# COLLEGE OF ENGINEERING AND TECHNOLOGY

# DEPARTMENT OF CIVIL ENGINEERING

# HIGHWAY ENGINEERING STREAM

**HIGHWAY FINAL PROJECT**

**WOLKITE, ETHIOPIA**

# WOLKITE UNIVERSITY

## COLLEGE OF ENGINEERING AND TECHNOLOGY

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# DECLARATION

We declare that all materials which are found in this report are our own work and were not copied from other written collaboration with, or fully specifically acknowledged wherever adapted from other source. And also we referred different types of other highway integrated projects and we have refers codes from ERA.

## Acknowledgement

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## ABSTRACT

The project began from a given already gathered survey data from the department and cope up the project with desirable design. The project deals with constructing new roadway. The design is made using ERA manual. This project embraces the following constituents:

- ✓ Introduction
- ✓ Route surveying
- ✓ Traffic survey and analysis
- ✓ Geometric design
- ✓ Earth work
- ✓ Pavement design
- ✓ Environmental impact
- ✓ Conclusion and recommendation

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## List of Abbreviations

| | |
|---|---|
| AADT | Average Annual Daily Traffic |
| AADTml | Average Annual Daily Traffic at mid life |
| ADT | Average Daily Traffic |
| BVC | Beginning of Vertical Curve |
| CBR | California Bearing Ratio |
| DHV | Daily High Volume |
| DC | Design Class |
| DV | Design vehicle |
| ELH | Economic Limit of Haul |
| ERA | Ethiopian Roads Authority |
| EVC | End of Vertical Curve |
| ESA | Equivalent Standard Axle |
| FH | Free Haul |
| NF | Night factor |
| PC | Point of Curvature |
| PI | Point of Intersection |
| PSD | Passing Sight Distance |
| PT | Point of Tangency |
| PVI | Point of Vertical Intersection |
| RFCS | Road Functional Classification System |
| ROW | Right-of-way |
| SF | Seasonal factor |
| SSD | Stopping Sight Distance |

# CHAPTER ONE

# 1. Introduction

## 1.1. General Description

Transportation plays an enormous role in our everyday lives. Each of us travels somewhere almost every day, whether it be to get to work or school, to go shopping, or for entertainment purposes. In addition, almost everything we consume or use has been transported at some point. There are so many ways of transportation, but in this document we concern on road transportation. The better of this structure is the faster, more effective and cheaper, can be the capacities of the society used. Traffic security efficiency, economy, environmental protections are some points which considered during design of highway.

Transportation deals with the movement of humans and materials from place to place. In the world there is various types of transportations like road, railway, air, water, etc.

Road transport is one of the most common mode of transport. Roads in the form of track ways, human pathways etc. were used even from the pre-historic times. Since then many experiments were going on to make the riding safe and comfort. Thus road construction became an inseparable part of many civilizations and empires.

The development of road transportation plays a great role in a country's economic development. Roads are the basic infrastructure in which its service extends facilitating the growth and keeping the different sectors of the economy functional. A country should have adequately designed enough number of roads connecting its main parts. This helps the sufficient mobility of products, raw materials and labor as well as it has a far reaching effects embracing administration convenience and creating national integration and cohesion, which enhance for a better economic achievement of the country, it is this and unmentioned needs which motivate us to do our integrated project on Highway.

From the above listed transportation types, the trends are towards road transportation. The reason behind is

- Roads provide a wide geographical coverage, particularly in hilly regions. And it provides services for the communities from the start up to end (termination)
- Road transportation gives a flexible service, i.e. free from fixed program.
- It gives door to door services, personalized service, creates higher employment potential for the community

For the development of any nation, infrastructure like road is very important. It's impossible to think of development without having accessible roads in a given nation.

Roads are very important for many reasons, some of them are:

- connecting nation to nation
- reduce wastage of energy during travelling
- connecting people to people living in different places
- facilitate international and national trades
- connecting the gap between producers and consumers
- helps in the explorations of natural resources
- used in the transportation of materials which are unevenly distributed
- also enable the governance of vast areas under control of nation

Besides the advantages, there are some side effects and these side effects should be reduced by proper design (project handing) and vehicle operation. Some of the disadvantages are:

- ✓ Environmental pollution, like noise, vibration, less due to aesthetics point of views.
- ✓ Safety: road accidents become a concern in much country.
- ✓ Energy: it consumes higher energy per KM.

## 1.2. Objective of the Project

- ❖ The general objectives are:
  - ✓ To get the knowledge of design methodology
  - ✓ To familiarize the student with analysis and design of highways.
  - ✓ To help the student revise what have been learnt.
  - ✓ To develop the habit of working together in a group and share ideas.
  - ✓ To get full knowledge and to know how of computer soft wares related to highway design like Eagle point.
- ❖ The specific objectives are:
  - ✓ To integrate a knowledge gained in different courses in to one project
  - ✓ To introduce ourselves with different computer programs
  - ✓ To upgrade our highway knowledge.

## 1.3. Scope of the Project

The project is done based on surveying given from department. We were given survey data. As a result we designed the horizontal alignment, vertical alignment, area and volume of earth work to be constructed .Other design data, which are related to the geometry of the road, are taken from ERA manual.

**Methodology**

In order to accomplish this project we are going to use different methodologies and different computer programming software. Some of this software's are;

- ✓ Eagle point 2007
- ✓ Auto cad
- ✓ Microsoft Excel
- ✓ Microsoft word

We have guided based on ERA Manual 2013, and we have put the definition and formula of each term that we are going to use based on the provision of this manual.

# CHAPTER TWO

# 2. ROUTE SELECTION

## 2.1.Corridor Selection

Projects are planned and carried out using a sequence of activities known as the "project cycle." The cycle is composed of the following steps: identification, feasibility, design commitment and negotiation, operation, and evaluation. Route corridor selection comprises of portion of the first three of these activities.

### 2.1.1. Identification

The first stage of the cycle is to find potential projects. This is sometimes known is the "prefeasibility" stage. There are many sources from which suggestions may come, including well informed technical specialists, local leaders, proposals to extend existing programs or projects, and from operating agencies responsible for project implementation.

The decision to proceed to the feasibility stage arouses expectations for the project. Dubious projects shall therefore be rejected at the identification stage. It becomes increasingly difficult to stop a project at the later stages of the cycle.

### 2.1.2. Feasibility

The feasibility study will provide sufficient information to decide whether to proceed to a more advanced stage of planning. The level of detail of this study will depend on the complexity of the project and how much is already known about the proposal. The feasibility study shall define the objectives of the project. It shall consider alternative ways of achieving these and eliminating poor alternatives. The study provides the opportunity to mold the project to fit its physical and social environment to maximize the return on the investment.

Once the feasibility study has indicated which project is likely to be the most worthwhile, detailed planning and analysis can begin. Less promising projects will have been eliminated by this time, and the selected project may be redefined and modified as more detailed information becomes available. At this stage, studies of traffic, geotechnics and design will be carried out to refine the prediction of costs and benefits and to enable an economic analysis to be carried out.

### *2.1.3* Design

Preliminary design and feasibility are often simultaneous, but detailed design, which can be very costly (up to 15 percent of project costs), usually follows a provisional commitment to the project. Numerous decisions, which will affect economic performance, are taken throughout design; and economic appraisal often results in redesign.

### 2.1.4. Commitment and Negotiation

Commitment of funds often takes place is a series of stages. This is followed by invitation to tender and negotiations with contractors, potential financiers and suppliers. At this stage, there are still considerable uncertainties.

### 2.1.5. Implementation

Detailed recommendations on project implementation are beyond the scope of this chapter. However, several aspects of the earlier stages in the project cycle will affect the success of the implementation.

The better and more realistic plan, the more likely it is that the plan can actually be carried out and the full benefits realized. A flexible implementation plan shall be sought. It is almost inevitable that some circumstances will change during the implementation. Technical changes may be required as more detailed soils information becomes available or as the relative prices of construction materials change. Project managers may need to change and re-plan parts of the project to take account of such variations. The more innovative and novel the project is, the greater is the likelihood that changes will have to be made during implementation.

### 2.1.6. Operation

This refers to the actual use of the road by traffic; it is during this phase that benefits are realized and maintenance is undertaken.

### 2.1.7. Evaluation

The final phase of the project cycle is evaluation. This consists of looking back systematically at the successful and unsuccessful elements of the project experience to learn how planning can be improved in the future.

For evaluation to be successful, it is important that data about the project is collected and recorded in a systematic way throughout all stages of the project cycle.

Without this, it is usually impossible to determine details of events and information that were available during periods leading up to the taking of important decisions.

Many different people may carry out evaluation. For each stage of the project, data shall be collected for identifying problems that need to be brought to the attention of the project's management.

The evaluation shall result in specific recommendations about improving aspects of the project design, which can be used to improve ongoing and future planning. The steps in the survey process are summarized in the following sections.

## 2.2. Criteria considered

There are different criteria taken into considerations while selecting a route these are:-

- Terrain: - according the consideration briefly to reduce more cut or fill, rolling type terrain or a terrain with more than 5% grade is selected.
- Structures: - when selecting a route structures such as bridges should be avoided so as to minimize the project cost.
- Land Cover: - in order to minimize the environmental cost open land that is no forest land is selected.
- Settlement:-population settlement between the two places is taken into consideration, so that the highway can connect them.

## 2.3. Route Selection on Field

After the route is selected on a map, the surveyors select a modified route on a field than on a disk. The main aim is for verification, during verification the surveyors can make adjustment on the route selected, on the paper, if there is geographical difference between the map and the land. The difference may be due to erosion, deformation or generally due to natural or manmade causes. Data gathering of the verified and adjusted route is done on the field.

## 2.4. Procedures Followed In Selecting Route

In selecting the route a contour with relatively flat portion is selected in order to avoid excessive excavation which results in high cost. Moreover, selecting a route on a steep slope may result in climbing difficulty of heavy vehicles .we tried to avoid sharp curves and provide sufficient arc length to ensure the safe turning of the vehicles.

# CHAPTER THREE

# 3. Traffic Survey and Analysis

## 3.1 Introduction

The traffic volume is one of the parameters used for determination of design standards. Collection of traffic data and estimation of future traffic composition, traffic volume and traffic growth rate should be carried out carefully and precisely. So the actual traffic encountered will be as expected and this reduces the effect of over dosing (traffic congestion). In addition over estimation used to uneconomical designs and often cause wastage of national resource. Among the various elements of the following are based on traffic forecast that are:

- ✓ Design speed
- ✓ Geometry of the road
- ✓ Drainage system
- ✓ Pavement type and thickness

## 3.2 General

Traffic counts carried out over a short period as a basis for estimating the AADT can produce estimates which are subject to large errors because traffic volumes can have large daily, weekly, monthly and seasonal variations. The daily variability in traffic volume depends on the volume of traffic, with particularly high variability on roads carrying less than 1000 vehicles per day.

## 3.3. Traffic Forecast

Even with stable economic conditions, traffic forecasting is an uncertain process. Although the pavement design engineer may often receive help from specialized professionals at this stage of the traffic evaluation, some general remarks are in order.

To forecast traffic growth it is usually necessary to separate traffic into the following three categories:

### 3.3.1. Normal traffic

The most common method of forecasting normal traffic is to extrapolate data on traffic levels and assume that growth will either remain constant in absolute terms i.e. a fixed number of vehicles per year, or constant in relative terms (a fixed percentage increase). As a general rule it is only safe to extrapolate forward for as many years as reliable traffic data exist from the past, and for as many years as the same general economic conditions are expected to continue.

As an alternative, growth can be related linearly to anticipate growth of Gross Domestic Product (GDP). This is normally preferable since it explicitly takes into account changes in overall economic activity.

### 3.3.2. Diverted traffic

Where parallel routes exist, traffic will usually travel on the quickest or cheapest route although this may not necessarily be the shortest. Thus, surfacing an existing road may divert traffic from a parallel and shorter route because higher speeds are possible on the surfaced road. Origin and destination surveys should preferably be carried out to provide data on the traffic diversions likely to arise. Diverted traffic is normally forecast to grow at the same rate as traffic on the road from which it diverted.

### 3.3.3. Generated traffic

Generated traffic arises either because a journey becomes more attractive by virtue of a cost or time reduction or because of the increased development that is brought about by the road investment.

**Assumptions**

- We have assumed the diverted traffic to be 10% of the normal traffic.
- We have assumed the generated traffic to be 25% of the normal traffic.

## 3.4.Road Functional Classification and Numbering

The functional classification in Ethiopia includes five functional classes. The following are the functional classes with their description.

**I. Trunk Roads (Class I)**

Centers of international importance and roads terminating at international boundaries are linked with Addis Ababa by trunk roads. Trunk roads have a present AADT ≥1000, although they can have volumes as low as 100 AADT.

**II. Link Roads (Class II)**

Centers of national or international importance, such as principal towns and urban centers, must be linked between each other by link roads. A typical link road has over 400 - 1000 first year AADT, although values can range between 50-10,000 AADT.

**III. Main Access Roads (Class III)**

Centers of provincial importance must be linked between each other by main access roads. First year AADTs are between 30 and 1,000 vehicles.

**IV. Collector Roads (Class IV)**

Roads linking locally important centers to each other, to a more important center, or to higher class roads must be linked by a collector road. First year AADTs are between 25- 400.

**V. Feeder Roads (Class V)**

Any road link to a minor center such as market and local locations is served by a feeder road. First year AADTs are between 0-100.

## 3.5. Determination of Cumulative Traffic Volumes

The classification and description of all existing trunk, link and main access roads within the country, including road name, distance, type of road and road numbering, are given in table

Table 1 Daily traffic count and AADT0 at 2011

| Day | Car | Utilities | S/bus | M/bus | L/bus | S/truck | M/truck | H/truck | Truck/trl | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| day1 | 5 | 13 | 8 | 26 | 8 | 26 | 34 | 5 | 8 | 133 |
| day2 | 8 | 13 | 26 | 22 | 17 | 8 | 13 | 22 | 17 | 146 |
| day3 | 8 | 8 | 22 | 34 | 26 | 30 | 8 | 5 | 17 | 158 |
| day4 | 13 | 8 | 13 | 17 | 39 | 8 | 13 | 26 | 17 | 154 |
| day5 | 5 | 8 | 13 | 17 | 8 | 26 | 22 | 22 | 17 | 138 |
| day6 | 13 | 17 | 22 | 39 | 30 | 13 | 26 | 17 | 8 | 185 |
| day7 | 8 | 22 | 26 | 30 | 30 | 22 | 26 | 22 | 5 | 191 |
| 7 days Average | 9 | 10 | 19 | 26 | 23 | 19 | 20 | 17 | 13 | 156 |
| Average NF | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | |
| ADT | 14 | 15 | 29 | 34 | 39 | 29 | 20 | 20 | 14 | 214 |
| Seasonal adj. Factor | 1 | 1.1 | 1.03 | 0.98 | 1.01 | 1 | 1.04 | 1.06 | 1.05 | |
| AADT | 14 | 16 | 30 | 33 | 39 | 29 | 21 | 21 | 15 | 218 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle composition | 0.0642 | 0.0734 | 0.1376 | 0.1514 | 0.1789 | 0.133 | 0.0963 | 0.0963 | 0.0688 | 1 |

In order to determine the cumulative number of vehicles over the design period of the road, the following procedure should be followed:

1. Determine the initial traffic volume, AADT (m)0, of each traffic class (m) using the results of the traffic survey and any other recent traffic count information that is available.
2. Estimate the annual growth rate "i" expressed as a decimal fraction, and the anticipated number of years "n" between the traffic survey and the opening of the road.
3. For each vehicle class, estimate the traffic in the first year that the road is opened to traffic. For normal traffic this is given by

$$AADT_{(m)1} = AADT(m)_0(1+i)^n$$

4. For each vehicle class, add the estimate for diverted traffic and for generated traffic if any are anticipated.

**Where;** T(m) = the cumulative traffic of traffic class m

$AADT_{(m)1}$ = The AADT of traffic class m in the first year

N = the design period in years

i = the annual growth rate of traffic in percent

### 3.5.1. Design Period

Determining an appropriate design period is the first step towards pavement design. Many factors may influence this decision, including budget constraints. However, the designer should follow certain guidelines in choosing an appropriate design period, taking into account the conditions governing the project. Some of the points to consider include:

- ✓ Functional importance of the road
- ✓ Traffic volume
- ✓ Location and terrain of the project
- ✓ Financial constraints
- ✓ Difficulty in forecasting traffic

Table 2 Design Period

| Road Classification | Design Period (Years) |
|---|---|
| Trunk Road | 20 |
| Link Road | 20 |
| Main Access Road | 15 |
| Other Roads | 10 |

**Assumptions**

- We have assumed that the road as Link Road. The design period will be 20 years.
- The traffic count is taken at 2011 EC
- The road will be open for service after four year after the traffic count. That is at 2015 EC
- The anticipated traffic growth is assumed 8%
- The determination of design class will be based on the traffic count at the mid-life of the road(at 2025 EC)
- By assuming the traffic count is taken at 2011 EC and the construction takes 4 year the opening period of the road will be at 2015 EC.

The projected AADTs in 2015 for both directions can be calculated as;

$AADT1 = AADT0\ (1+r)^{X}$

Where: r=growth rate = 8%, x=the anticipated number of years between traffic survey & the opening of the road.

