9. 9766
994	988036	982107784	31. 5278	9. 9800
995	990025	985074875	31. 5436	9. 9833
996	992016	988047936	31. 5595	9. 9866
997	994009	991026973	31. 5753	9. 9900
998	996004	994011992	31. 5911	9. 9933
999	998001	997002999	31. 6070	9. 9967
1000	1000000	1000000000	31. 6228	10.

WEIGHTS OF MATERIALS

Material	Average Specific Gravity Water = 1	Average Weight Cu. Ft. in Lbs.	Angle of Repose
Air, atmosphere 60°F. pressure one atmosphere, or 14.7 lbs. per sq. in. weighs 1/815 as much as water		.0765	
Asphaltum, natural	1.4	87.3	
Brick, common soft		100.0	
Brick, pressed or paving		150.0	
Brick, fire		137.0	
Cement, Portland (net, per barrel, 376 lbs; per bag net, 94 lbs; std. prop.		100.0	
Cement Mortar, 1:2½		135.0	
Cinders, blast furnace		57.0	
Cinders (coal, ashes and clinkers)		40.0	
Clay, dry in lump, loose		63.0	35°
Coal, anthracite		55.0	25°-40°
Coal, bit. lump, aver.		50.0	25°-40°
Concrete, gravel		150.0	27°
Concrete, limestone with Portland cement		148.0	
Earth, common loam, slightly moist, loose		73.0	35°
Gasoline	.71-.75	44.-47	
Granite, crushed		96.0	
Gravel		120.0	35°
Gypsum, plaster of paris	2.27	141.6	
Iron, cast	7.15	446.0	30°-40°
Iron, wrought	7.69	480.0	
Limestone, broken	1.61	100.0	

Material	Average Specific Gravity Water = 1	Average Weight Cu. Ft. in Lbs.	Angle of Repose
Marl	2.1	140.0	
Mercury at 32° F.	13.62	849.0	
Mud, dry close		80 to 110	
Petroleum	.878	54.8	
Pitch	1.15	71.7	
Plaster		53.0	
Sand, dry, loose		90.0	33°
Sand, wet		110.0	
Sand, molding		77.0	
Shale, red or black	2.6	162.0	
Slag, bank crushed		80.0	34°
Slag, furnace granulated		60.0	15°-30°
Steel	7.85	489.6	
Stone, crushed		100.0	
Tar	1.15	71.7	
Trap, quarried in piles		107.0	
Water, pure rain distilled at 32° F., bar. 30″		62.417	
Woods (Dry)			
Cypress		29.8	
Spruce & eastern fir		25.0	
White Pine		25.6	
Douglas Fir		32.1	
Short-leaf Yellow Pine		38.4	
White Oak		46.4	



OBLIQUE TRIANGLES

$$\text{Area} = \tfrac{1}{2}a \cdot b \sin C = \frac{a^2 \cdot \sin B \sin C}{2 \sin A}$$

$$\text{Area} = \sqrt{s(s-a)(s-b)(s-c)} \qquad \text{Let } S = \tfrac{1}{2}(a+b+c)$$

$$b = \frac{a \cdot \sin B}{\sin A} \qquad \text{Sin } B = \frac{\sin A \cdot b}{a} \qquad \text{Cos } B = \frac{a^2+c^2-b^2}{2ac}$$

$$c = \frac{(a+b)\cos\frac{1}{2}(A+B)}{\cos\frac{1}{2}(A-B)} = \frac{(a-b)\sin\frac{1}{2}(A+B)}{\sin\frac{1}{2}(A-B)}$$

$$c = \frac{a \cdot \sin A+B}{\sin A} = \frac{a \cdot \sin C}{\sin A} = \frac{b \cdot \sin C}{\sin B}$$

$$c = \sqrt{a^2+b^2-2ab \cdot \cos C}$$

$$\sin\tfrac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{bc}} \qquad \text{Sin } A = 2\sqrt{\frac{s(s-a)(s-b)(s-c)}{bc}}$$

$$\text{Cos}\tfrac{1}{2}A = \sqrt{\frac{s(s-a)}{bc}} \qquad \text{Tan}\tfrac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$$

