1115 COMPUTATIONS

1115-1 General

The project field office is given the responsibility of computing the construction survey notes. Since the pay quantities of the contract are determined from the calculations based on the construction survey notes, the project office should be furnished with the necessary equipment and staffed with qualified personnel to facilitate an early determination of pay quantities.

All construction notes and electronic data should be left in the field office on completion of a notebook or when a notebook is not in use in the field. Notes requiring explanation should not exist; however, should an occasion arise where an explanation of notes or diagrams becomes necessary, the Party Chief and the Office Supervisor will collaborate in making necessary explanations in the book. This work should be performed in the field at the site of the work in order to preclude uncertainty of the facts involved.

Cross-section books consisting of notes on roadway excavation, slides, drainage excavation or channel excavation, borrow pits, and any other items that require measurement by the average end area method shall be computed and checked by the field office, and then submitted to Construction Operations for verification of quantities.

Computations may also be done by a CADD/Mapping technician if an electronic data collector is used.

1115-2 Average End Area

The volume of material removed between two stations along the roadway is determined by the average end area method. The crisscross or loop method of computing cross sections is relatively simple, providing care is exercised in observing a few simple rules, as follows:

1. Check the section for grade points (0.0 sections) between cut and fill.
2. Note all ground line breaks between the shoulder point and catch point.
3. Be careful to place the end area quantities in the proper column provided for cut or fill.
4. Show whether the end areas are double-end areas or single-end areas. The area is always a double end area unless the quantity is divided by two before recording the result shown on the calculator.
5. Make certain that all points necessary for proper computation are indicated in the cross section notes, i.e., hinge points, slope stake, etc.

In computing quantities from areas obtained by the double-end area method the following formula applies:

Volume (cubic yards) = $$\frac{1}{2}\left(\frac{A'+A''}{2}\right) X \frac{L}{27} = L\left(\frac{A'+A''}{108}\right)$$

in which A' and A" equal double areas of end sections.

1115-3 Overhaul

The specifications require that the Contractor shall place roadway excavation, structural excavation, drainage excavation, or other material as required. The cost of hauling and placing this material is included in the contract price for the item involved. Although there normally is no pay item for overhaul, it is sometimes necessary to calculate the haul for special studies or as a part of a claim analysis.

Overhaul is generally computed using the cubic-yard-mile.

When the Engineer desires to arrive at the number of cubic-yard-miles of overhaul actually performed by the Contractor, it is necessary to construct a mass diagram of the area in question.

1115-4 Mass Diagram

Volumes may be calculated as shown below or done by CADD/Mapping if an electronic data collector is used on a project.

The plans provide the Contractor with the theoretical overhaul and balance points. The actual balance points and cross-hauled quantities will vary to fit the Contractor's method of operation. This requires the Engineer to keep accurate records of all field balance points and of the materials placed between the balance points.

The mass diagram is constructed in units that extend between the actual field balance points, as reported by the Inspector, with the shrinkage or swell of the excavated material considered uniform. The horizontal scale or abscissa represents stations along the centerline, and is usually plotted to a scale of 1 inch = 100 feet (1 centimeter = 10 meters). The vertical scale or ordinate represents the algebraic sum of the excavation and embankment from some selected station to any station in question and is called the solidity line. The scale shall be determined from the maximum ordinates on the particular projects. It may be 500, 1000, or 2000 cubic yards (250, 500, or 1500 cubic meters) or more to 1 inch (25.4 millimeters).

A curve is drawn connecting the points plotted and is called the mass diagram. Reading from left to right, all ascending lines indicate amount and location of excavation; all descending lines indicate amount and location of embankment.

Instead of starting with the origin as zero, it is better to start with an ordinate figure of say 300,000 so as to keep from having to change from plus to minus, or vice versa, when crossing the "datum line." The initial abscissa shall be the beginning station of the project or station of the nearest balance point back of the point where overhaul is questionable.

As the quantities involved in the mass diagram are computed, they shall be tabulated opposite their corresponding stations. The columns will show roadway excavation, drainage excavation, or overbreakage (if used in the roadway), ground compaction, embankment, embankment equivalent to excavation, and finally "solidity," the ordinate which contains the algebraic accumulated sums of all quantities used in constructing the mass diagram. The initial solidity of 300,000 is the horizontal datum line and should always be of such value that the accumulated solidity value is above zero.

Since excavation usually swells or shrinks, making more or less embankment, it is necessary to adjust the measured embankment quantities to make them correspond to the excavation quantities. To make this correction, first obtain the total net quantity of excavation (considered positive or plus) that went into the roadway, including borrow, overbreakage, drainage, etc., and then obtain the total ground compaction and embankment (negative or minus) quantity. Next, divide the total plus quantities by the total minus quantities to obtain a factor that when multiplied by the measured embankment quantities, gives the corresponding "Embankment Equivalent to Excavation." Each measured embankment quantity per station or plus 50 foot (15 meter) station shall be multiplied by the factor in order to compute the solidity at all stations.