AADT at the opening year of the road ($AADT2015_{)}$

$AADT\ (for\ car) = AADT0\ (1+r)^{X}$

$= 14^{*}\ (1+0.08)^{4} = 19.05 = \underline{19}$

$AADT\ (for\ Utilities) = AADT0\ (1+r)^{X}$

$= 16^{*}\ (1+0.08)^{4} = 21.77 = \underline{22}$

AADT (for small Bus) = AADT0 $(1+r)^X$

$=30*(1+0.08)^4 = 40.81 = \underline{41}$

AADT (for Medium Bus) = AADT0 $(1+r)^X$

$=33*(1+0.08)^4 = 44.9 = \underline{45}$

AADT (for large Bus) = AADT0 $(1+r)^X$

$=39*(1+0.08)^4 = 53.06 = \underline{53}$

AADT (for small truck) = AADT0 $(1+r)^X$

$= 29*(1+0.08)^4 = 39.45 = \underline{39}$

AADT (for medium Truck) = AADT0 $(1+r)^X$

$=21*(1+0.08)^4 = 28.57 = \underline{29}$

AADT (for Heavy Truck) = AADT0 $(1+r)^X$

$=21*(1+0.08)^4 = 28.57 = \underline{29}$

AADT (for Truck Trailer) = AADT0 $(1+r)^X$

$=15*(1+0.08)^4 = 20.41 = \underline{20}$

$\sum$ AADT=19+22+41+45+53+39+29+29+20

$\Rightarrow \sum AADT = \underline{297}$

**Total traffic**

Total traffic = Normal traffic + Diverted traffic + Generated traffic

*Table 3 Total traffic*

| Vehicle classification | Car | Utilities | S/bus | M/bus | L/bus | S/truck | M/truck | H/truck | Truck/trl | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| AADT0 2011 | 14 | 16 | 30 | 33 | 39 | 29 | 21 | 21 | 15 | 218 |
| AADT1 2015 | 19 | 22 | 41 | 45 | 53 | 39 | 29 | 29 | 20 | 297 |
| Diverted 0.1* AADT1 | 2 | 3 | 5 | 5 | 6 | 4 | 3 | 3 | 2 | 33 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Generated 0.25* AADT1 | 5 | 6 | 11 | 12 | 14 | 10 | 8 | 8 | 5 | 79 |
| Total AADT1 (2015) | 26 | 31 | 57 | 62 | 73 | 53 | 40 | 40 | 27 | 409 |
| AADTml (2025) AADT1 $(1+r)^N$ | 57 | 67 | 123 | 134 | 158 | 115 | 87 | 87 | 59 | 887 |

From the above AADT2025 value and table: 3, our road standard is DC5 link road**.**

*Table 4 Road Classification, AADT, Carriageway widths and design speed*

| Road Functional Classification | | | | | Design Standard | Design Traffic Flow (AADT) (Mid-life) | Surface Type | Width (m) | Design Speed (km/hr.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Carriageway | Flat | Rolling | Mountainous | Escarpment | Urban/Peri-Urban |
| | | | | TRUNK | DC8 | 10,000 –15,000 | Paved | Dual 2 x 7.3 | 120 | 100 | 85 | 70 | 50 |
| | | | LINK | | DC7 | 3,000 – 10,000 | Paved | 7.3 | 120 | 100 | 85 | 70 | 50 |
| | | | | | DC6 | 1,000 – 3,000 | Paved | 7.0 | 100 | 85 | 70 | 60 | 50 |
| | | MAIN ACCESS | | | DC5 | 300 – 1,000 | Paved | 7.0 | 85 | 70 | 60 | 50 | 50 |
| | COLLECTOR | | | | DC4 (2) | 150 – 300 | Paved | 6.5 – 7.0 (1) | 70 | 60 | 50<br>45(3) | 30 | 50 |
| | | | | | | | Unpaved | 7.0 – 7.5 (1) | | | | | |
| FEEDER | | | | | DC3 (2) | 75 – 150 | Paved | 6.0 | 70 | 60 | 50<br>45(3) | 30 | 50 |
| | | | | | | | Unpaved | 7.0 | | | | | |
| | | | | | DC2 (2) | 25 – 75 | Paved | 3.3 | 60 | 50 | 40<br>35(3) | 25 | 50 |
| | | | | | | | Unpaved | 6.0 | | | | | |
| | | | | | DC1 | 1 – 25 | Unpaved | 4.5 | 50 | 40 | 30 | 20 | 40 |
| | | | | | Basic Access | <10 | Unpaved | 3.5 | | | | | |

# CHAPTER FOUR

# 4 Geometric Design

## 4.1 Elements of Geometric Design

Geometric design is the process whereby the layout of the road through the terrain is designed to meet the needs of the road users. The principal geometric features are the road cross-section and horizontal and vertical alignment.

- Horizontal alignment
  - ✓ Minimum radius of curve
  - ✓ Minimum stopping sight distance
  - ✓ Minimum passing sight distance
- Vertical alignment
  - ✓ Maximum gradient
  - ✓ Length of maximum gradient
  - ✓ Minimum stopping sight distance on vertical curves
  - ✓ Length of vertical curves
- Cross section
  - ✓ Width of carriage way
  - ✓ Width of shoulders
  - ✓ Right of way
  - ✓ Cross fall, camber and super elevation

Design of elements are influenced by a variety of design controls engineering criteria like:

- function and classification of the road
- required design speed
- topography of the surrounding land
- projected traffic volume and composition
- traffic safety considerations
- environmental considerations

- ❖ capital cost of construction and
- ❖ Roadway users etc.

## 4.2 Design Control Factors

For the above principal geometric features, there should be a design control to satisfy them.

These controls are the following:

- ✓ Topography/ Terrain
- ✓ Design speed
- ✓ Traffic factor
- ✓ Volume and capacity traffic
- ✓ Environmental factor
- ✓ Design class

### 4.2.1 Terrain

The geometric design elements of a road depend on the transverse terrain through which the road passes. Transverse terrain properties are categorized into four classes as follows:

Table 5 Terrain classification according to ERA 2013 design

| **Terrain type** | **Properties** |
|---|---|
| Flat | Transverse terrain slope up to 3% |
| Rolling | Transverse terrain slope 3% to 25% |
| Mountainous | Transverse terrain slope 25% to 50% |
| Escarpment | Transverse terrain slope beyond 50% |

We have taken our stations at 20m intervals and prepared the terrain category of the road aliment throughout its stations. We have taken right of way as 30m (15m to the right and 15m to the left of the center line). The terrain type is provided in the Appendix **A.**

### 4.2.2 Design Speed

The Design Speed is used as an index which links road function, traffic flow and terrain to the design parameters of sight distance and curvature to ensure that a driver is presented with a reasonably consistent speed environment. In practice, most roads will only be constrained to minimum parameter values over short sections or on specific geometric elements.

Design elements such as lane and shoulder widths, horizontal radius, super-elevation, sight distance and gradient are directly related to, and vary, with design speed. Thus all of the geometric design parameters of a road are directly related to the selected design speed.

### 4.2.3 Traffic

The design of a road should be based on the estimated traffic expected to use the facility. A good design should provide flexibility for changing conditions. Apart from volume, the number of each of the different types of vehicles should be estimated.

### 4.2.4 Capacity

Capacity of a road is the maximum number of vehicles that can pass over a given section of a roadway in both direction over a given time period, usually one hour. It is the maximum rate of flow that has a reasonable expectation of occurring.

### 4.2.5 Environmental consideration

Another design control factor is environmental condition in which the road is to be designed. The road going to be constructed has many advantages so that it should provide its function without disturbed by the atmosphere of area. Also aesthetic and landscaping should affect the geometry of the road. So it should be considered in the design of the road.

Table 6 Geometric parameters for Design Class DS5 Paved (AADT 300 – 1000)

| Design Element | | Unit | Flat | Rolling | Mountain | Escarp't | Urban Peri-Urban |
|---|---|---|---|---|---|---|---|
| Design Speed | | km/hr | 85 | 70 | 60 | 50[3] | 50 |
| Width of Running Surface | | m | 7.0 | | | | 7.0+ |
| Width of Shoulders | | m | Table 2.2 and Table 2.5 | | | | |
| Minimum. Stopping Sight Distance | g = 0% | m | 155 | 110 | 85 | 65 | 65 |
| | g = 5% | m | 175 | 120 | 90 | 70 | 70 |
| | g = 10% | m | 205 | 140 | 105 | 75 | 75 |
| Min. Passing Sight Distance[2] | | m | 330 | 270 | 230 | 180 | 180 |
| % Passing Opportunity | | % | 25 | 25 | 15 | 0 | 20 |
| Minimum Horizontal Curve Radius[4] | SE = 4% | m | 350 | 215 | 145 | 95[3] | 95 |
| | SE = 6% | m | 310 | 195 | 135 | 85[3] | 85 |
| | SE = 8% | m | 280 | 175 | 120 | 80[3] | - |
| Transition Curves Required | | | Yes | Yes | No | No | No |
| Max. Gradient (desirable) | | % | 4 | 6 | 8 | 8 | 7 |
| Max. Gradient (absolute) | | % | 6 | 8 | 10[4] | 10[4] | 9 |
| Minimum Gradient | | % | 0.5[5] | 0.5 | 0.5 | 0.5 | 0.5 |
| Maximum Super-elevation | | % | 8 | 8 | 8 | 8 | 4 |
| Min. Crest Vertical Curve [1] | | K | 55 | 30 | 17 | 10 | 10 |
| Min. Sag Vertical Curve | | K | 18 | 12 | 9 | 7 | 7 |
| Normal Cross-fall | | % | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Shoulder Cross-fall | | % | 4 | 4 | 4 | 4 | 4 |
| Right of Way | | m | 50 | 50 | 50 | 50 | 50 |

## 4.3 Horizontal alignment design

The design elements of the horizontal alignment are the tangent, or straight section, the circular curve, the transition curve (spiral) and the super-elevation section.

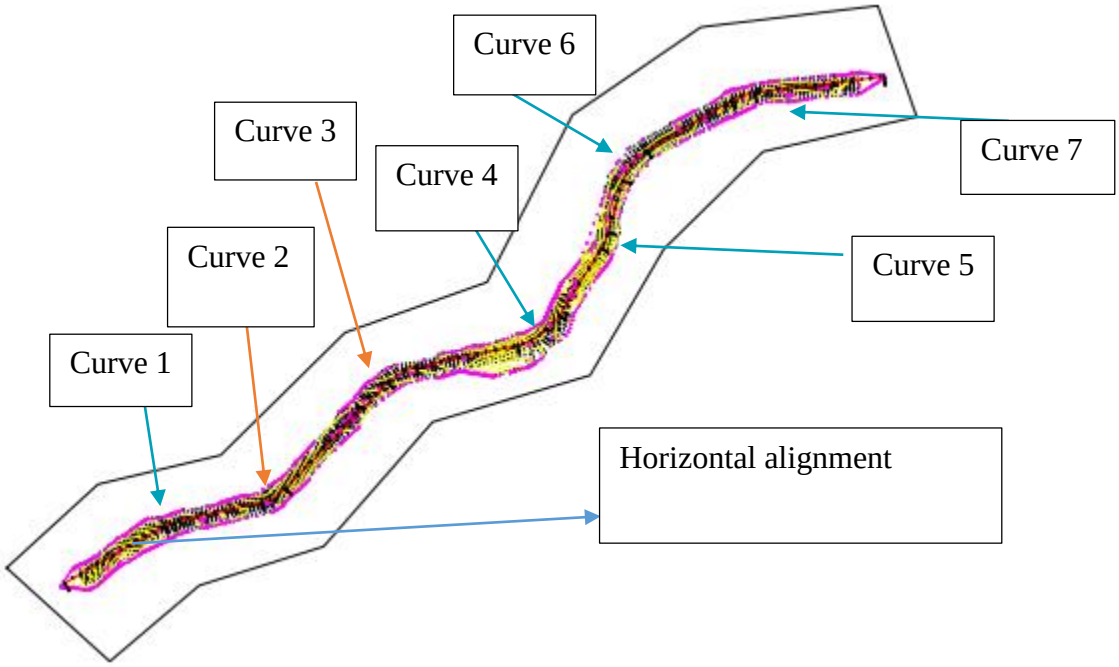



Figure 1 Horizontal alignment

### 4.3.1 Tangent Sections

From an aesthetic point of view, tangent sections may often be beneficial in flat country but are less so in rolling or mountainous terrain. From a safety standpoint, they provide better visibility and more passing opportunities. However, long tangent sections increase the danger from headlight glare and usually lead to excessive speeding.

ERA manual sets the maximum length between tangent sections should not exceed 4.0 kilometers. Based on this, the length between each tangent line of circular curves is less than 4 kilometer.

### 4.3.2 The Circular Curve

When a vehicle moves in a circular path, it is forced radially outward by centrifugal force. The centrifugal force is counterbalanced by super-elevation of the roadway and/or the side friction developed between the tires and the road surface. For calculation of the minimum horizontal radius, R min, for a particular design speed, the following equation shall be used:

$$Rmin = V_d^2 /[127(f+e)]$$

Where:-

Vd = Design Speed (km/h)
e = Maximum super elevation (%)
f = Side friction coefficient

Table 7 Minimum Radii for Horizontal Curves

| Design speed (km/h) | 20 | 25 | 30 | 40 | 50 | 60 | 70 | 80 | 85 | 100 | 120 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Side Friction Factor (f) | 0.23 | 0.22 | 0.21 | 0.19 | 0.17 | 0.16 | 0.14 | 0.13 | 0.12 | 0.11 | 0.10 |
| Super-elevation = 4% | 15 | 19 | 30 | 55 | 95 | 145 | 215 | 300 | 350 | 515 | 780 |
| Super-elevation = 6% | 15 | 18 | 27 | 50 | 85 | 135 | 195 | 270 | 310 | 455 | 685 |
| Super-elevation = 8% | 15 | 17 | 25 | 50 | 80 | 120 | 175 | 240 | 280 | 410 | 610 |
| Super-elevation = 10% | 15 | 16 | 25 | 45 | 75 | 110 | 160 | 220 | 255 | 375 | 555 |

- ✓ For **DS5**, mountainous terrain: Vd=60km/h, super-elevation=6%, f=16%, e=6%

  **Rmin**= $60^2$/ [127(0.06+0.16)] = 128.848m

  Rmin = 128.48 is less than Rmin recommended by ERA. That is 135m.

  Therefore, use R = 200m

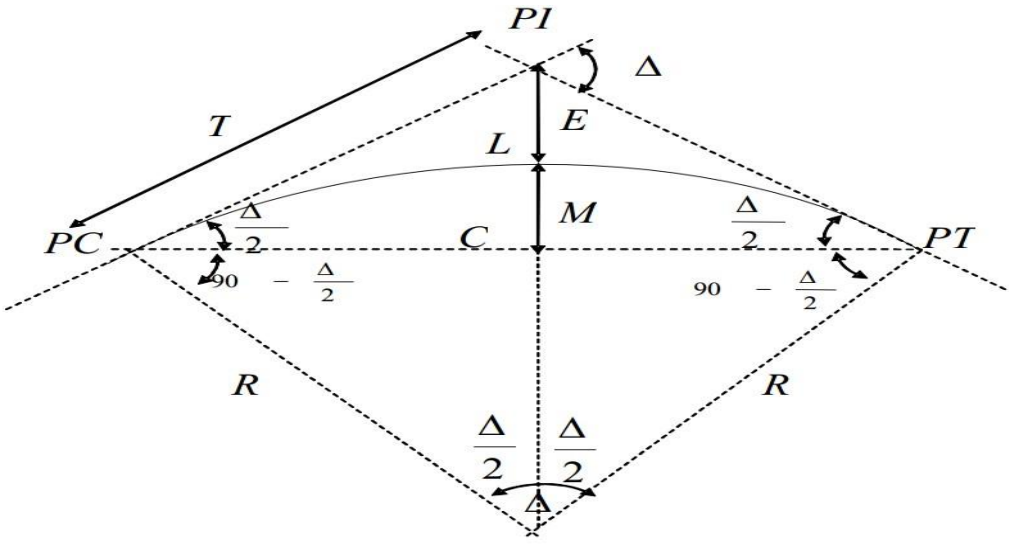



*Figure 2 horizontal curves*

Where:

- ✓ R= Radius usually measured to the center line of the road, in meter.
- ✓ Δ = Central angle of the curve in degrees
- ✓ PC = Point of curve (the beginning point of the horizontal curve)
- ✓ PI = Point of tangent intersection
- ✓ PT = Point of tangent (the ending point of the horizontal curve)
- ✓ T = Tangent length in m.
- ✓ M = Middle ordinate from middle point of cord to middle point of curve in m.
- ✓ E = External distance in m.
- ✓ L = Length of curve
- ✓ D = Degree of curvature (the angle subtended by a 20m arc along the horizontal curve)
- ✓ C = Chord length from PC to PT.