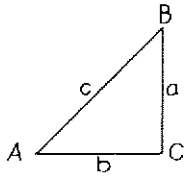
$$\text{Cos } A = \frac{b^2+c^2-a^2}{2bc}$$

$$x = \frac{b^2+c^2-a^2}{2b} \qquad \text{Cos } C = \frac{b-x}{a}$$

$$s = \frac{a+b+c}{2} \qquad r = \sqrt{\frac{(s-a)(s-b)(s-c)}{s}}$$

$$\text{Tan}\tfrac{1}{2}A = \frac{r}{s-a} \qquad \text{Tan}\tfrac{1}{2}B = \frac{r}{s-b}$$

$$\text{Tan}\tfrac{1}{2}C = \frac{r}{s-c}$$



RIGHT TRIANGLES

FUNCTIONS

$\frac{a}{c}$ = sine of A

$\frac{b}{c}$ = cosine of A

$\frac{a}{b}$ = tangent of A

$\frac{b}{a}$ = cotangent of A

$\frac{c}{b}$ = secant of A

$\frac{c}{a}$ = cosecant of A

$\frac{c-b}{c}$ = versine of A

$\frac{c-b}{b}$ = exsecant of A

$\frac{c-a}{c}$ = coversine of A

$\frac{c-a}{a}$ = coexsecant of A

FORMULAE

$a = \sqrt{(c+b)(c-b)}$

$b = \sqrt{(c+a)(c-a)}$

$c = \sqrt{a^2+b^2}$

$a = c \cdot \sin A = b \cdot \tan A$

$b = c \cdot \cos A = a \cdot \cot A$

$c = \frac{a}{\sin A} = \frac{b}{\cos A}$

$a = c \cdot \cos B = b \cdot \cot B$

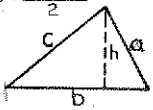
$b = c \cdot \sin B = a \cdot \tan B$

$c = \frac{a}{\cos B} = \frac{b}{\sin B}$

A = Area V = Volume C = Circumference

TRIANGLE

$s = \frac{a+b+c}{2}$



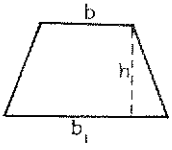
$A = \frac{1}{2}bh$

$A = \sqrt{s(s-a)(s-b)(s-c)}$

POLYGON TRAPEZIUM

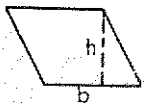
Divide figure into triangle

TRAPEZOID



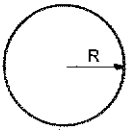
$A = \frac{1}{2}h(b+b_1)$

PARALLELOGRAM RHOMBOID RHOMBUS



$A = bh$

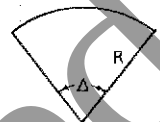
CIRCLE



$A = \pi R^2$

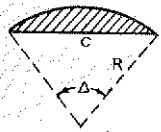
$C = 2\pi R$

SECTOR



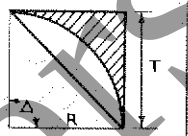
$A = \frac{\Delta}{360}\pi R^2$

SEGMENT



$A = \frac{\Delta}{360}\pi R^2 - \frac{R^2 \sin\Delta}{2}$

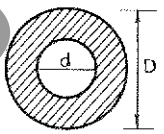
FILLET



$A = R \times T - \frac{\Delta}{360}\pi R^2$

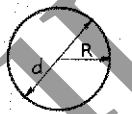
Where $\Delta = 90°$ $A = .2146R^2$

ANNULUS



$A = \frac{\pi}{4}D^2 - d^2$

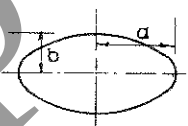
SPHERE



$A = \pi d^2$

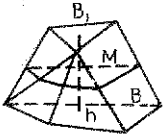
$V = \frac{1}{6}\pi d^3$

ELLIPSE



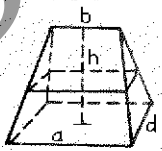
$A = \pi ab$

PRISMATOID PRISMOID



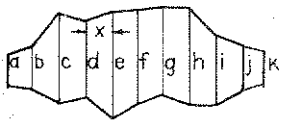
$V = \frac{1}{6}h(B+B_1+4M)$

WEDGE



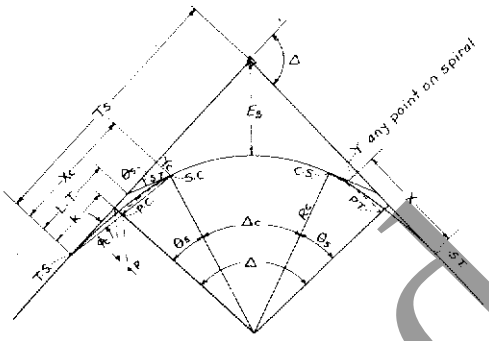