As a check, the total "Embankment Equivalent to Excavation" should equal the total measured excavation quantity contained in the tabulated list. Since the total embankment times the factor equals the total excavation, the desired quantity (solidity) may then be obtained by progressive addition: excavation (positive) and embankment equivalent to excavation (negative).

It is obvious from the method of computation of the solidity that a cut will be represented by a rising line or increasing quantity, and a fill by a falling line or a decreasing quantity. When the curve is above the datum line, it indicates that material must be hauled ahead or to the right; when below the line, material must be hauled back or to the left. The loops which convex upward indicate that the haul from cut to fill is to be in one direction, to the right in this case, while loops concave upward indicate a reverse direction for haul. The maxima and minima of these curves are opposite the 0.0 or grade points on the profile, the changes from cut to fill, or vice versa. (See Exhibit 1115-4-1.)

In general, the mass diagram is composed of balanced loops obtained by drawing horizontal lines across the diagram as shown in Exhibit 1115-4-1. Every loop of the diagram is composed of two equal parts, one of cut and the other of fill. The excavation and the embankment are in balance where the diagram crossed any horizontal line, as at Station 1474+50 to the point where it returns to that line as at Station 1494+33, in the example. The loops above and below this line are balanced sections that may be considered apart from the rest of the diagram.

It is usually impossible to balance successive loops within the same datum line for an entire project, especially where imported borrow quantities are required. (See Exhibit 1115-4-1.)

At times, it will be necessary to show several balanced sections within the field balance points, Stations 1474+50, 1494+33, and 1501+00, as shown in the loops above the datum plane between Stations 1474+50, and 1494+33. These field balance points will be used for computing the swell and shrinkage factors that will be applied to the embankment.

The horizontal lines are drawn through the loops so as to attain as near as possible a straight line on the mass curve between the horizontal lines. The difference in solidity of any two adjacent horizontal lines is the actual quantity of excavated and embankment material between the stationing of the two lines.

In determining where to place these horizontal lines, keep in mind that the excavation shall be placed into the nearest fill. This requires drawing the horizontal line through the loops so that the roadway cut will be placed into an adjacent fill section, keeping in mind that cross haul shall be avoided except where a poor quality of material must be hauled and placed in the bottom of a large fill not adjacent to the poor material.

The most economical distribution of material demands that in making a fill, the material should be obtained from the following sources:

1. from the nearest cut,

2. from a cut such that the cost of haul shall not exceed the cost of excavating the material, and

3. from a nearby borrow pit.

The cubic-yard-mile overhaul is only that quantity hauled beyond the 1500 feet free haul limit.

The only quantities to be considered when computing the cubic yard mile haul are those quantities between the datum line and the line representing the free haul limits. The line representing the 1500' free haul may be determined graphically by first obtaining the approximate stationing of the extreme ends; compute the exact location by applying ratio and proportion to the rate of change per foot and the solidity of the near stations which are 1500 feet apart as determined graphically.

In Exhibit 1115-4-1, the first horizontal line drawn across the large loop is the 1500 foot line crossing the loop at Station 1475+76.7 and at Station 1490+76.7. These stations were determined as directed in the above paragraph. The next horizontal line to be drawn crosses the loop at Station 1475+40.3 and at Station 1492+00. This line is drawn in order to "attain as near as possible, a straight line on the mass curve between the horizontal lines." The difference between the ordinate represented by the datum line and the ordinate between Stations 1475+40 and 1492+00 is the quantity of material to be hauled as indicated in the example of computations below.

The horizontal line between Stations 1476+50 and 1488+47.5 is drawn to show three balanced sections within the large balanced loop. These small loops were drawn to indicate the most economical distribution of the material within the free haul limits. At times it will be necessary to show several balanced sections within a large loop and the sections may consist of one or more loops in excess of the 1500 foot free haul limits.

The vertical distance between the horizontal lines represents embankment if on a falling line, or excavation if on a rising line. Since imported borrow appears only in calculating the swell or shrinkage factor, the quantity represented by the borrow will always be represented by an excess embankment quantity, depressing the diagram, as indicated on Exhibit 1115-4-1, between Stations 1494+44 and 1497+12.1. Waste material appears only as excavation in the computations and has the opposite effect.

At Station 1497+12.1, a new datum line is used, as all the embankment above this line has been taken care of by imported borrow. The same condition will exist where waste material is used in the mass except that the datum line will be above the original datum line. There may be several datum lines to consider, depending on the type and quantities of materials in a project. It is usually impossible to balance successive loops with the same datum line as shown in Exhibit 1115-4-1.