**Sample calculation (Curve no. One)**

$\Delta = 2^0\ 30'\ 54''$

Topography=mountainous

Rmin=135m for DC5

R provided=200m

- **Tangent length,**

$T = R*\tan\Delta/2$

$T = 200*\tan(2^0\ 30'\ 54''/2)$

T=29.944m

- **Length of curve,**

$Lc = \prod R\Delta/180$

$Lc = 3.14*200*2^0 30'\ 54''/180$

Lc=59.447m

- Chainage of PC = PI-T

=0+643.27 – 29.944m = 0 + 613.326m

- Chainage of PT =PC + Lc

  =0 + 613.326m + 59.447

  =0+672.773m

Table 8 Summary of horizontal alignment

| Curve no | Chainage 0f PI | Central angle | Topography | Rmin | Rprovide | Tangent angle | Curve length |
|---|---|---|---|---|---|---|---|
| 1 | 0+643.270 | 2.515 | Mountain | 135 | 200 | 29.944 | 59.447 |
| 2 | 1+228.064 | 2.173 | Rolling | 195 | 250 | 74.597 | 144.989 |
| 3 | 2+178.658 | 1.544 | Rolling | 195 | 300 | 91.401 | 177.442 |
| 4 | 2+966.790 | 1.381 | Rolling | 195 | 350 | 147.600 | 274.349 |
| 5 | 3+570.650 | 1.441 | Flat | 320 | 330 | 16.989 | 93.350 |
| 6 | 4+015.279 | 2.025 | Rolling | 195 | 400 | 111.758 | 212.665 |
| 7 | 4+705.953 | 1.381 | Rolling | 195 | 350 | 71.900 | 141.826 |

### 4.3.3 Transition curve

The characteristic of a transition curve is that it has a constantly changing radius. Transition curves may be inserted between tangents and circular curves to reduce the abrupt introduction of lateral acceleration. They may also be used between two circular curves.

For large radius curves, the rate of change of lateral acceleration is small and transition curves are not normally required. For Ethiopian roads, transition curves are a requirement for trunk and link road segments having a design speed of equal to or greater than 80 km/hr.

### 4.3.4 Sight distances

Sight distance is the distance visible to the driver of a passenger car. For highway safety, the designer must provide sight distances of sufficient length that drivers can control the operation of their vehicles.

Sight distance includes:-

- ✓ stopping sight distance
- ✓ passing sight distance

### 4.3.5 Stopping Sight Distance

The stopping sight distance on a roadway must be sufficiently long to enable a vehicle traveling at the design speed to stop before reaching a stationary object in its path. The minimum stopping sight distance is determined from the following formula, which takes into account both the driver reaction time and the distance required to stop the vehicle.

The formula is:

$$d=0.278(t)(v)+V^2/127f$$

Where;

d = distance (meter)

t = driver reaction time, generally taken to be 2.5 seconds

V = initial speed (km/h)

F = coefficient of friction between tires and roadway

Table 9 Sight Distances

| Design Speed (km/h) | Coefficient of Friction (f) | Stopping Sight Distance (m) | | | Minimum Passing Sight Distance (m) (from formulae) | Passing Sight Distance to allow manoeuvre to be aborted (m) |
|---|---|---|---|---|---|---|
| | | g = 0 | g = 5% | g = 10% | | |
| 20 | .42 | 18 | 18 | 19 | 160 | - |
| 25 | .41 | 23 | 24 | 25 | 190 | 50 |
| 30 | .40 | 30 | 32 | 33 | 220 | 80 |
| 40 | .37 | 45 | 47 | 50 | 285 | 135 |
| 50 | .35 | 65 | 70 | 75 | 350 | 180 |
| 60 | .33 | 85 | 90 | 105 | 415 | 230 |
| 70 | .315 | 110 | 120 | 140 | 480 | 270 |
| 80 | .305 | 140 | 155 | 180 | 545 | 310 |
| 85 | .295 | 155 | 175 | 205 | 575 | 330 |
| 90 | .29 | 170 | 195 | 230 | 610 | 345 |
| 100 | .285 | 210 | 240 | 285 | 675 | 375 |
| 110 | .28 | 245 | 285 | 340 | 740 | 405 |
| 120 | .28 | 285 | 330 | 400 | 805 | 425 |

### 4.3.5.1 Break reaction distance

It is a distance that will be travelled by the driver at the instant he/she sees an object. ERA states the following formula for determining break reaction distance as:-

**D = (0.278) (t) (V)…**Where: - D = break reaction distance (m)

t = driver reaction time, generally taken to be 2.5sec

V = initial speed (km/h)

### 4.3.5.2 Breaking distance

Braking distance is a distance covered by the driver while applying break at the instant the driver apply the brake up to stoppage of the vehicle.

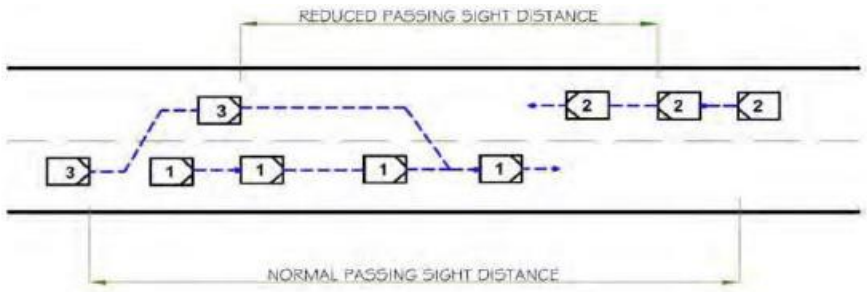



*Figure 3 sight distance*

**D = $V^2$/254f** Where, f = coefficient of friction between tires and roadway.

Therefore, SSD= **(0.278) (t) (V) + $V^2$/254f**

**Sample calculation**

**Curve -1**: Given;

Vd = 60km/hr

T=2.5se

f=0.33

d1=0.33*60*2.5=<u>49.50m</u>

d2=$60^2$/254*0.33=<u>42.95m</u>

Therefore; SSD=49.50m +42.95m =92.449m > 90m……ERA's recommended stopping sight distance (90m) is acceptable.

#### 4.3.5.3 Passing Sight Distance

Passing Sight Distance is the minimum sight distance on two-way single roadway roads that must be available to enable the driver of one vehicle to pass another vehicle safely without interfering with the speed of an oncoming vehicle traveling at the design speed.

Within the sight area the terrain should be the same level or a level lower than the roadway. Otherwise, for horizontal curves, it may be necessary to remove obstructions and widen cuttings on the insides of curves to obtain the required sight distance.

**Sight distance calculation**

- Case 1

S=Lc=∏RΔ/180

M=Rn*(1-cosΔ/2)

- Case 2

S<Lc

M=Rn*(1-cos (28.65*S/ Rn))

- Case3

S>Lc

M=Lc (2*S-Lc)/8 Rn

- **Sample calculation**

Curve-1

- ✓ R=200m
- ✓ W=7m
- ✓ SSD=92.449m
- ✓ Lc=59.447 m
- ✓ Rn=R-w/4=200-7/4=198.25m

- This shows Lc<SSD, Therefore use case 3.

M=59.447*(2*92.449-59.447)/8*198.25m

M=2.66m

Table 10 lateral clearance

| Curve no. | Radius, R | Lane Radius, Rn | Curve Length, Lc | SSD | Lateral Clearance(M) | |
|---|---|---|---|---|---|---|
| | | | | | Lc > SSD | Lc < SSD |
| 1 | 200 | 198.25 | 59.447 | 90 | | 2.66 |
| 2 | 250 | 148.25 | 144.989 | 120 | 16.92 | |
| 3 | 300 | 298.25 | 177.442 | 120 | 17.31 | |
| 4 | 350 | 348.25 | 279.359 | 120 | 23.24 | |
| 5 | 330 | 328.25 | 93.350 | 175 | | 11.28 |
| 6 | 400 | 398.25 | 212.665 | 120 | 15.47 | |
| 7 | 350 | 348.25 | 141.826 | 120 | 11.8 | |

## 4.4.Super elevation

Although transition curves can be used to introduce the radial force gradually in attempt to minimize its effect, this effect can also be greatly reduced and even eliminated by raising one side of the road way or one side of the track relative to the other. The difference in height b/n the road channel is known as the super elevation. Maximum value is controlled by:

- ✓ Climatic condition; frequency and amount of snow/icing.
- ✓ Terrain condition; flat vs. mountainous
- ✓ Area type; rural vs. urban.
- ✓ Frequency of very slow moving vehicles

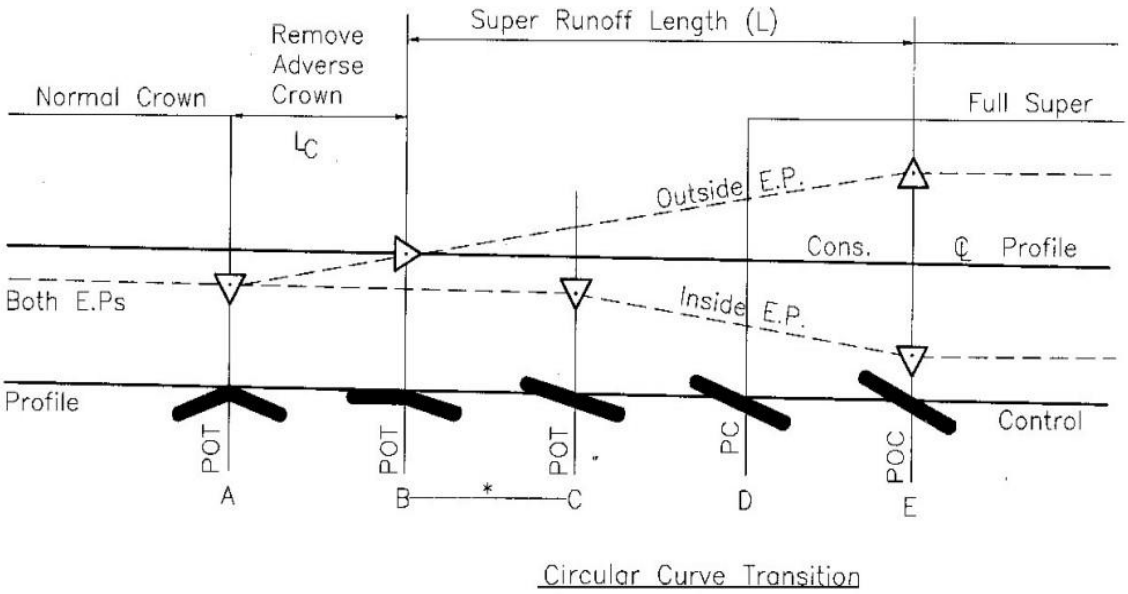



Figure 4 circular curve transition

## 4.5. Vertical alignment

The two major aspects of vertical alignment are vertical curvature, which is governed by sight distance criteria, and gradient, which is related to vehicle performance and level of service. The following text gives the formula and features of the vertical curve; gives values for maximum and minimum gradients; indicates gradient requirements through villages; develops the criteria for incorporation of a climbing lane; and provides vertical clearance standards.

There are two types of vertical curves. These are;

- ✓ Crust vertical curve and
- ✓ Sag vertical curve

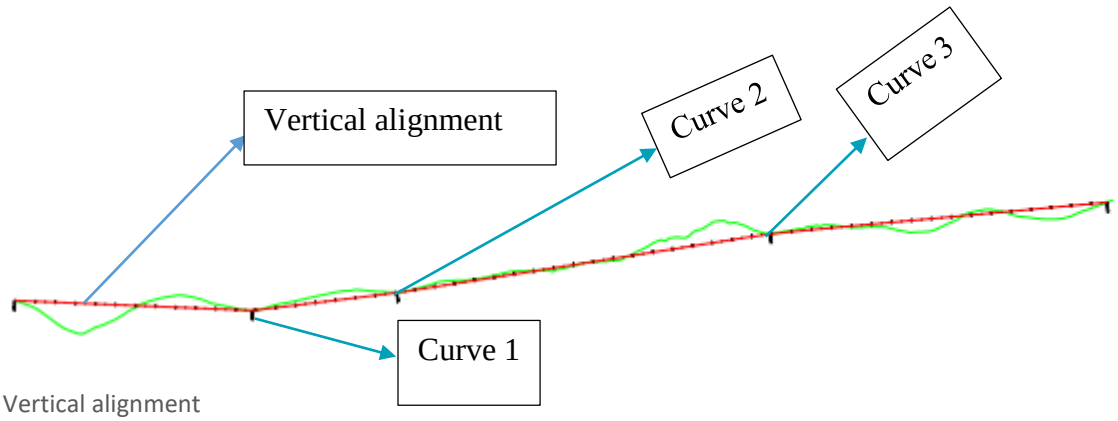



Figure 5 Vertical alignment

### 4.5.1. Vertical Curve Formula

Vertical curves are required to provide smooth transitions between consecutive gradients. The simple parabola is specified for these. The parabola provides a constant rate of change of curvature, and hence acceleration and visibility, along its length and has the form:

$$r = \frac{g2-g1}{L} \qquad Y = \frac{rx^2}{2} + g_1x + \text{elevation of BVC}$$

Where

- r = rate of change of grade per section (%)
- g1 = starting grade (%)
- g2 = ending grade (%)
- L = length of curve (horizontal distance m)
- y = elevation of a point on the curve
- x = distance in stations from the BVC (meters/100)

- BVC = beginning of the vertical curve
- EVC = end of the vertical curve

A related formula is:

$$Y = \frac{G*L}{200}\left[\frac{X}{L}\right]^2$$

Where

- ✓ y = vertical distance from the tangent to the curve (meters)
- ✓ x = horizontal distance from the start of the vertical curve (meters)
- ✓ G = algebraic difference in gradients (%) = $g_1$-$g_2$
- ✓ L = length of vertical curve (meters)
- ✓ $K = \frac{L}{G}$ = Horizontal distance required to achieve a 1% change in grade
- ✓ Z = vertical distance from the tangent to the curve (meter) Useful

**relationships are:**

- Equation of tangent $g_1$ is $Y(X) = Y(0) + \frac{g_1 x}{100}$
- Equation of tangent $g_2$ is $Y(X) = Y(L) + \frac{g_2(x-L)}{100}$

- The Y coordinate of the EVC is Y(L) = $\frac{(g1+g2)L}{200} + Y(0)$
- The intersection point always occurs at an x coordinate of 0.5L hence the elevation is always; Y(IP) = $\frac{(g2+3.g1)L}{800}$ + Y(0)

Table 11 vertical curve data

| Curve no. | Terrain type | IVC | Elevation of BVC | Grade | Distance | Kmin | K provided |
|---|---|---|---|---|---|---|---|
| | | 00+00 | 1765.500 | | | | |
| 1 | Flat | 1+185 | 1762.564 | 0.42 | 715.00 | 18 | 20 |
| 2 | Flat | 1+900 | 1771.356 | 1.23 | 1860.00 | 18 | 30 |
| 3 | Flat | 3+760 | 1800.753 | 1.58 | 1680.00 | 55 | 60 |
| | | 5+440 | 1816.361 | 0.93 | | | |

**Sample Calculation**

**Curve no. 1**

g1 = 0.42%, g2 = 1.23%and K = 20;

G=g1-g2 = 0.42% - 1.23% = -0.81%

Lmin = K*G = 20*0.81= 16.2m

X = 0.5*Lmin = 0.5*16.2 = 8.1m

Y(X)= y(0) + glx/100 = 1762.564+0.42*8.1/100

= 1762.598

Y(L) =(g1 + g2)/200 + Y(0) = (0.42 +1.23)/200 + 1762.564

=1762.572

Y(IP) = (g2 + 3g1 )L/800 +Y(0) = (0.42 + 3*1.23)*715.00/800 + 1762.564

=1766.237

E = Y(IP) - Y(X)

= 1766.237 - 1764.598

= 1.639m

- The remaining vertical curves also follow the same procedure

Table 12 Vertical curve values

| Curve no. | 0 | 1 | 2 | 3 | |
|---|---|---|---|---|---|
| **Terrain** | - | Flat | Flat | Flat | - |
| **Grade** | | 0.42 | 1.23 | 1.58 | 0.93 |
| **Curve type** | | Sag | Sag | crust | |
| **Kmin** | | 18 | 18 | 55 | |
| **Kprovided** | | 20 | 30 | 60 | |
| **BVC station** | | 1+185 | 1+900 | 3+760 | |
| **BVC elevation** | | 1762.564 | 1771.356 | 1800.753 | |
| **Lmin** | | 16.2 | 10.5 | 39.00 | |
| **X** | | 8.1 | 5.25 | 19.5 | |
| **Y(X)** | | 1762.598 | 1771.421 | 1801.061 | |
| **Y(L)** | | 1762.572 | 1771.370 | 1800.337 | |
| **Y(IP)** | | 1766.237 | 1771.425 | 1801.029 | |
| **E** | | 1.639 | 0.0042 | -0.032 | |

### 4.5.2. Crest curve

If the offsets of curve are below the tangent line (grade) the curve is called crest curve.

This curve occurred;

- If there is a change in gradient from large positive to small positive.
- If there is a change in gradient from positive to negative.
- If there is a change in gradient small negative to large negative.

Table 13 Minimum value of K for crest vertical curves (paved)

| Design speed (Km/hr) | K for stopping sight distance | | | K for passing sight distance |
|---|---|---|---|---|
| | h2=0m | h2=0.2m | h2=0.6m | |
| 20 | 2 | 1 | 1 | 10 |
| 25 | 3 | 1 | 1 | 30 |
| 30 | 4 | 3 | 1 | 50 |
| 40 | 10 | 5 | 3 | 90 |
| 50 | 20 | 10 | 7 | 130 |
| 60 | 35 | 17 | 11 | 180 |
| 70 | 60 | 30 | 20 | 245 |
| 80 | 95 | 45 | 30 | 315 |
| 85 | 115 | 55 | 35 | 350 |
| 90 | 140 | 67 | 45 | 390 |
| 100 | 205 | 100 | 67 | 480 |
| 110 | 285 | 140 | 95 | 580 |
| 120 | 385 | 185 | 125 | 680 |

### 4.5.3. Sag curve

If the offsets of curve are above the tangent the curve is called sag curve.