$V = \frac{1}{6}dh(2a+b)$

IRREGULAR FIGURES



$A = \left(\frac{a+k}{2} + b + c + d, \text{etc.}\right) x$

SPIRAL CURVE DATA



Ls = Length of spiral in feet. $Ls = \frac{1.6\ V^3}{Rc}$ (Recommended minimum)
V = Speed in M.P.H.
Rc = Radius of circular curve in feet.
θs = Spiral angle in degrees except as noted. $\theta s = \frac{28.64789\ Ls}{Rc}$
in degrees = $\frac{Ls}{2Rc}$ in radians.

Δc = Angle of circular curve S.C. to C.S. $\Delta c = \Delta - 2\theta s = \Delta - \frac{57.29578\ Ls}{Rc}$

$$X = L\left[1 - \frac{\theta^2}{10} + \frac{\theta^4}{216} - \frac{\theta^6}{9360} - \ldots\ldots\right] \quad \text{Use } \theta \text{ in radians}$$

$$Y = L\left[\frac{\theta}{3} - \frac{\theta^3}{42} + \frac{\theta^5}{1320} - \frac{\theta^7}{75600} + \ldots\ldots\right] \quad \text{Use } \theta \text{ in radians}$$

1 Radian = 57.295780 Degrees
1 Degree = 0.01745329 Radians

Compute Xc & Yc by substituting Ls for L & θs for θ .
p = Offset distance of P.C. of circular curve produced from tangent. (Spiral) almost exactly bisects p) p=Yc-Rc vers.θs=Yc-Rc(1-Cos θs)
k = Distance from T.S. to point on tangent opposite P.C. of circular curve produced. k = Xc - Rc sin θs = $\frac{Ls}{2}$ approximately.
Ts = Tangent distance P.I. to T.S. or S.T.
$Ts = (Rc + p) \tan \frac{\Delta}{2} + k$

L.T. = Long tangent distance. $L.T. = Xc - \frac{Yc}{\tan \theta s}$

S.T. = Short tangent distance $S.T. = \frac{Yc}{\sin \theta s}$

Es = External distance P.I. to curve $Es = \frac{Rc + p}{\cos \frac{\Delta}{2}} - Rc$

θ = Intersecting angle between the tangent of the complete curve and the tangent at any other point on spiral. $\theta = \frac{L^2 \theta s}{Ls^2}$

L.C. = Straight line chord distance from T.S. to S.C. L.C. = $\frac{Xc}{\cos \phi c}$

L = Distance from T.S. to any point on spiral in feet.

Lp = Distance from set-up to any point on spiral in feet.

Dc = Degree of circular curve S.C. to C.S.
$Dc = \frac{5729.578}{Rc} = \frac{200\ \theta s}{Ls}$

D = Degree of curve of spiral at any point = Degree of local circular curve at any point. $D = \frac{L\ Dc}{Ls} = \frac{5729.578\ L}{(Ls)(Rc)} = \frac{200\ \theta s\ L}{Ls^2}$

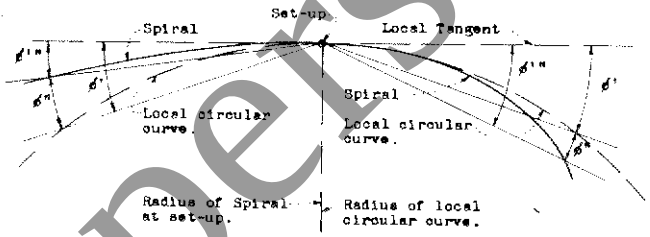
ϕc = Deflection angle at T.S. to S.C. in degrees. $\phi c = \frac{\theta s}{3}$ (very nearly)