The method of computing hauls varies but the method most commonly used is as follows:

The cubic-yard-mile overhaul is the product of the vertical dimension (the number of cubic yards between the horizontal lines) starting at the 1500 foot line, and the average length of haul – 1500 foot free haul, divided by 5280 feet.

The number of cubic yards between the horizontal lines equals
300,964.2 - 300,789.3 = 174.9 Cubic Yards.

The average length of haul =

$$\frac{(1490+76.7-1475+76.7)}{2}+\frac{(1492+00-1475+40.3)}{2}=\frac{1500+1659.7}{2}=1579.85$$

$$\left(\frac{(1579.85-1500)}{5280}\right)\mathrm{X}174.9=2.6\,\mathrm{C.Y.\,Mile\,Overhaul}$$

This brief outline is for a mass diagram of a completed project. Preliminary diagrams are used in computing quantities for estimates prior to construction by using assumed swell and shrinkage in constructing the mass diagram and computing the haul.

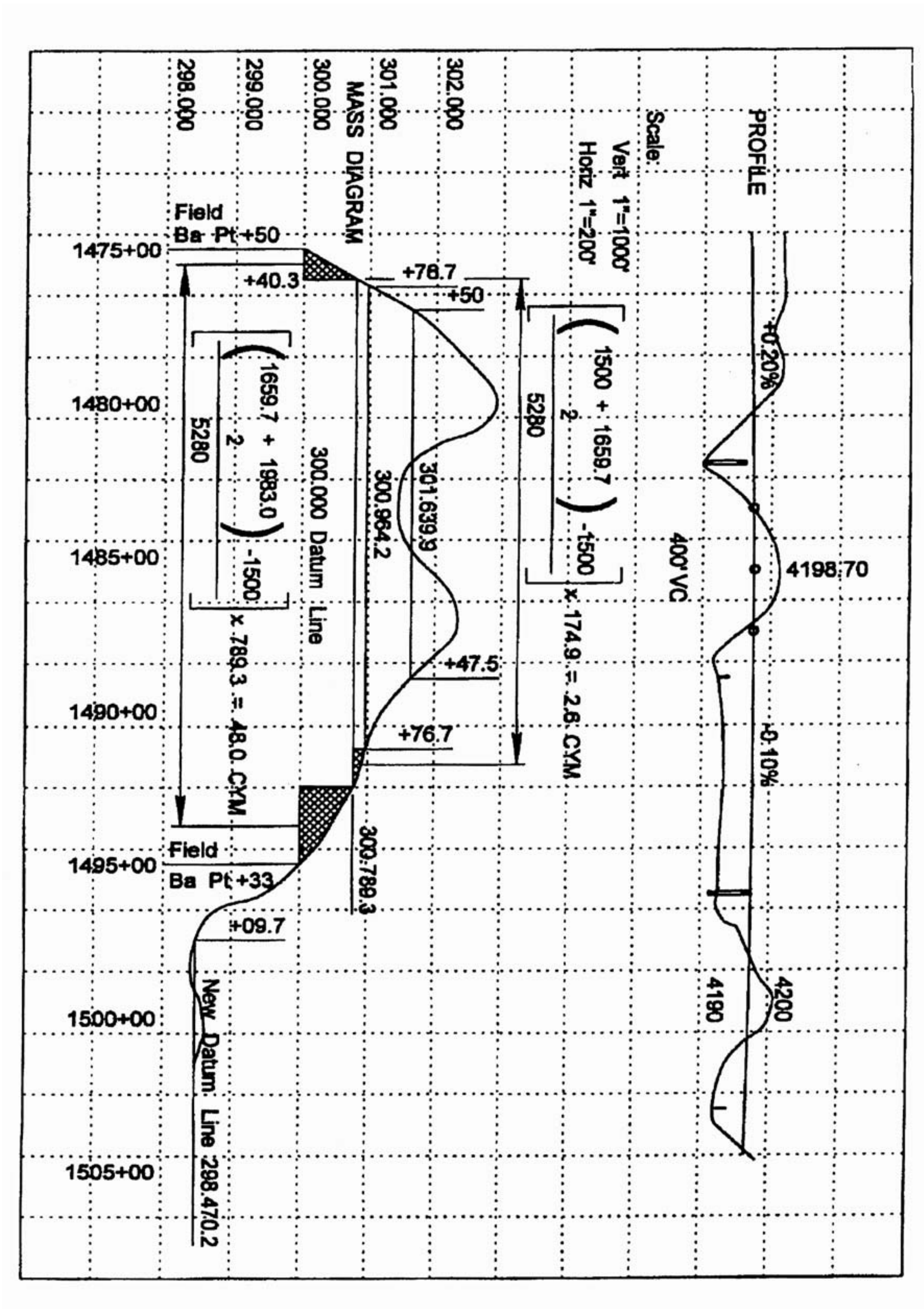

Exhibit 1115-4-1. Mass Diagram