This curve occurred;

- If there is a change in gradient from large negative to small negative and, □ If there is a change in gradient from negative to positive.
- If there is a change in gradient from small positive to large positive

In this project we have provided one vertical sag curve are applied. Minimum lengths of crest and sag vertical curves have been recommended based on design Speeds and stopping sight distance requirements.

Table 14 Minimum value of K for sag vertical

| Design speed (km/hr) | K for Drivers Comfort |
|---|---|
| 20 | 1 |
| 25 | 1.5 |
| 30 | 2.5 |
| 40 | 4 |
| 50 | 6.5 |
| 60 | 9 |
| 70 | 12 |
| 80 | 16 |
| 85 | 18 |
| 90 | 20 |
| 100 | 25 |
| 110 | 30 |
| 120 | 36 |

## 4.6. Highway Gradients

### 4.6.1. Maximum Gradients

Vehicle operations on gradients are complex and depend on a number of factors: severity and length of gradient; level and composition of traffic; and the number of overtaking opportunities on the gradient and in its vicinity.

Maximum vertical gradient is therefore and extremely important criterion that greatly effects both the serviceability and cost of the road.

Table 15 Maximum Gradients

| Terrain | Maximum Gradient (%), for Design Standard | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DC8,DC7,DC6 | | DC5,DC4 | | DC3,DC2 | | DC1 | | Basic Access | |
| | D | A | D | A | D | A | D | A | D | A |
| Flat | 3 | 5 | 4 | 6 | 6 | 8 | 6 | 10 | NA | NA |
| Rolling | 4,5 | 7 | 6 | 8 | 7 | 9 | 7 | 10 | | |
| Mountainous | 6,7 | 9 | 8 | 10 | 10 | 12 | 10 | 12 | | |
| Escarpment | 6,7 | 9 | 8 | 10 | 10 | 12 | 10 | 12 | | |
| Urban | 6 | 8 | 7 | 9 | 7 | 9 | 7 | 9 | 7 | 9 |

**Note:** First value shown is desirable value (D), second is absolute value (A)

As traffic flows increase, the economic dis-benefits of more severe gradients, measured as increased vehicle operating and travel time costs, are more likely to result in economic justification for reducing the severity and/or length of a gradient. On the higher design classes or road, the lower maximum recommended gradients reflect these economics.

### 4.6.2. Minimum Gradients

The minimum gradient for the usual case is 0.5 percent. However, flat and level gradients on uncurbed paved highways are acceptable when the cross slope and carriageway elevation above the surrounding ground is adequate to drain the surface laterally. With curbed highways or streets, longitudinal gradients should be provided to facilitate surface drainage.

#### 4.6.2.1. Gradients through Villages

In many instances the natural grade level is flat through villages. The adjacent roadside ditches in such circumstances can readily become clogged and ineffective. It is also the case that they are deliberately blocked to provide access to adjacent property or to channel flow for agricultural use. These practices lead to saturation of the sub-grade and hence pavement failure, and should be avoided.

#### 4.6.2.2. Critical length of gradient

Critical length may be defined at the point at which a truck reaches a certain speed or the point at which it has lost a certain amount of speed. Critical length of gradient is considered

to be the maximum length of a designated upgrade upon which a loaded truck can operate without unreasonable reduction in speed.

According to ERA Manual 2013, all of the gradient of this road project is between 1.09% and 4.57%. It is in the range of the maximum and the minimum gradients.

### 4.6.3. Special facilities for heavy vehicles on steep slope

Large trucks have different operating characteristics than those of passenger cars, a difference that increases with their weight and size. For example, as the grade of a highway section increases, the presence of trucks become more pronounced. Thus, it becomes necessary to consider the provision of special facilities on highways with steep grades where high volumes of heavy vehicles exist. The most common facilities that address this problem are climbing lanes and emergency escape ramps.

#### 4.6.3.1. Climbing Lanes

The need for a climbing lane is evident when a grade is longer than its critical length, defined as the length that will cause a speed reduction of the heavy vehicles. The amount by which a truck's speed is reduced when climbing a steep grade depends on the length of the grade.

Climbing lanes are not typically used on multilane highways, since relatively faster moving vehicles can pass the slower moving vehicles by using a passing lane. Also, the provision of a climbing lane cannot be justified based on capacity criterion since multilane highways are designed to have capacity sufficient to carry the forecast traffic demand, which include slow moving vehicles.

In our project the opening year AADT values of the traffic flow is greater than 400 veh/day but all of the road alignment grades are less than 5% as per ERA Manual provision. Therefore we don't need to design climbing lane for this project.

#### 4.6.3.2. Emergency Escape Ramps

An emergency escape ramp is provided on the downgrade of a highway for use by a truck that has lost control and cannot slow down. A lane is provided that diverges such that when a vehicle enters the escape ramp, its speed is gradually reduced, and eventually it stops.

We can construct an emergency escape rumps at any of the hills at the side of the road way by providing steep slope.

#### 4.6.3.3. Vertical Clearances

Bridges over water shall normally have a minimum clearance height. Unless a refined hydraulic analysis has been made. The standard minimum headroom or clearance under bridges or tunnels shall be 5.1m for all classes of roads. This clearance should be maintained over the roadway(s) and shoulders. Where future maintenance of the roadway is likely to lead to a raising of the road level, then an additional clearance of up to 0.1m may be

provided. Light superstructures (i.e. - timber, steel trusses, steel girders, etc.) over roadways shall have a clearance height of at least 5.3m.

### 4.6.4. Sight distance

Sight distance is the length of the highway that's visible to a driver. A safe sight distance is the distance needed by the driver on arterial, or a driver exiting a drive way or a street, to verify that the road is clear and avoid conflicts with other vehicles. Sight line must be kept free of objects which might interfere with ability of drivers to see other vehicles. Features like hills, curves in the road, vegetation, other land escaping, sins and buildings can reduce sight distance. In design of highway there are two sight distances which are considered: passing sight distance and stopping sight distance.

#### 4.6.4.1. Stopping sight distance on vertical curves

To calculate the following points must be considered:-Driver's eye height: 1.07m, Object height for stopping sight distance: 0.15 meters and object height for passing sight distance: 1.30 meters.

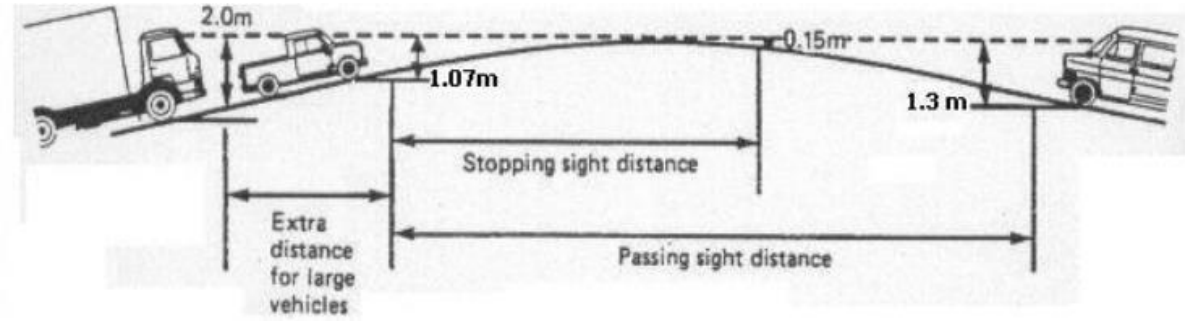



Figure 6 stopping sight distance at crest curve

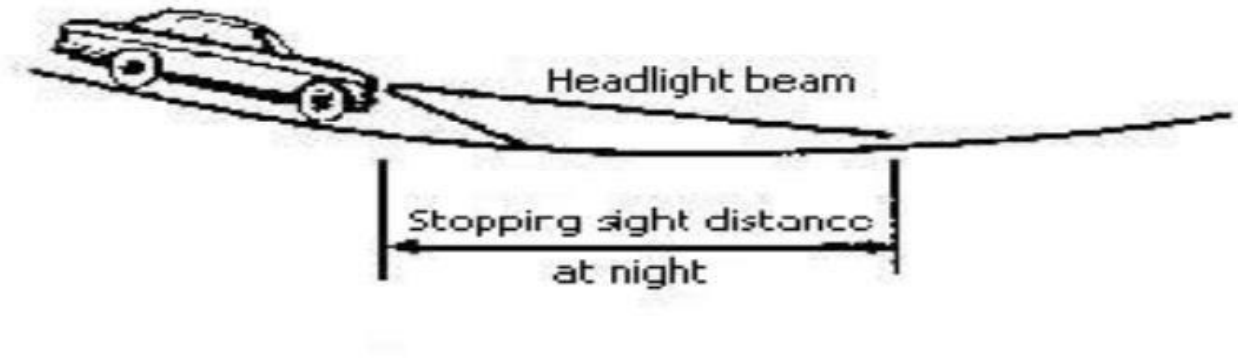



Figure 7 stopping sight distance at crest

Brake reaction distance is the distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied and braking distance is the distance required to stop the vehicle from the instant brake application begins. So, sum of the two distances is called stopping sight distance.

#### 4.6.4.2. Passing Sight distance on vertical curves

Passing sight distance is the minimum sight distance that must be available to enable the driver of one vehicle to pass another vehicle safely and comfortably without interfering with the speed of an oncoming vehicle travelling at the design speed, should it come into view after the overtaking maneuver is started. The sight distance available for passing at any place is the longest distance at which a driver whose eyes are 1.07m above the pavement surface can see the object. Passing sight distance is considered only on two-lane roads. At critical locations, a stretch of four-lane construction with stopping sight distance is some times more economical than two lanes top of an object 1.07m high on the road with passing sight distance.

## 4.7. Road cross - sectional elements

The principal elements of a highway cross section consist of the travel lanes, shoulders, and medians (for some multilane highways). Marginal elements include median and roadside barriers, curbs, gutters, guard rails, sidewalks, and side slopes. Figure 6 shows a typical cross section for a two-lane highway,

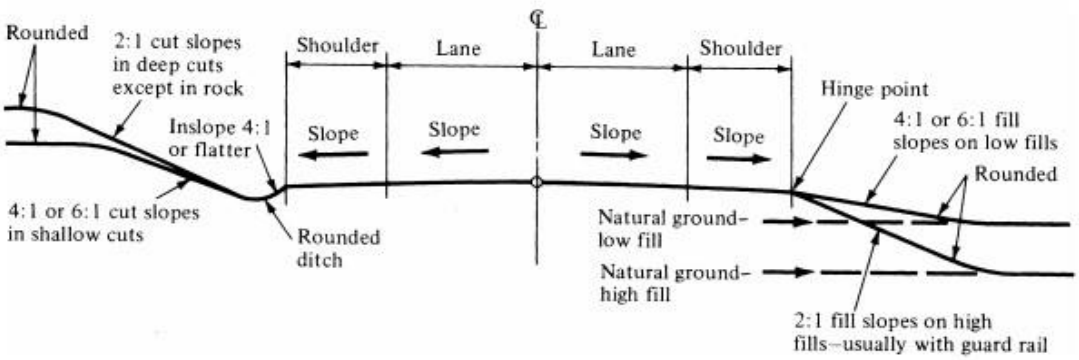



Figure 8 Typical Cross Section for Two-Lane Highways

A. **Carriageway**-the part of the road constructed for use by moving traffic, including traffic lanes, auxiliary lanes such as acceleration and deceleration lanes, climbing lanes, and passing lanes, and bus bays and lay-byes.
B. **Roadway** consists of the carriageway and the shoulders, parking lanes and viewing areas C. Earthwork profiles-includes side slopes and back slopes

D. **Lane width** Feature of a highway having great influence on safety and comfort in the width of the carriage way, due to this we use a lane width of 3.5 meter used which is recommended for **DC5** road & are shown in table of ERA manual for all roads design standards.

E. **Shoulder** Shoulders is a portion of the road way contiguous to carriage way for the accumulation of stopped vehicles, traditional and intimidated non-motorized traffic, animals, pedestrians and emergency use. And also used for the recovery of stopped vehicles and lateral support of the pavement course. Shoulder width is specified on ERA manual standards. For this particular project we choose a shoulder width of 1.5 m.

F. **Normal cross fall** Normal cross fall should be sufficient to provide adequate surface drainage whilst not being so great as to make steering difficult. According to ERA normal cross fall should be 2.5% on paved roads and 4% on unpaved road. And shoulders are 4%. For this particular project, the normal cross falls are designed with a slope of 2.5% & the shoulder are designed with a slope of 4%.

G. **Side slope and back slope** Side slopes and back slopes should be designed to insure the stability of the road way and to provide a reasonable opportunity for recovery of an out of control vehicle. The selection of a side slope and back slope is dependent on safety consideration, height of cut or fill and economic consideration.

# CHAPTER FIVE

# 5 Earth Work

## 5.1 Introduction

Earthwork is excavation of material from cutting and/or construction of embankments which is required to convert right of way from natural condition and configuration to a level that is ready for pavement works as prescribed in the design of the road.

Earth work is conversion of natural condition to required section and grade. Earth work in high way design includes determination of cuts and fills, location of borrow, waste sites, the free haul and over-haul distance determination. The most common item of work encountered in high project is earth work.

- Earth work includes:
  - ✓ Clearing and Grabbing,
  - ✓ Excavation of drainage channels,
  - ✓ Borrows,
  - ✓ Haul & overhaul,
  - ✓ Grading,
  - ✓ Preparation of side slopes

## 5.2 Embankments

For the design of embankments, the following areas of concern should be addressed:

- Foundations conditions, with their associated potential problems of settlements and stability.
- Embankment materials and related topics regarding specified methods of placing and compaction.
- Protection of the completed embankment slopes.

### 5.2.1 Embankment foundations

The design of embankments over soft and compressible soils requires the determination of both the magnitude of settlement which will occur under the future embankments and the anticipated rate of settlement. It also requires verification of the allowable height of embankment, or side slopes, or construction rate to prevent shear failure and ensure embankment stability.

### 5.2.2 Embankment stability

When no specific foundation problem is encountered, the suitability of the side slopes is largely determined by the internal stability of the embankment material (provided erosion is controlled). In those cases, general recommendations can be made as follows for embankments up to 10 meters high:

Table 16 Slope ratio table- vertical to horizontal

| Material | Height of Slope (m) | Side Slope (V:H) | | Back Slope |
|---|---|---|---|---|
| | | Fill | Cut | |
| Earth Soil | 0.0 – 1.0 | 1:3 | 1:2 | 1:3 |
| | 1.0 – 2.0 | 1:2 | | 1:2 |
| | >2.0 | 2:3 | | 2:3 |
| Strong Rock | 0.0 – 2.0 | 4:5 | | 2:1 |
| | >2.0 | 1:1 | | 4:1 |
| Weathered Rock | 0.0 – 2.0 | 2:3 | | 2:1 |
| | >2.0 | 1:1 | | 3:1 |
| Decomposed Rock | 0.0 – 1.0 | 1:3 | | 1:3 |
| | 2.0 – 2.0 | 1:2 | | 1:2 |
| | >2.0 | 2:3 | | 2:3 |
| Black Cotton Soil (expansive clays)[1] | 0.0 – 2.0 | 1:6 | - | - |
| | >2.0 | 1:4 | | |

### 5.2.3 Types of Embankment Materials

Most soils are suitable for embankment construction and the use of the majority of available materials should be encouraged. Some soils are, however, generally unsuitable:

- ✓ Materials with more than 5% by weight of organic materials
- ✓ Materials with a swell of more than 3% (e.g. black cotton soils)
- ✓ Clays with a plasticity index over 45 or a liquid limit over 90

### 5.2.4 Placing and Compaction of Embankment Materials

Whenever the slopes against which the embankment is to be constructed are steeper than 1(V) to 3 (H). Benching should be a minimum of 2 meters in width in order to integrate the new embankment with the existing slope. Material cut out should be re-compacted along with the new embankment. A uniform compaction is important in order to prevent uneven settlement. Some settlement can be tolerated, but it should be minimized, particularly at the approaches to bridges and culverts where adequate compaction is essential.

## 5.3 Mass haul diagram

The mass haul diagram is a curve in which the abscissas represent the stations of the survey and the ordinates represent the algebraic sum of excavation and embankment quantities from some point of beginning on the profile. The plot can be to any scale, depending on the quantities involved. Project designed by computer will list, tabulate, and plot all of the data shown above including a mass haul diagram and balance points.

The mass haul diagram shows excavation (adjusted) and embankment quantities from some point of beginning on the profile, considering cut volumes positive and fill volumes negative. At the beginning of the curve the ordinate is zero, and ordinates are calculated continuously from the initial station to the end of the project.

# CHAPTER – SIX

# 6 Pavement design

## 6.1 General Overview of Pavement Structure

A pavement structure is a layer structure which supports the vehicle load on its surface and transfers and spreads the load to the subgrade without exceeding either the strength of the subgrade or the internal strength of the pavement itself.
The basic idea in building a pavement for all-weather use by vehicles is to prepare a suitable subgrade, provide necessary drainage, and construct a pavement that will:

- Have sufficient total thickness and internal strength to carry expected traffic loads, and distribute them over the subgrade soil without overstressing
- Have adequate properties to prevent or minimize the penetration or internal accumulation of moisture; and
- Have a surface that is reasonably smooth and skid resistant at the same time, as well as reasonably resistant to wear, distortion and deterioration by vehicle loads and weather.

## 6.2 Types of Pavements

Highway pavements are divided into two main categories:
1) Rigid pavement and
2) Flexible pavement

### 6.2.1 Rigid pavement

Rigid pavements are pavement structures constructed of cement concrete slabs, which derive their capacity to withstand vehicle loads from flexural strength or beam strength due to high modulus of elasticity. The performance of rigid pavements is governed by the strength of the pavement structure.