ϕ = Deflection angle at T.S. from L.T. to any point on spiral.
$\phi = \frac{\theta}{3} = \frac{L^2\ \theta s}{3\ Ls^2}$

ϕ' = Deflection, at set-up, from local tangent to local circular curve. $\phi' = \frac{Lp\ D}{200}$

ϕ'' = Deflection, at set-up, from local circular curve to spiral.
$\phi'' = \frac{Lp^2\ \theta s}{3\ Ls^2}$

ϕ''' = Deflection, at set-up, from local tangent to any point on spiral. $\phi''' = \phi' - \phi''$ for all points on T.S. side of set-up.
$\phi''' = \phi' + \phi''$ for all points on S.C. side of set-up.



Note:- At any point on a spiral, the spiral leaves the local circular curve at the same rate it leaves the long tangent at the T.S.

The deflection angle from local tangent (short tangent) at S.C. to T.S. = $\frac{2\ \theta s}{3}$ (very nearly) = $\frac{2\ L^2\ \theta s}{3\ Ls^2}$

The deflection angle from local tangent at any point on spiral to T.S. = 2ϕ

When θs is 20° or more a correction "C" as shown in "Barnett" or "Nickerson" is necessary.

To lay out spiral in field, set T.S. & S.T. direct. The S.C. & C.S. are set using Xc & Yc coordinates or by deflection angle ϕc from long tangent at T.S. & S.T. respectively.

Sometimes for reasons of obstruction in the way S.C. cannot be seen from T.S. and it is necessary to move transit ahead. Below is an example showing method of computing deflection angles from local tangent to any other points on spiral when set-up at T.S., S.C., and any other point on spiral.

-: EXAMPLE :-

Given :- Rc = 600' Ls = 300' θs = 14.324° = 14°-19'-26"
Set-up at T.S.

$Dc = \frac{200\ \theta s}{Ls} = \frac{200 \times 14.324}{300} = 9.5493°$ $D = \frac{L\ Dc}{Ls} = \frac{0 \times 9.5493}{300} = 0°$

$\phi' = \frac{Lp\ D}{200} = \frac{Lp \times 0}{200} = 0$ $\phi'' = \frac{Lp^2\ \theta s}{3\ Ls^2} = \frac{Lp^2 \times 14.324}{3\ (300)(300)} = Lp^2 \times .00005305$

Sta.	Lp	Lp^2	$\phi' = Lp \times 0000000$	$\phi'' = Lp^2 \times .00005305$	ϕ'' in Deg.	ϕ''
T.S. 510+90.6	0	0	0.000	0.000°	0.000°	00°-00'
511+00	9.4	88	0.000	0.005°	0.005°	00°-00'
511+50	59.4	3528	0.000	0.187°	0.187°	00°-11'
512+00	109.4	11968	0.000	0.635°	0.635°	00°-38'
512+50	159.4	25408	0.000	1.348°	1.348°	01°-21'
513+00	209.4	43848	0.000	2.326°	2.326°	02°-20'
513+50	259.4	67286	0.000	3.570°	3.570°	03°-34'
S.C. 513+90.6	300.0	90000	0.000	4.775°	4.775°	04°-46'

Sight on long tangent and turn deflections as shown in last column.
Set-up at S.C.

$D = \frac{L\ Dc}{Ls} = \frac{300 \times 9.5493}{300} = 9.5493°$ $\phi' = \frac{Lp\ D}{200} = \frac{Lp \times 9.5493}{200} = \frac{Lp \times .0477465}{}$

Sta.	Lp	Lp^2	$\phi' = Lp \times .0477465$	$\phi'' = Lp^2 \times .00005305$	ϕ'' in Deg.	ϕ''
T.S. 510+90.6	300.6	90000	14.324	4.7750°	9.5490°	09°-33'
511+00	290.6	84488	13.875	4.480°	9.395°	09°-24'
511+50	240.6	57888	11.488	3.071°	8.417°	08°-25'
512+00	190.6	36328	9.100	1.927°	7.173°	07°-10'
512+50	140.6	19768	6.713	1.049°	5.664°	05°-40'
513+00	90.6	8208	4.326	0.435°	3.891°	03°-53'
513+50	40.6	1648	1.939	0.087°	1.852°	01°-51'
S.C. 513+90.6	0	0	0.000	0.000°	0.000°	00°-00'

Sight on short tangent and turn deflections as shown in last column.