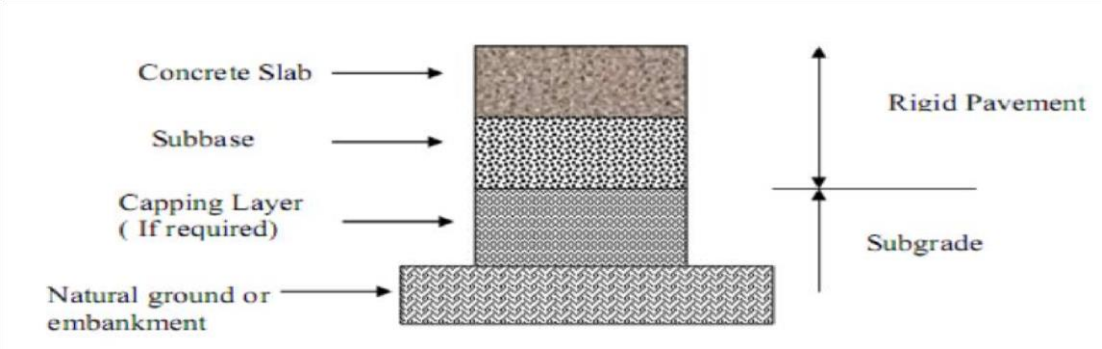



Figure 9 Rigid pavement

It is always a necessity to build a base course under cement concrete slab and it is widely used for rigid pavements where the subgrade soil cannot provide a uniform support, or for one or more of the following reasons described here under;

- ✓ For the control of pumping.
- ✓ For the improvement of drainage.
- ✓ For the control of shrinkage and swell.
- ✓ For the control of frost action.

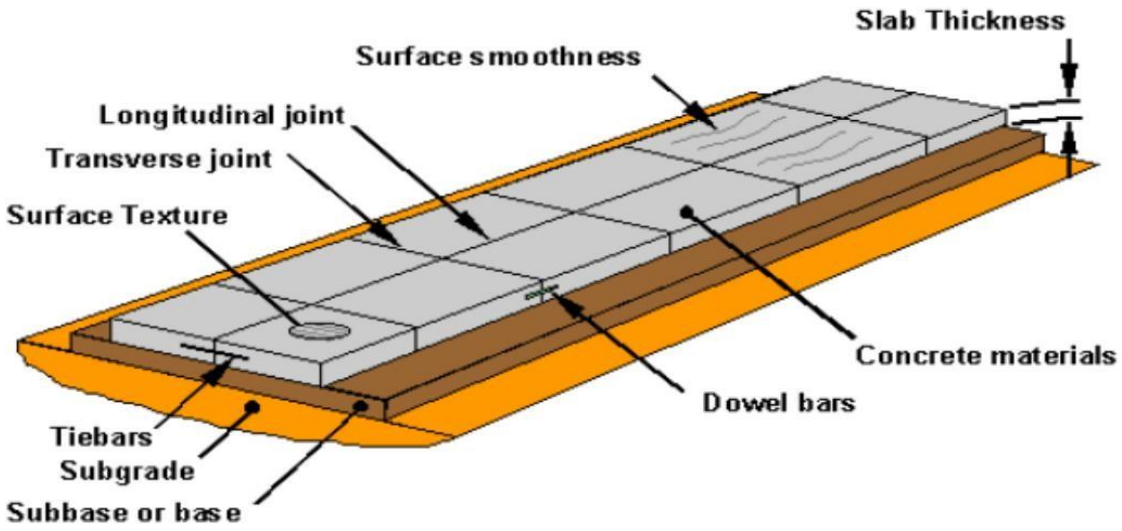



Figure 10 Basic Components of rigid pavement

### 6.2.2 Flexible pavements

Road flexible pavements are intended to limit the stress created at the subgrade level by the traffic traveling on the pavement surface, so that the subgrade is not subject to significant deformations. At the same time, the pavement materials themselves should not deteriorate to such an extent as to affect the riding quality and functionality of the pavement. These goals must be achieved throughout a specific design period.

Pavements do deteriorate, however, due to time, climate and traffic. Therefore, the goal of the pavement design is to limit, during the period considered, deteriorations which affect the riding quality, such as, in the case of flexible pavements, cracking, rutting, potholes and other such surface distresses to acceptable levels.
To give satisfactory service, a flexible pavement must satisfy a number of structural criteria or considerations; some of the important considerations are:

- The subgrade should be able to sustain traffic loading without excessive deformation; this is controlled by the vertical compressive stress or strain at this level,
- Bituminous materials and cement-bound materials used in road base design should not crack under the influence of traffic; this is controlled by the horizontal tensile stress or strain at the bottom of the road base,
- The road base is often considered the main structural layer of the pavement, required to distribute the applied traffic loading so that the underlying materials are not over stressed. It must be able to sustain the stress and strain generated within itself without excessive or rapid deterioration of any kind.
- In pavements containing a considerable thickness of bituminous materials, the internal deformation of these materials must be limited; their deformation is a function of their creep characteristics,
- The load spreading ability of granular sub-base and capping layers must be adequate to provide a satisfactory construction platform.

The essential difference between the two types of pavements is the manner in which they distribute the load over the subgrade. The rigid pavement, because of its rigidity and high modulus of elasticity, tends to distribute the load over a relatively wide area of soil; thus, the slab itself supplies a major portion of the structural capacity. The major factor considered in the design of rigid pavements is the structural strength of the concrete, and a certain amount of variation in subgrade strength has little influence upon the structural capacity of the pavement.

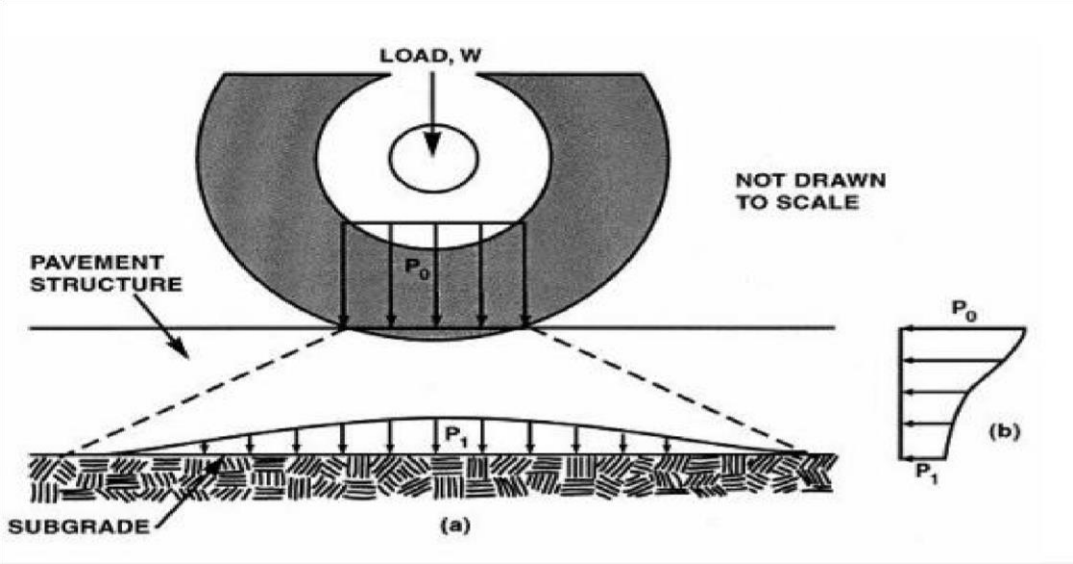



Figure 11 Spread of wheal load through pavement structure

### 6.2.2.1 Parts of flexible pavement

- sub-grade
- Sub-base course
- Base course
- Surface course

- **Sub-grade;** the subgrade is usually the natural material located along the horizontal alignment of the pavement and serves as the foundation of the pavement structure. It also may consist of a layer of selected borrow materials, well compacted to prescribed specifications. It may be necessary to treat the subgrade material to achieve certain strength properties required for the type of pavement being constructed.
- **Sub-base Course;** Located immediately above the subgrade, the sub-base component consists of material of a superior quality to that which is generally used for subgrade construction. The requirements for sub-base materials usually are given in terms of the gradation, plastic characteristics, and strength. When the quality of the subgrade material meets the requirements of the sub-base material, the sub-base component may be omitted. In cases where suitable sub-base material is not readily available, the available material can be treated with other materials to achieve the necessary properties. This process of treating soils to improve their engineering properties is known as stabilization.
- **Base Course:** The base course lies immediately above the sub-base. It is placed immediately above the subgrade if a sub-base course is not used. This course usually consists of granular materials such as crushed stone, crushed or uncrushed slag, crushed or uncrushed gravel, and sand. The specifications for base course materials usually include more strict requirements than those for sub-base materials, particularly with respect to their plasticity, gradation, and strength. Materials that do not have the required properties can be used as base materials if they are properly stabilized with Portland

cement, asphalt, or lime. In some cases, high-quality base course materials also may be treated with asphalt or Portland cement to improve the stiffness characteristics of heavy-duty pavements.

- **Surface course:** The surface course is the upper course of the road pavement and is constructed immediately above the base course. The surface course in flexible pavements usually consists of a mixture of mineral aggregates and asphalt. It should be capable of withstanding high tire pressures, resisting abrasive forces due to traffic, providing a skid resistant driving surface, and preventing the penetration of surface water into the underlying layers.

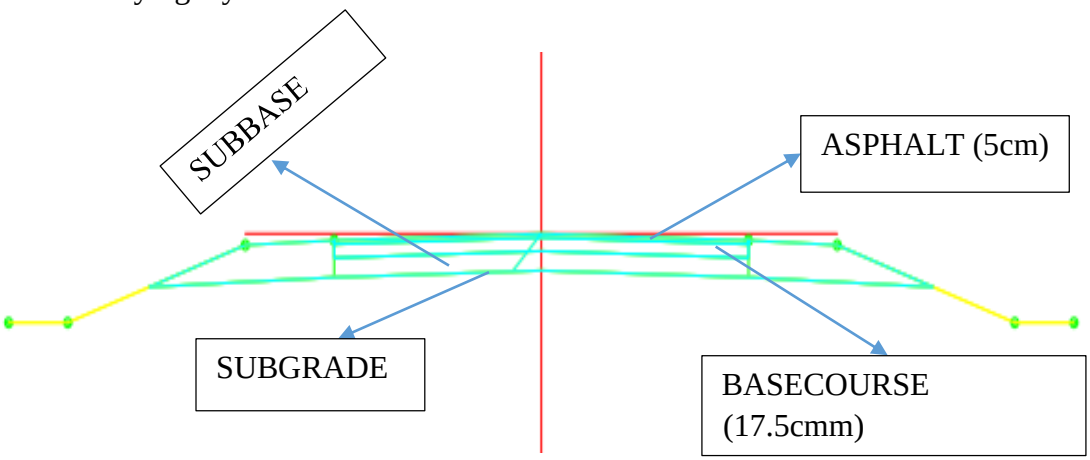



Figure 12 pavement layers

## 6.3 Basic Design Factors

Design factors can be divided into four broad categories:

1. Traffic loading
2. Environment
3. Materials and Construction
4. Performance and Failure criteria

**Traffic loading:** The loading applied by traffic is one of the major factors affecting the design and performance of pavements. It is fundamental to estimate the structural wear produced by traffic quantitatively both for the purposes of pavement design and maintenance andfor making comparisons of the structural effects of different traffic loading conditions. The traffic load is determined in terms of the number of repetitions of an 80kN single-axle load applied to the pavement on two sets of dual tires. The primary loading factors that are important in the structural analysis and design of pavements are the magnitude, configuration, and repetition of traffic loading.

**Environment:** The environmental factors that influence pavement design include temperature and precipitation. The effects of temperature on asphalt pavements include stresses induced by

thermal action, changes in the creep properties, and the effect of freezing and thawing of the subgrade soil. The effect of rainfall is due mainly to the penetration of the surface water into the underlying material.

**Materials and Construction:** Pavement materials include soils, aggregates, bituminous binders, and cement. The properties of these materials under traffic loading in a given environmental conditions is fundamental for the proper design of pavement structures. Moreover, if economically constructed facilities are to be obtained, locally available materials are to be used efficiently.

**Performance and Failure criteria:** Pavements are normally designed and constructed to provide, during the design life, a riding quality acceptable for both private and commercial vehicles with acceptable maintenance. Fatigue cracking, rutting, and thermal cracking are the three principal types of distress generally considered for flexible pavement design.

## 6.4 Pavement design by ERA method

In ERA method of pavement design, the layer thickness of the pavement relies on the sub-grade CBR (California bearing ratio) value and the cumulative standard axel load from the traffic forecast.

### 6.4.1 Traffic class determination

According to ERA adoption of pavement thickness design cumulative axle load of traffic are classified as given below.

### 6.4.2 Determination of Cumulative Traffic Volumes

In order to determine the cumulative number of vehicles over the design period of the road, the following procedure should be followed:

1. Determine the initial traffic volume, AADT $(m)_0$, of each traffic class (m) using the results of the traffic survey and any other recent traffic count information that is available.
2. Estimate the annual growth rate "i" expressed as a decimal fraction, and the anticipated number of years "n" between the traffic survey and the opening of the road.
3. For each vehicle class, estimate the traffic in the first year that the road is opened to traffic. For normal traffic this is given by

$$AADT_{(m)1} = AADT(m)_0(1+i)_n$$

4. For each vehicle class, add the estimate for diverted traffic and for generated traffic if any are anticipated.

For structural pavement design the cumulative traffic loading of each of the motorized vehicle classes over the design life of the road in one direction is required.

For a given class, m, this is given by the following equation:

$T(m) = 0.5 \times 365 \times AADT_{(m)0}[(1+i/100)^N - 1]/(i/100)$

**Where;** T(m) = the cumulative traffic of traffic class m

$AADT_{(m)1}$ = The AADT of traffic class m in the first year

N = the design period in years

i = the annual growth rate of traffic in percent

The cumulative traffic for each class of vehicle is multiplied by the average number of equivalent standard axles of vehicles in that class to calculate the cumulative total number of equivalent standard axles over the life of the road.

## 6.5. Total traffic volume

**Total traffic = Normal traffic + Diverted traffic + Generated traffic**

Table 17 total traffic volume

| Vehicle classification | Car | Utilities | S/bus | M/bus | L/bus | S/trck | M/trck | H/trck | Trck/trl | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **AADT0 2011** | 14 | 16 | 30 | 33 | 39 | 29 | 21 | 21 | 15 | 218 |
| **AADT1 2015** | 19 | 22 | 41 | 45 | 53 | 39 | 29 | 29 | 20 | 297 |
| **Diverted 0.1* AADT1** | 2 | 3 | 5 | 5 | 6 | 4 | 3 | 3 | 2 | 33 |
| **Generated 0.25*AADT1** | 5 | 6 | 11 | 12 | 14 | 10 | 8 | 8 | 5 | 79 |
| **Total AADT1 2015** | 26 | 31 | 57 | 62 | 73 | 53 | 40 | 40 | 27 | 409 |

## 6.6. Design Period determination

Determining an appropriate design period is the first step towards pavement design. Many factors may influence this decision, including budget constraints. Some of the points to consider include:

- ✓ Functional importance of the road
- ✓ Traffic volume

- ✓ Location and terrain of the project
- ✓ Financial constraints
- ✓ Difficulty in forecasting traffic

Table 18 Design period of a pavement

| Road Classification | Design Period (Years) |
|---|---|
| Trunk Road | 20 |
| Link Road | 20 |
| Main Access Road | 15 |
| Other Roads | 10 |

Table 19 One directional traffic

| Vehicle classification | Car | Utilities | S/bus | M/bus | L/bus | S/truck | M/truck | H/truck | Truck/ trl |
|---|---|---|---|---|---|---|---|---|---|
| Class | 1 | | 3 | 3 | 4 | 5 | 6 | | |
| AADT1 2015 | 26 | 31 | 57 | 62 | 73 | 53 | 40 | 40 | 27 |
| One directional flow | 13 | 16 | 57 | 31 | 37 | 27 | 20 | 20 | 14 |

Table 20 Cumulative Traffic

| Vehicle | Class | Cumulative number in one direction over 20 year |
|---|---|---|
| Car | 1 | $365 \times 13 \times [(1.08)^{20}-1]/0.08 = 217141$ |
| Utilities | 1 | $365 \times 16 \times [(1.08)^{20}-1]/0.08 = 267250$ |
| S/bus | 3 | $365 \times 57 \times [(1.08)^{20}-1]/0.08 = 952078$ |

| | | |
|---|---|---|
| M/bus | 4 | 365 x 31 x $[(1.08)^{20}-1]/0.08$ = 517797 |
| L/bus | 4 | 365 x 37 x $[(1.08)^{20}-1]/0.08$ = 618016 |
| S/truck | 5 | 365 x 27 x $[(1.08)^{20}-1]/0.08$ = 450985 |
| M/truck | 6 | 365 x 20 x $[(1.08)^{20}-1]/0.08$ = 334063 |
| H/truck | 8 | 365 x 20 x $[(1.08)^{20}-1]/0.08$ = 334063 |
| Truck/trl | 13 | 365 x 14 x $[(1.08)^{20}-1]/0.08$ = 233844 |

Table 21 Cumulative ESAs

| Vehicle | Equivalency Factor | Cumulative number in one direction over 20 year | Total ESA ($10^6$) |
|---|---|---|---|
| Car | 0 | 217141 | 0 |
| Utilities | 0 | 267250 | 0 |
| S/bus | 0.15 | 952078 | 0.04 |
| M/bus | 1.0 | 517797 | 0.52 |
| L/bus | 1.0 | 618016 | 0.62 |
| S/truck | 0.7 | 450985 | 0.32 |
| M/truck | 2.5 | 334063 | 0.84 |
| H/truck | 3.5 | 334063 | 1.17 |
| Truck/trl | 6 | 233844 | 1.40 |
| Total ESAs | | | 4.91 |

### 6.6.1. Traffic Classes for Flexible Pavement Design

Accurate estimates of cumulative traffic are difficult to achieve due to errors in the surveys and uncertainties with regard to traffic growth, axle loads and axle equivalencies. To a reasonable extent, however, pavement thickness design is not very sensitive to cumulative axle loads and the

method recommended in ERA manual provides fixed structures of paved roads for ranges of traffic as shown in Table 22

Table 22 Traffic Classes for Flexible Pavement Design

| Traffic Classes | Range of ESAs (millions) |
|---|---|
| LV1 | < 0.01 |
| LV2 | 0.01 – 0.1 |
| T1/LV3 (see note) | 0.1 – 0.3 |
| T2/LV4 (see note) | 0.3 – 0.5 |
| T2/LV5 (see note) | 0.5 – 0.7 |
| T3 | 0.7 – 1.5 |
| T4 | 1.5 – 3.0 |
| T5 | 3.0 – 6.0 |
| T6 | 6.0 – 10 |
| T7 | 10 – 17 |
| T8 | 17 - 30 |
| T9 | 30 - 50 |
| T10* | 50 - 80 |
| T11 | >80 |

From the above table the traffic class of our project is **T5**

### 6.6.2. Determining the sub-grade strength class

Taking Design CBR=8% our sub grade strength class is:

CBR class=S4 from ERA

From the analysis of the CBR value, we found the sub grade class to be **S4**. The traffic class of the road is **T5** based on cumulative ESAs. The following cost comparison was made to select the most economical alternative from the various design charts.

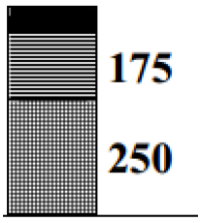



*Figure 13 Cross section of a pavement for T5 & S4 parameters*

THIN (50mm) FLEXIBLE AC SURFACING, GRANULAR ROAD-BASE

(Chart B1)

## 6.7. Quantity of pavement material

We have prepared the quantity of pavement materials by using eagle point software as provided in the ERA manual 2013. We have prepared the quantity of the pavement materials required for our project in the table below.

Table 23 pavement materials

| Material | Thickness (m) | End area ($m^2$) | Volume ($m^3$) | |
|---|---|---|---|---|
| | | | Per 20m length | Total |
| Surface | 0.05 | 0.350 | 7.000 | 1907.500 |
| Base | 0.175 | 1.225 | 24.500 | 6676.250 |
| Sub-base | o.25 | 3.944 | 78.884 | 18369.541 |

# CHAPTER SEVEN

# 7. Environmental Impact

## 7.1. The Environment of Highway Engineering

The highway-engineering problem, like any other problem, exists in a complex environment that must be taken into account in decision-making. The engineer must analyze a particular problem and, on the basis of this analysis, make recommendations which are not only scientifically sound but are also adaptable to the physical environment, technologically achievable, economically viable, and in the final analysis, socially acceptable.

## 7.2. The Physical Environment

This has traditionally been the environment of most concern to engineers, and includes the following factors:

- ✓ Topography
- ✓ Geology
- ✓ Soils
- ✓ Natural drainage
- ✓ Vegetation
- ✓ Land use
- ✓ Rainfall
- ✓ Climate
- ✓ Materials

Highway engineers quickly come to know the effect of topography on alignment and gradient or of geology on location and depth of cuts, or of materials on pavement design, or of vegetation on clearing and grubbing.

## 7.3. The Technological Environment

The technological environment in which a solution may be prescribed seriously affects the success of its implementation, whether success is measured in terms of quality, completion or time. Technological factors that affect highway-engineering decisions include:

- ❖ Skilled manpower
- ❖ Management manpower
- ❖ Tools and equipment
- ❖ Construction technology
- ❖ Technological literacy and awareness

## 7.4. The Economic Environment

Some of the factors that define the economic environment in so far as it affects highway engineering decision are as follows:

- Gross national product (GNP) or gross domestic product (GDP).
- Cash versus food crop cultivation.
- Agricultural versus industrial production.
- Distribution of economic activity.
- Export-import ratio.

With very few exceptions, the development of roads is the responsibility of governments, and the extent to which this responsibility can be met is a function of the ability to set aside funds from government revenue. The overall performance of the economy, therefore, whether measured in GNP, GDP or per capita income, compelled with competing demands from other development sectors establishes the limits of expenditure on road engineering, whether it is construction or maintenance.

## 7.5. The Social Environment

Social acceptance is a vital factor in highway planning and engineering. A road program which makes maximum utilization of the surplus manpower that is likely to exist in the rural community through which it passes or into which it extends, and the construction of which is timed to coincide with off-harvest peaks, is more likely to have the support of the community than a program which is based on equipment technology requiring the importation of skilled manpower that is not likely
to be found waiting around.

## 7.6. The Highway Engineering Problem

- ✓ The route location problem
- ✓ The design problem
- ✓ The construction problem
- ✓ The maintenance problem

**The Route Location Problem:**

Between any two points that are to be connected by a road, there exist an infinite number of combinations of horizontal and vertical alignment. The route location problem is to establish, initially, a general location, or a narrow band, within which a more precise alignment would be finally designed.

**The Design problem:**

- ❖ Geometric Design
- ❖ Drainage design
- ❖ Pavement design

## 7.7. Economic Evaluation of Highways

Economic evaluation is a rational approach at quantifying the future benefits and costs of proposed highway improvements with a view to determine to what extent the schemes will contribute to the goal of raising the living standard of the people and their general welfare.

The economic evaluation of highway schemes is generally done by computing the total transport cost which consists of the following components:

- ✓ Cost of construction of the facility
- ✓ Cost of maintenance of the facility
- ✓ Cost to the society

Road user cost is composed of:

- ✓ Vehicle operation cost
- ✓ Travel time costs
- ✓ Accident cost

Cost of society includes:

- ❖ Impact on the environment (noise pollution, air pollution, vibration)
- ❖ Changes in land values
- ❖ Land severance
- ❖ Loss of aesthetic

## 7.8. Effect of Highways on the Environment

Highway and traffic have earned the dubious distinction of being the worst defilers of the environment. They have a direct impact on social and community values, the environment and the ecology. In view of the growing awareness of the community and the government to preserve and enhance the environmental values, highway engineers have to plan, construct and maintain highways with this special requirement in mind. Before the highway engineer prepares any scheme, he should prepare an environmental impact statement. The environmental impact statement containing an assessment of the anticipated significantly effects that the proposed action may have on the quality of the environment. The purpose of the environmental impact statement is to ensure that careful attention is given to environmental matters and that such matters are appropriately considered in the highway agency's decision.

- ❖ Contents of an environmental impact statement:
  - ■ Description of the proposed action and alternatives considered
  - ■ Location, type, and length of facility, termini, number of lanes, right-of way width. Other design features such as general horizontal and vertical alignment, structures, etc.
  - ■ Deficiencies of existing facilities, anticipated benefits
  - ■ Land use planning: description of planning processes for the area
  - ■ Probable impact of proposed action on the environment
  - ■ Natural, ecological, scenic resource impacts
  - ■ Relocation of individuals and families

- Social impacts
  - Air quality impacts
  - Noise impacts
  - Water quality impacts
  - Construction impacts
- Alternatives to the proposed action
  - ✓ Probable adverse environmental effects that cannot be avoided.
  - ✓ The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity.
  - ✓ Irreversible and irretrievable commitments of resources.
  - ✓ The impact on properties and sites of historic and cultural significance

The effect of highways and traffic on the environment will be of the following type:

- ✓ Noise pollution
- ✓ Air pollution
- ✓ Visual intrusion and degrading the aesthetics
- ✓ Community impact: relocation of individuals and families

# CHAPTER EIGHT

# 8. Conclusion and Recommendation

## 8.1. Conclusion

Basically, this highway design project considered safety and economy for the design of the particular road mentioned within the desired design period, social and environmental factors and the traffic volume collected. Safety was maintained on the road horizontal and vertical alignment to give comfort for the road users and minimize the accidental risk that may occur on the road. The other important consideration is economy. To fulfill this requirement we have tried to minimize the length of the road and the earth work. But we haven't calculated the project cost.

The geometric alignment design is provided based on the chosen manuals and engineering judgments which are related to the condition of the project. Survey data was the basic information's for the design. Ethiopian road authority (ERA) design manual 2013 was used as a clear guidance for the geometric design, pavement design and other structural design. Based on the ERA specification and other manuals, selection was done on the most economical pavement thickness using traffic analysis.

## 8.2. Recommendation

When we were doing this project we were faced some challenges and we couldn't fulfill the actual requirement of the road design as provided by ERA manual. This is because the shortage of data about the project site. For the future it is better to make some adjustments to get a better and real design of a road. Some of this adjustments are

- ✓ It was better if we were given hydrologic data and runoff catchment area. The lack of this prevents us from the design of drainage structures like culverts and runoff ditches.
- ✓ It was better if we were given a data about cities, market places, soil type, places of protected forests, presence natural, traditional and cultural heritages in our alignments. The survey data was also small and it shows the alignment of a single road. This prevents us from developing our knowledge about route selection by considering different parameters.
- ✓ The course is semester project to work through one semester, But we have taken data after three month. This made us don't do properly on time. There should be sufficient time to work.
- ✓ There is no practical lesson adopted during regular class, hence it fessed us hard to do road pavement and cross sectional elements. So it was better if there were practiced laboratory tests on pavement materials adopted.

# Appendixes

Table 24 Appendix A

| STATION | CUT VOLUME | FILL VOLUME | ADJUSTED VOLUME | NET VOLUME | COORDINATE |
|---|---|---|---|---|---|
| 0+000.000 | 0 | 0 | 0 | 0 | 0 |
| 0+020.000 | 190.02 | 16.17 | 228.024 | -211.854 | 0 |
| 0+040.000 | 93.613 | 117.262 | 112.3356 | 4.9264 | -211.854 |
| 0+060.000 | 0.702 | 298.351 | 0.8424 | 297.5086 | -206.9276 |
| 0+080.000 | 1.238 | 490.489 | 1.4856 | 489.0034 | 90.581 |
| 0+100.000 | 1.91 | 715.282 | 2.292 | 712.99 | 579.5844 |
| 0+120.000 | 2.851 | 1090.888 | 3.4212 | 1087.4668 | 1292.5744 |
| 0+140.000 | 4.107 | 1692.495 | 4.9284 | 1687.5666 | 2380.0412 |
| 0+160.000 | 5.65 | 2457.502 | 6.78 | 2450.722 | 4067.6078 |
| 0+180.000 | 7.475 | 3348.267 | 8.97 | 3339.297 | 6518.3298 |
| 0+200.000 | 9.462 | 4360.427 | 11.3544 | 4349.0726 | 9857.6268 |
| 0+220.000 | 11.663 | 5479.883 | 13.9956 | 5465.8874 | 14206.6994 |
| 0+240.000 | 13.999 | 6569.568 | 16.7988 | 6552.7692 | 19672.5868 |
| 0+260.000 | 15.994 | 7488.418 | 19.1928 | 7469.2252 | 26225.356 |
| 0+280.000 | 17.614 | 8177.264 | 21.1368 | 8156.1272 | 33694.5812 |
| 0+300.000 | 19.169 | 8709.004 | 23.0028 | 8686.0012 | 41850.7084 |
| 0+320.000 | 20.703 | 9293.289 | 24.8436 | 9268.4454 | 50536.7096 |

| | | | | | |
|---|---|---|---|---|---|
| 0+340.000 | 22.122 | 9591.334 | 26.5464 | 9564.7876 | 59805.155 |
| 0+360.000 | 23.284 | 9094.617 | 27.9408 | 9066.6762 | 69369.9426 |
| 0+380.000 | 24.157 | 8127.717 | 28.9884 | 8098.7286 | 78436.6188 |
| 0+400.000 | 24.979 | 7170.322 | 29.9748 | 7140.3472 | 86535.3474 |
| 0+420.000 | 25.607 | 6332.081 | 30.7284 | 6301.3526 | 93675.6946 |
| 0+440.000 | 25.842 | 5593.959 | 31.0104 | 5562.9486 | 99977.0472 |
| 0+460.000 | 25.328 | 4821.656 | 30.3936 | 4791.2624 | 105539.9958 |
| 0+480.000 | 24.166 | 4008.232 | 28.9992 | 3979.2328 | 110331.2582 |
| 0+500.000 | 22.752 | 3235.257 | 27.3024 | 3207.9546 | 114310.491 |
| 0+520.000 | 20.877 | 2474.913 | 25.0524 | 2449.8606 | 117518.4456 |
| 0+540.000 | 18.801 | 1779.893 | 22.5612 | 1757.3318 | 119968.3062 |
| 0+560.000 | 16.754 | 1172.214 | 20.1048 | 1152.1092 | 121725.638 |
| 0+580.000 | 14.852 | 658.784 | 17.8224 | 640.9616 | 122877.7472 |
| 0+600.000 | 13.156 | 285.415 | 15.7872 | 269.6278 | 123518.7088 |
| 0+613.325 | 530.404 | 42.782 | 636.4848 | -593.7028 | 123788.3366 |
| 0+615.000 | 74.764 | 0.046 | 89.7168 | -89.6708 | 123194.6338 |
| 0+620.000 | 101.093 | 0.026 | 121.3116 | -121.2856 | 123104.963 |
| 0+625.000 | 138.466 | 0.026 | 166.1592 | -166.1332 | 122983.6774 |
| 0+630.000 | 174.69 | 0.026 | 209.628 | -209.602 | 122817.5442 |
| 0+635.000 | 174.783 | 0.023 | 209.7396 | -209.7166 | 122607.9422 |
| 0+640.000 | 134.07 | 0.019 | 160.884 | -160.865 | 122398.2256 |
| 0+645.000 | 119.757 | 0.017 | 143.7084 | -143.6914 | 122237.3606 |

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|---|---|---|---|---|---|
| 0+650.000 | 136.903 | 0.018 | 164.2836 | -164.2656 | 122093.6692 |
| 0+655.000 | 152.257 | 0.017 | 182.7084 | -182.6914 | 121929.4036 |
| 0+660.000 | 165.654 | 0.016 | 198.7848 | -198.7688 | 121746.7122 |
| 0+665.000 | 181.651 | 0.014 | 217.9812 | -217.9672 | 121547.9434 |
| 0+670.000 | 200.889 | 0.015 | 241.0668 | -241.0518 | 121329.9762 |
| 0+672.772 | 119.969 | 0.008 | 143.9628 | -143.9548 | 121088.9244 |
| 0+680.000 | 334.245 | 0.022 | 401.094 | -401.072 | 120944.9696 |
| 0+700.000 | 1079.978 | 0.08 | 1295.9736 | -1295.8936 | 120543.8976 |
| 0+720.000 | 1348.256 | 0.091 | 1617.9072 | -1617.8162 | 119248.004 |
| 0+740.000 | 1616.778 | 0.084 | 1940.1336 | -1940.0496 | 117630.1878 |
| 0+760.000 | 1843.167 | 0.089 | 2211.8004 | -2211.7114 | 115690.1382 |
| 0+780.000 | 2059.176 | 0.094 | 2471.0112 | -2470.9172 | 113478.4268 |
| 0+800.000 | 2260.938 | 0.098 | 2713.1256 | -2713.0276 | 111007.5096 |
| 0+820.000 | 2421.143 | 0.103 | 2905.3716 | -2905.2686 | 108294.482 |
| 0+840.000 | 2468.443 | 0.107 | 2962.1316 | -2962.0246 | 105389.2134 |
| 0+860.000 | 2368.514 | 0.11 | 2842.2168 | -2842.1068 | 102427.1888 |
| 0+880.000 | 2193.393 | 0.116 | 2632.0716 | -2631.9556 | 99585.082 |
| 0+900.000 | 2001.266 | 0.124 | 2401.5192 | -2401.3952 | 96953.1264 |
| 0+920.000 | 1786.532 | 0.13 | 2143.8384 | -2143.7084 | 94551.7312 |
| 0+940.000 | 1548.422 | 0.134 | 1858.1064 | -1857.9724 | 92408.0228 |
| 0+960.000 | 1303.049 | 0.138 | 1563.6588 | -1563.5208 | 90550.0504 |
| 0+980.000 | 1075.443 | 0.141 | 1290.5316 | -1290.3906 | 88986.5296 |