Set-up at Sta. 512+50.

$D = \frac{L\ Dc}{Ls} = \frac{159.4 \times 9.5493}{300} = 5.074^{\circ}$ $\quad \phi' = \frac{Lp\ D}{200} = \frac{Lp \times 5.074}{200} = .0253700$ $\quad \frac{Lp}{Ls}$

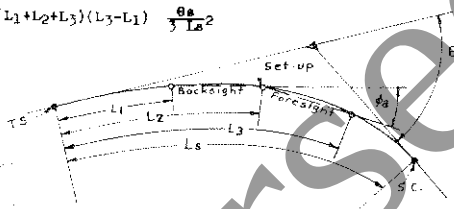
	Sta.	Lp	Lp^2	ϕ' = Lp x .0253700	ϕ'' = Lp^2 x .00005305	ϕ''' in Deg.	ϕ'''
T.S.	510+90.6	159.4	25408	4.044	1.347°	2.697°	02°-42'
	512+50	0	0	0.000	0.000°	0.000°	00°-00'
	513+00	50.0	2500	1.268	0.133°	1.401°	01°-24'
	513+50	100.0	10000	2.537	0.530°	3.067°	03°-04'
S.C.	513+90.6	140.6	19768	3.567	1.049°	4.616°	04°-37'

Set vernier on deflection angle 2°-42' and sight on T.S. Reverse telescope and turn back to zero which will put line of sight on local tangent, turn the rest of the deflections shown in last column.

DEFLECTION ANGLES FOR SET-UP AT ANY POINT

When set-up at any point of a spiral the deflection angle from any backsight to any foresight may be found by the formula:-

$\phi a = (L_1+L_2+L_3)(L_3-L_1) \frac{\theta s}{3\ Ls^2}$



Values are reasonably accurate for all purposes except where "C" corrections for sharp spiral are appreciable. When T.S. & S.C. are located directly and not by carrying spiral station from T.S. to S.C. errors are not accumulative and "C" corrections are rarely necessary.

When set-up on T.S. $L_1 = L_2 = 0$ and backsight is on tangent

When set-up on S.C. $L_2 = L_3 = Ls$ and foresight is on tangent.

When set-up on any point, deflection angle from backsight to local tangent can be computed by making $L_3 = L_2$ and from foresight by making $L_1 = L_2$

1947

	S	M	T	W	T	F	S
JAN				1	2	3	4
	5	6	7	8	9	10	11
	12	13	14	15	16	17	18
	19	20	21	22	23	24	25
	26	27	28	29	30	31	
FEB							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	
MAR							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	29
	30	31					
APR			1	2	3	4	5
	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30			
MAY					1	2	3
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28	29	30	31
JUN	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30					

	S	M	T	W	T	F	S
JUL			1	2	3	4	5
	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30	31		
AUG						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28	29	30
	31						
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	21	22	23	24	25	26	27
	28	29	30				
OCT				1	2	3	4
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	12	13	14	15	16	17	18
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	30						
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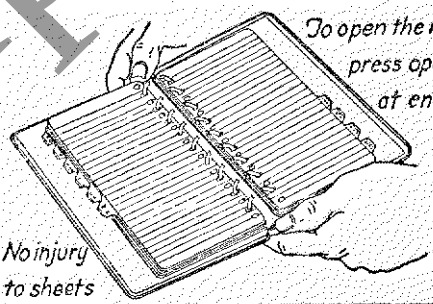

MADE IN U.S.A.

1948

JAN

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25	26	27	28	29	30	31

FEB

S	M	T	W	T	F	S
1	2	3	4	5	6	7
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MAR

S	M	T	W	T	F	S
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APR

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MAY

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JUN

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JUL

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AUG

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SEP

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26	27	28	29	30		

OCT

S	M	T	W	T	F	S
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NOV

S	M	T	W	T	F	S
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DEC

S	M	T	W	T	F	S
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