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|---|---|---|---|---|---|
| 1+000.000 | 894.292 | 0.148 | 1073.1504 | -1073.0024 | 87696.139 |
| 1+020.000 | 737.475 | 0.179 | 884.97 | -884.791 | 86623.1366 |
| 1+040.000 | 618.861 | 0.204 | 742.6332 | -742.4292 | 85738.3456 |
| 1+060.000 | 540.567 | 0.205 | 648.6804 | -648.4754 | 84995.9164 |
| 1+080.000 | 550.76 | 0.252 | 660.912 | -660.66 | 84347.441 |
| 1+100.000 | 524.886 | 0.299 | 629.8632 | -629.5642 | 83686.781 |
| 1+120.000 | 489.616 | 0.344 | 587.5392 | -587.1952 | 83057.2168 |
| 1+140.000 | 437.123 | 0.379 | 524.5476 | -524.1686 | 82470.0216 |
| 1+153.467 | 213.817 | 0.263 | 256.5804 | -256.3174 | 81945.853 |
| 1+155.000 | 22.015 | 0.032 | 26.418 | -26.386 | 81689.5356 |
| 1+160.000 | 66.752 | 0.11 | 80.1024 | -79.9924 | 81663.1496 |
| 1+165.000 | 231.461 | 0.08 | 277.7532 | -277.6732 | 81583.1572 |
| 1+170.000 | 510.299 | 0.022 | 612.3588 | -612.3368 | 81305.484 |
| 1+175.000 | 613.959 | 0 | 736.7508 | -736.7508 | 80693.1472 |
| 1+180.000 | 592.771 | 6.279 | 711.3252 | -705.0462 | 79956.3964 |
| 1+185.000 | 481.449 | 6.298 | 577.7388 | -571.4408 | 79251.3502 |
| 1+190.000 | 224.055 | 0.05 | 268.866 | -268.816 | 78679.9094 |
| 1+195.000 | 64.264 | 0.072 | 77.1168 | -77.0448 | 78411.0934 |
| 1+200.000 | 181.776 | 0.058 | 218.1312 | -218.0732 | 78334.0486 |
| 1+205.000 | 294.217 | 0.033 | 353.0604 | -353.0274 | 78115.9754 |
| 1+210.000 | 286.338 | 0.033 | 343.6056 | -343.5726 | 77762.948 |
| 1+215.000 | 278.326 | 0.033 | 333.9912 | -333.9582 | 77419.3754 |

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|---|---|---|---|---|---|
| 1+220.000 | 276.342 | 0.033 | 331.6104 | -331.5774 | 77085.4172 |
| 1+225.000 | 283.092 | 0.034 | 339.7104 | -339.6764 | 76753.8398 |
| 1+230.000 | 291.682 | 0.082 | 350.0184 | -349.9364 | 76414.1634 |
| 1+235.000 | 299.198 | 0.189 | 359.0376 | -358.8486 | 76064.227 |
| 1+240.000 | 193.923 | 0.183 | 232.7076 | -232.5246 | 75705.3784 |
| 1+245.000 | 92.728 | 0.123 | 111.2736 | -111.1506 | 75472.8538 |
| 1+250.000 | 108.321 | 0.129 | 129.9852 | -129.8562 | 75361.7032 |
| 1+255.000 | 123.171 | 0.131 | 147.8052 | -147.6742 | 75231.847 |
| 1+260.000 | 137.622 | 0.134 | 165.1464 | -165.0124 | 75084.1728 |
| 1+265.000 | 152.366 | 0.133 | 182.8392 | -182.7062 | 74919.1604 |
| 1+270.000 | 167.31 | 0.134 | 200.772 | -200.638 | 74736.4542 |
| 1+275.000 | 183.221 | 0.142 | 219.8652 | -219.7232 | 74535.8162 |
| 1+280.000 | 200.378 | 0.139 | 240.4536 | -240.3146 | 74316.093 |
| 1+285.000 | 218.408 | 0.13 | 262.0896 | -261.9596 | 74075.7784 |
| 1+290.000 | 236.337 | 0.136 | 283.6044 | -283.4684 | 73813.8188 |
| 1+295.000 | 190.327 | 0.132 | 228.3924 | -228.2604 | 73530.3504 |
| 1+298.456 | 95.244 | 0.085 | 114.2928 | -114.2078 | 73302.09 |
| 1+300.000 | 43.919 | 0.038 | 52.7028 | -52.6648 | 73187.8822 |
| 1+320.000 | 618.622 | 0.437 | 742.3464 | -741.9094 | 73135.2174 |
| 1+340.000 | 607.442 | 0.346 | 728.9304 | -728.5844 | 72393.308 |
| 1+360.000 | 575.839 | 0.324 | 691.0068 | -690.6828 | 71664.7236 |
| 1+380.000 | 632.079 | 0.339 | 758.4948 | -758.1558 | 70974.0408 |

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|---|---|---|---|---|---|
| 1+400.000 | 703.401 | 0.351 | 844.0812 | -843.7302 | 70215.885 |
| 1+420.000 | 788.863 | 0.367 | 946.6356 | -946.2686 | 69372.1548 |
| 1+440.000 | 884.16 | 0.352 | 1060.992 | -1060.64 | 68425.8862 |
| 1+460.000 | 1010.214 | 0.332 | 1212.2568 | -1211.9248 | 67365.2462 |
| 1+480.000 | 1166.479 | 0.338 | 1399.7748 | -1399.4368 | 66153.3214 |
| 1+500.000 | 1319.62 | 0.347 | 1583.544 | -1583.197 | 64753.8846 |
| 1+520.000 | 1437.928 | 0.369 | 1725.5136 | -1725.1446 | 63170.6876 |
| 1+540.000 | 1507.556 | 0.391 | 1809.0672 | -1808.6762 | 61445.543 |
| 1+560.000 | 1580.502 | 0.397 | 1896.6024 | -1896.2054 | 59636.8668 |
| 1+580.000 | 1644.968 | 0.405 | 1973.9616 | -1973.5566 | 57740.6614 |
| 1+600.000 | 1663.179 | 0.404 | 1995.8148 | -1995.4108 | 55767.1048 |
| 1+620.000 | 1661.735 | 0.408 | 1994.082 | -1993.674 | 53771.694 |
| 1+640.000 | 1646.647 | 0.44 | 1975.9764 | -1975.5364 | 51778.02 |
| 1+660.000 | 1615.133 | 0.454 | 1938.1596 | -1937.7056 | 49802.4836 |
| 1+680.000 | 1541.328 | 0.457 | 1849.5936 | -1849.1366 | 47864.778 |
| 1+700.000 | 1427.215 | 0.467 | 1712.658 | -1712.191 | 46015.6414 |
| 1+720.000 | 1284.503 | 0.48 | 1541.4036 | -1540.9236 | 44303.4504 |
| 1+740.000 | 1129.67 | 0.486 | 1355.604 | -1355.118 | 42762.5268 |
| 1+760.000 | 959.217 | 0.496 | 1151.0604 | -1150.5644 | 41407.4088 |
| 1+780.000 | 795.033 | 0.563 | 954.0396 | -953.4766 | 40256.8444 |
| 1+800.000 | 669.458 | 0.763 | 803.3496 | -802.5866 | 39303.3678 |
| 1+820.000 | 572.468 | 0.736 | 686.9616 | -686.2256 | 38500.7812 |

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|---|---|---|---|---|---|
| 1+840.000 | 477.634 | 0.609 | 573.1608 | -572.5518 | 37814.5556 |
| 1+860.000 | 433.323 | 0.751 | 519.9876 | -519.2366 | 37242.0038 |
| 1+880.000 | 403.239 | 0.871 | 483.8868 | -483.0158 | 36722.7672 |
| 1+900.000 | 919.01 | 0.802 | 1102.812 | -1102.01 | 36239.7514 |
| 1+920.000 | 936.667 | 0.996 | 1124.0004 | -1123.0044 | 35137.7414 |
| 1+940.000 | 414.93 | 1.298 | 497.916 | -496.618 | 34014.737 |
| 1+960.000 | 952.174 | 0.841 | 1142.6088 | -1141.7678 | 33518.119 |
| 1+980.000 | 982.63 | 0.642 | 1179.156 | -1178.514 | 32376.3512 |
| 2+000.000 | 409.629 | 0.997 | 491.5548 | -490.5578 | 31197.8372 |
| 2+020.000 | 367.165 | 1.036 | 440.598 | -439.562 | 30707.2794 |
| 2+040.000 | 452.95 | 0.984 | 543.54 | -542.556 | 30267.7174 |
| 2+060.000 | 544.753 | 1.046 | 653.7036 | -652.6576 | 29725.1614 |
| 2+080.000 | 555.833 | 0.922 | 666.9996 | -666.0776 | 29072.5038 |
| 2+087.257 | 196.733 | 0.265 | 236.0796 | -235.8146 | 28406.4262 |
| 2+090.000 | 78.944 | 0.101 | 94.7328 | -94.6318 | 28170.6116 |
| 2+095.000 | 149.208 | 0.179 | 179.0496 | -178.8706 | 28075.9798 |
| 2+100.000 | 157.274 | 0.267 | 188.7288 | -188.4618 | 27897.1092 |
| 2+105.000 | 160.1 | 0.305 | 192.12 | -191.815 | 27708.6474 |
| 2+110.000 | 158.726 | 0.226 | 190.4712 | -190.2452 | 27516.8324 |
| 2+115.000 | 160.062 | 0.204 | 192.0744 | -191.8704 | 27326.5872 |
| 2+120.000 | 163.258 | 0.205 | 195.9096 | -195.7046 | 27134.7168 |
| 2+125.000 | 167.263 | 0.203 | 200.7156 | -200.5126 | 26939.0122 |

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|---|---|---|---|---|---|
| 2+130.000 | 168.686 | 0.204 | 202.4232 | -202.2192 | 26738.4996 |
| 2+135.000 | 165.623 | 0.191 | 198.7476 | -198.5566 | 26536.2804 |
| 2+140.000 | 161.33 | 0.196 | 193.596 | -193.4 | 26337.7238 |
| 2+145.000 | 158.361 | 0.215 | 190.0332 | -189.8182 | 26144.3238 |
| 2+150.000 | 156.429 | 0.216 | 187.7148 | -187.4988 | 25954.5056 |
| 2+155.000 | 154.151 | 0.231 | 184.9812 | -184.7502 | 25767.0068 |
| 2+160.000 | 154.295 | 0.265 | 185.154 | -184.889 | 25582.2566 |
| 2+165.000 | 152.509 | 0.282 | 183.0108 | -182.7288 | 25397.3676 |
| 2+170.000 | 150.732 | 0.248 | 180.8784 | -180.6304 | 25214.6388 |
| 2+175.000 | 150.877 | 0.229 | 181.0524 | -180.8234 | 25034.0084 |
| 2+180.000 | 146.604 | 0.246 | 175.9248 | -175.6788 | 24853.185 |
| 2+185.000 | 141.658 | 0.253 | 169.9896 | -169.7366 | 24677.5062 |
| 2+190.000 | 134.833 | 0.264 | 161.7996 | -161.5356 | 24507.7696 |
| 2+195.000 | 129.675 | 0.273 | 155.61 | -155.337 | 24346.234 |
| 2+200.000 | 127.022 | 0.282 | 152.4264 | -152.1444 | 24190.897 |
| 2+205.000 | 123.588 | 0.256 | 148.3056 | -148.0496 | 24038.7526 |
| 2+210.000 | 119.737 | 0.212 | 143.6844 | -143.4724 | 23890.703 |
| 2+215.000 | 112.352 | 0.202 | 134.8224 | -134.6204 | 23747.2306 |
| 2+220.000 | 100.531 | 0.231 | 120.6372 | -120.4062 | 23612.6102 |
| 2+225.000 | 119.368 | 0.291 | 143.2416 | -142.9506 | 23492.204 |
| 2+230.000 | 172.932 | 0.349 | 207.5184 | -207.1694 | 23349.2534 |
| 2+235.000 | 172.168 | 0.355 | 206.6016 | -206.2466 | 23142.084 |

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|---|---|---|---|---|---|
| 2+240.000 | 131.989 | 0.337 | 158.3868 | -158.0498 | 22935.8374 |
| 2+245.000 | 141.824 | 0.366 | 170.1888 | -169.8228 | 22777.7876 |
| 2+250.000 | 131.822 | 0.355 | 158.1864 | -157.8314 | 22607.9648 |
| 2+255.000 | 100.264 | 0.347 | 120.3168 | -119.9698 | 22450.1334 |
| 2+260.000 | 133.159 | 0.512 | 159.7908 | -159.2788 | 22330.1636 |
| 2+264.699 | 154.565 | 0.637 | 185.478 | -184.841 | 22170.8848 |
| 2+280.000 | 477.43 | 2.039 | 572.916 | -570.877 | 21986.0438 |
| 2+300.000 | 595.818 | 3.018 | 714.9816 | -711.9636 | 21415.1668 |
| 2+320.000 | 584.507 | 2.627 | 701.4084 | -698.7814 | 20703.2032 |
| 2+340.000 | 588.323 | 1.712 | 705.9876 | -704.2756 | 20004.4218 |
| 2+360.000 | 628.341 | 1.729 | 754.0092 | -752.2802 | 19300.1462 |
| 2+380.000 | 499.25 | 1.432 | 599.1 | -597.668 | 18547.866 |
| 2+400.000 | 367.22 | 1.092 | 440.664 | -439.572 | 17950.198 |
| 2+420.000 | 521.132 | 1.249 | 625.3584 | -624.1094 | 17510.626 |
| 2+440.000 | 571.084 | 1.272 | 685.3008 | -684.0288 | 16886.5166 |
| 2+460.000 | 510.504 | 1.078 | 612.6048 | -611.5268 | 16202.4878 |
| 2+480.000 | 521.252 | 1.112 | 625.5024 | -624.3904 | 15590.961 |
| 2+500.000 | 488.321 | 1.37 | 585.9852 | -584.6152 | 14966.5706 |
| 2+520.000 | 532.869 | 1.795 | 639.4428 | -637.6478 | 14381.9554 |
| 2+540.000 | 515.107 | 1.763 | 618.1284 | -616.3654 | 13744.3076 |
| 2+560.000 | 388.832 | 1.829 | 466.5984 | -464.7694 | 13127.9422 |
| 2+580.000 | 315.188 | 2.059 | 378.2256 | -376.1666 | 12663.1728 |

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|---|---|---|---|---|---|
| 2+600.000 | 217.359 | 5.274 | 260.8308 | -255.5568 | 12287.0062 |
| 2+620.000 | 135.096 | 23.129 | 162.1152 | -138.9862 | 12031.4494 |
| 2+640.000 | 251.288 | 74.677 | 301.5456 | -226.8686 | 11892.4632 |
| 2+660.000 | 347.366 | 133.013 | 416.8392 | -283.8262 | 11665.5946 |
| 2+680.000 | 185.332 | 256.421 | 222.3984 | 34.0226 | 11381.7684 |
| 2+700.000 | 63.782 | 361.398 | 76.5384 | 284.8596 | 11415.791 |
| 2+720.000 | 937.276 | 323.54 | 1124.7312 | -801.1912 | 11700.6506 |
| 2+740.000 | 1796.075 | 270.163 | 2155.29 | -1885.127 | 10899.4594 |
| 2+760.000 | 1794.067 | 203.767 | 2152.8804 | -1949.1134 | 9014.3324 |
| 2+780.000 | 1050.532 | 133.613 | 1260.6384 | -1127.0254 | 7065.219 |
| 2+800.000 | 262.039 | 114.578 | 314.4468 | -199.8688 | 5938.1936 |
| 2+819.191 | 240.411 | 72.703 | 288.4932 | -215.7902 | 5738.3248 |
| 2+820.000 | 11.402 | 1.531 | 13.6824 | -12.1514 | 5522.5346 |
| 2+825.000 | 78.437 | 10.088 | 94.1244 | -84.0364 | 5510.3832 |
| 2+830.000 | 85.546 | 9.873 | 102.6552 | -92.7822 | 5426.3468 |
| 2+835.000 | 82.998 | 7.838 | 99.5976 | -91.7596 | 5333.5646 |
| 2+840.000 | 78.455 | 5.332 | 94.146 | -88.814 | 5241.805 |
| 2+845.000 | 75.925 | 3.038 | 91.11 | -88.072 | 5152.991 |
| 2+850.000 | 155.657 | 2.203 | 186.7884 | -184.5854 | 5064.919 |
| 2+855.000 | 154.853 | 1.849 | 185.8236 | -183.9746 | 4880.3336 |
| 2+860.000 | 72.344 | 1.806 | 86.8128 | -85.0068 | 4696.359 |
| 2+865.000 | 68.775 | 2.148 | 82.53 | -80.382 | 4611.3522 |

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|---|---|---|---|---|---|
| 2+870.000 | 64.636 | 2.731 | 77.5632 | -74.8322 | 4530.9702 |
| 2+875.000 | 60.063 | 3.764 | 72.0756 | -68.3116 | 4456.138 |
| 2+880.000 | 58.731 | 6.09 | 70.4772 | -64.3872 | 4387.8264 |
| 2+885.000 | 58.253 | 8.452 | 69.9036 | -61.4516 | 4323.4392 |
| 2+890.000 | 54.95 | 9.958 | 65.94 | -55.982 | 4261.9876 |
| 2+895.000 | 51.738 | 12.204 | 62.0856 | -49.8816 | 4206.0056 |
| 2+900.000 | 239.686 | 14.547 | 287.6232 | -273.0762 | 4156.124 |
| 2+905.000 | 427.918 | 15.657 | 513.5016 | -497.8446 | 3883.0478 |
| 2+910.000 | 424.717 | 16.543 | 509.6604 | -493.1174 | 3385.2032 |
| 2+915.000 | 419.951 | 18.154 | 503.9412 | -485.7872 | 2892.0858 |
| 2+920.000 | 413.923 | 20.29 | 496.7076 | -476.4176 | 2406.2986 |
| 2+925.000 | 408.967 | 22.127 | 490.7604 | -468.6334 | 1929.881 |
| 2+930.000 | 405.726 | 25.234 | 486.8712 | -461.6372 | 1461.2476 |
| 2+935.000 | 400.48 | 30.423 | 480.576 | -450.153 | 999.6104 |
| 2+940.000 | 391.939 | 35.651 | 470.3268 | -434.6758 | 549.4574 |
| 2+945.000 | 380.737 | 39.523 | 456.8844 | -417.3614 | 114.7816 |
| 2+950.000 | 372.024 | 40.829 | 446.4288 | -405.5998 | -302.5798 |
| 2+955.000 | 368.076 | 41.257 | 441.6912 | -400.4342 | -708.1796 |
| 2+960.000 | 191.048 | 42.57 | 229.2576 | -186.6876 | -1108.6138 |
| 2+965.000 | 16.099 | 45.09 | 19.3188 | 25.7712 | -1295.3014 |
| 2+970.000 | 16.724 | 49.04 | 20.0688 | 28.9712 | -1269.5302 |
| 2+975.000 | 16.649 | 52.947 | 19.9788 | 32.9682 | -1240.559 |

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|---|---|---|---|---|---|
| 2+980.000 | 16.46 | 56.183 | 19.752 | 36.431 | -1207.5908 |
| 2+985.000 | 16.451 | 59.563 | 19.7412 | 39.8218 | -1171.1598 |
| 2+990.000 | 16.138 | 61.798 | 19.3656 | 42.4324 | -1131.338 |
| 2+995.000 | 15.83 | 62.363 | 18.996 | 43.367 | -1088.9056 |
| 3+000.000 | 15.961 | 63.501 | 19.1532 | 44.3478 | -1045.5386 |
| 3+005.000 | 16.2 | 66.41 | 19.44 | 46.97 | -1001.1908 |
| 3+010.000 | 16.399 | 69.952 | 19.6788 | 50.2732 | -954.2208 |
| 3+015.000 | 16.383 | 71.626 | 19.6596 | 51.9664 | -903.9476 |
| 3+020.000 | 16.234 | 70.249 | 19.4808 | 50.7682 | -851.9812 |
| 3+025.000 | 16.22 | 64.688 | 19.464 | 45.224 | -801.213 |
| 3+030.000 | 16.649 | 62.678 | 19.9788 | 42.6992 | -755.989 |
| 3+035.000 | 16.566 | 52.162 | 19.8792 | 32.2828 | -713.2898 |
| 3+040.000 | 193.529 | 31.109 | 232.2348 | -201.1258 | -681.007 |
| 3+045.000 | 381.679 | 17.428 | 458.0148 | -440.5868 | -882.1328 |
| 3+050.000 | 399.983 | 10.361 | 479.9796 | -469.6186 | -1322.7196 |
| 3+055.000 | 417.227 | 7.893 | 500.6724 | -492.7794 | -1792.3382 |
| 3+060.000 | 242.323 | 4.852 | 290.7876 | -285.9356 | -2285.1176 |
| 3+065.000 | 174.54 | 1.514 | 209.448 | -207.934 | -2571.0532 |
| 3+070.000 | 193.763 | 0.618 | 232.5156 | -231.8976 | -2778.9872 |
| 3+075.000 | 107.064 | 0.717 | 128.4768 | -127.7598 | -3010.8848 |
| 3+080.000 | 129.791 | 0.873 | 155.7492 | -154.8762 | -3138.6446 |
| 3+085.000 | 114.282 | 0.855 | 137.1384 | -136.2834 | -3293.5208 |

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|---|---|---|---|---|---|
| 3+090.000 | 96.367 | 0.667 | 115.6404 | -114.9734 | -3429.8042 |
| 3+095.000 | 115.891 | 0.652 | 139.0692 | -138.4172 | -3544.7776 |
| 3+098.549 | 94.765 | 0.461 | 113.718 | -113.257 | -3683.1948 |
| 3+100.000 | 42.029 | 0.193 | 50.4348 | -50.2418 | -3796.4518 |
| 3+120.000 | 626.996 | 2.443 | 752.3952 | -749.9522 | -3846.6936 |
| 3+140.000 | 829.98 | 1.889 | 995.976 | -994.087 | -4596.6458 |
| 3+160.000 | 1166.621 | 1.578 | 1399.9452 | -1398.3672 | -5590.7328 |
| 3+180.000 | 1516.513 | 1.635 | 1819.8156 | -1818.1806 | -6989.1 |
| 3+200.000 | 1818.587 | 2.031 | 2182.3044 | -2180.2734 | -8807.2806 |
| 3+220.000 | 2083.001 | 2.003 | 2499.6012 | -2497.5982 | -10987.554 |
| 3+240.000 | 2159.912 | 1.81 | 2591.8944 | -2590.0844 | -13485.1522 |
| 3+260.000 | 2203.048 | 1.716 | 2643.6576 | -2641.9416 | -16075.2366 |
| 3+280.000 | 2298.361 | 1.567 | 2758.0332 | -2756.4662 | -18717.1782 |
| 3+300.000 | 2226.553 | 1.513 | 2671.8636 | -2670.3506 | -21473.6444 |
| 3+320.000 | 2052.839 | 1.695 | 2463.4068 | -2461.7118 | -24143.995 |
| 3+340.000 | 1909.06 | 1.854 | 2290.872 | -2289.018 | -26605.7068 |
| 3+360.000 | 2020.469 | 1.693 | 2424.5628 | -2422.8698 | -28894.7248 |
| 3+380.000 | 2501.057 | 1.843 | 3001.2684 | -2999.4254 | -31317.5946 |
| 3+400.000 | 3199.829 | 1.981 | 3839.7948 | -3837.8138 | -34317.02 |
| 3+420.000 | 3848.339 | 1.953 | 4618.0068 | -4616.0538 | -38154.8338 |
| 3+440.000 | 4445.254 | 1.918 | 5334.3048 | -5332.3868 | -42770.8876 |
| 3+460.000 | 5027.788 | 1.296 | 6033.3456 | -6032.0496 | -48103.2744 |

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|---|---|---|---|---|---|
| 3+480.000 | 5578.239 | 0.678 | 6693.8868 | -6693.2088 | -54135.324 |
| 3+500.000 | 5857.685 | 0.848 | 7029.222 | -7028.374 | -60828.5328 |
| 3+520.000 | 5810.416 | 0.869 | 6972.4992 | -6971.6302 | -67856.9068 |
| 3+523.661 | 1050.305 | 0.132 | 1260.366 | -1260.234 | -74828.537 |
| 3+525.000 | 378.386 | 0.055 | 454.0632 | -454.0082 | -76088.771 |
| 3+530.000 | 1398.514 | 0.217 | 1678.2168 | -1677.9998 | -76542.7792 |
| 3+535.000 | 1365.251 | 0.215 | 1638.3012 | -1638.0862 | -78220.779 |
| 3+540.000 | 1324.317 | 0.228 | 1589.1804 | -1588.9524 | -79858.8652 |
| 3+545.000 | 1283.884 | 0.371 | 1540.6608 | -1540.2898 | -81447.8176 |
| 3+550.000 | 1242.599 | 0.508 | 1491.1188 | -1490.6108 | -82988.1074 |
| 3+555.000 | 1201.447 | 0.509 | 1441.7364 | -1441.2274 | -84478.7182 |
| 3+560.000 | 1159.149 | 0.508 | 1390.9788 | -1390.4708 | -85919.9456 |
| 3+565.000 | 1115.083 | 0.51 | 1338.0996 | -1337.5896 | -87310.4164 |
| 3+570.000 | 1072.5 | 0.512 | 1287 | -1286.488 | -88648.006 |
| 3+575.000 | 1034.351 | 0.545 | 1241.2212 | -1240.6762 | -89934.494 |
| 3+580.000 | 1001.398 | 0.578 | 1201.6776 | -1201.0996 | -91175.1702 |
| 3+585.000 | 965.599 | 0.587 | 1158.7188 | -1158.1318 | -92376.2698 |
| 3+590.000 | 925.195 | 0.544 | 1110.234 | -1109.69 | -93534.4016 |
| 3+595.000 | 887.485 | 0.493 | 1064.982 | -1064.489 | -94644.0916 |
| 3+600.000 | 852.971 | 0.496 | 1023.5652 | -1023.0692 | -95708.5806 |
| 3+605.000 | 818.286 | 0.499 | 981.9432 | -981.4442 | -96731.6498 |
| 3+610.000 | 781.721 | 0.497 | 938.0652 | -937.5682 | -97713.094 |

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|---|---|---|---|---|---|
| 3+615.000 | 746.293 | 0.493 | 895.5516 | -895.0586 | -98650.6622 |
| 3+617.011 | 290.738 | 0.199 | 348.8856 | -348.6866 | -99545.7208 |
| 3+620.000 | 424.958 | 0.306 | 509.9496 | -509.6436 | -99894.4074 |
| 3+640.000 | 2563.222 | 2.3 | 3075.8664 | -3073.5664 | -100404.051 |
| 3+660.000 | 2034.187 | 2.289 | 2441.0244 | -2438.7354 | -103477.6174 |
| 3+680.000 | 1483.239 | 2.082 | 1779.8868 | -1777.8048 | -105916.3528 |
| 3+700.000 | 1005.743 | 2.314 | 1206.8916 | -1204.5776 | -107694.1576 |
| 3+720.000 | 658.044 | 2.675 | 789.6528 | -786.9778 | -108898.7352 |
| 3+740.000 | 468.134 | 3.173 | 561.7608 | -558.5878 | -109685.713 |
| 3+760.000 | 499.088 | 3.98 | 598.9056 | -594.9256 | -110244.3008 |
| 3+780.000 | 596.169 | 5.172 | 715.4028 | -710.2308 | -110839.2264 |
| 3+800.000 | 442.862 | 4.832 | 531.4344 | -526.6024 | -111549.4572 |
| 3+820.000 | 286.354 | 3.809 | 343.6248 | -339.8158 | -112076.0596 |
| 3+840.000 | 314.281 | 3.815 | 377.1372 | -373.3222 | -112415.8754 |
| 3+860.000 | 349.052 | 3.779 | 418.8624 | -415.0834 | -112789.1976 |
| 3+880.000 | 380.792 | 3.904 | 456.9504 | -453.0464 | -113204.281 |
| 3+900.000 | 471.204 | 3.942 | 565.4448 | -561.5028 | -113657.3274 |
| 3+903.521 | 97.628 | 0.686 | 117.1536 | -116.4676 | -114218.8302 |
| 3+905.000 | 41.516 | 0.291 | 49.8192 | -49.5282 | -114335.2978 |
| 3+910.000 | 140.459 | 0.993 | 168.5508 | -167.5578 | -114384.826 |
| 3+915.000 | 139.228 | 1.098 | 167.0736 | -165.9756 | -114552.3838 |
| 3+920.000 | 138.194 | 1.206 | 165.8328 | -164.6268 | -114718.3594 |

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|---|---|---|---|---|---|
| 3+925.000 | 114.214 | 0.983 | 137.0568 | -136.0738 | -114882.9862 |
| 3+930.000 | 98.996 | 0.764 | 118.7952 | -118.0312 | -115019.06 |
| 3+935.000 | 113.967 | 0.96 | 136.7604 | -135.8004 | -115137.0912 |
| 3+940.000 | 122.345 | 0.996 | 146.814 | -145.818 | -115272.8916 |
| 3+945.000 | 129.914 | 0.768 | 155.8968 | -155.1288 | -115418.7096 |
| 3+950.000 | 138.556 | 0.691 | 166.2672 | -165.5762 | -115573.8384 |
| 3+955.000 | 144.34 | 0.681 | 173.208 | -172.527 | -115739.4146 |
| 3+960.000 | 148.136 | 0.673 | 177.7632 | -177.0902 | -115911.9416 |
| 3+965.000 | 149.671 | 0.666 | 179.6052 | -178.9392 | -116089.0318 |
| 3+970.000 | 148.142 | 0.638 | 177.7704 | -177.1324 | -116267.971 |
| 3+975.000 | 148.38 | 0.645 | 178.056 | -177.411 | -116445.1034 |
| 3+980.000 | 151.267 | 0.672 | 181.5204 | -180.8484 | -116622.5144 |
| 3+985.000 | 152.599 | 0.693 | 183.1188 | -182.4258 | -116803.3628 |
| 3+990.000 | 153.077 | 0.714 | 183.6924 | -182.9784 | -116985.7886 |
| 3+995.000 | 153.874 | 0.713 | 184.6488 | -183.9358 | -117168.767 |
| 4+000.000 | 150.69 | 0.7 | 180.828 | -180.128 | -117352.7028 |
| 4+005.000 | 142.975 | 1.038 | 171.57 | -170.532 | -117532.8308 |
| 4+010.000 | 135.015 | 1.312 | 162.018 | -160.706 | -117703.3628 |
| 4+015.000 | 126.51 | 1.142 | 151.812 | -150.67 | -117864.0688 |
| 4+020.000 | 127.266 | 1.009 | 152.7192 | -151.7102 | -118014.7388 |
| 4+025.000 | 136.078 | 0.961 | 163.2936 | -162.3326 | -118166.449 |
| 4+030.000 | 141.711 | 0.955 | 170.0532 | -169.0982 | -118328.7816 |

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|---|---|---|---|---|---|
| 4+035.000 | 143.71 | 0.959 | 172.452 | -171.493 | -118497.8798 |
| 4+040.000 | 140.86 | 0.91 | 169.032 | -168.122 | -118669.3728 |
| 4+045.000 | 135.615 | 0.851 | 162.738 | -161.887 | -118837.4948 |
| 4+050.000 | 130.692 | 0.8 | 156.8304 | -156.0304 | -118999.3818 |
| 4+055.000 | 125.189 | 0.832 | 150.2268 | -149.3948 | -119155.4122 |
| 4+060.000 | 119.377 | 0.804 | 143.2524 | -142.4484 | -119304.807 |
| 4+065.000 | 115.488 | 0.7 | 138.5856 | -137.8856 | -119447.2554 |
| 4+070.000 | 113.088 | 0.707 | 135.7056 | -134.9986 | -119585.141 |
| 4+075.000 | 109.657 | 0.718 | 131.5884 | -130.8704 | -119720.1396 |
| 4+080.000 | 105.039 | 0.72 | 126.0468 | -125.3268 | -119851.01 |
| 4+085.000 | 121.783 | 0.82 | 146.1396 | -145.3196 | -119976.3368 |
| 4+090.000 | 136.079 | 0.98 | 163.2948 | -162.3148 | -120121.6564 |
| 4+095.000 | 125.82 | 1.033 | 150.984 | -149.951 | -120283.9712 |
| 4+100.000 | 115.456 | 1.032 | 138.5472 | -137.5152 | -120433.9222 |
| 4+105.000 | 134.461 | 1.218 | 161.3532 | -160.1352 | -120571.4374 |
| 4+110.000 | 150.792 | 1.36 | 180.9504 | -179.5904 | -120731.5726 |
| 4+115.000 | 135.416 | 1.33 | 162.4992 | -161.1692 | -120911.163 |
| 4+116.186 | 29.933 | 0.318 | 35.9196 | -35.6016 | -121072.3322 |
| 4+120.000 | 91.5 | 1.015 | 109.8 | -108.785 | -121107.9338 |
| 4+140.000 | 830.554 | 8.583 | 996.6648 | -988.0818 | -121216.7188 |
| 4+160.000 | 683.928 | 41.05 | 820.7136 | -779.6636 | -122204.8006 |
| 4+180.000 | 819.735 | 104.058 | 983.682 | -879.624 | -122984.4642 |

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|---|---|---|---|---|---|
| 4+200.000 | 778.689 | 175.789 | 934.4268 | -758.6378 | -123864.0882 |
| 4+220.000 | 95.548 | 247.857 | 114.6576 | 133.1994 | -124622.726 |
| 4+240.000 | 100.515 | 294.996 | 120.618 | 174.378 | -124489.5266 |
| 4+260.000 | 101.156 | 324.44 | 121.3872 | 203.0528 | -124315.1486 |
| 4+280.000 | 102.379 | 367.455 | 122.8548 | 244.6002 | -124112.0958 |
| 4+300.000 | 100.926 | 402.12 | 121.1112 | 281.0088 | -123867.4956 |
| 4+320.000 | 100.976 | 429.497 | 121.1712 | 308.3258 | -123586.4868 |
| 4+340.000 | 104.206 | 496.59 | 125.0472 | 371.5428 | -123278.161 |
| 4+360.000 | 106.602 | 605.542 | 127.9224 | 477.6196 | -122906.6182 |
| 4+380.000 | 114.601 | 789.343 | 137.5212 | 651.8218 | -122428.9986 |
| 4+400.000 | 127.851 | 1058.28 | 153.4212 | 904.8588 | -121777.1768 |
| 4+420.000 | 141.079 | 1364.266 | 169.2948 | 1194.9712 | -120872.318 |
| 4+440.000 | 155.035 | 1674.005 | 186.042 | 1487.963 | -119677.3468 |
| 4+460.000 | 166.247 | 1962.725 | 199.4964 | 1763.2286 | -118189.3838 |
| 4+480.000 | 173.948 | 2163.633 | 208.7376 | 1954.8954 | -116426.1552 |
| 4+500.000 | 179.913 | 2249.858 | 215.8956 | 2033.9624 | -114471.2598 |
| 4+520.000 | 182.843 | 2305.912 | 219.4116 | 2086.5004 | -112437.2974 |
| 4+540.000 | 184.229 | 2347.144 | 221.0748 | 2126.0692 | -110350.797 |
| 4+560.000 | 184.974 | 2348.151 | 221.9688 | 2126.1822 | -108224.7278 |
| 4+580.000 | 182.354 | 2272.929 | 218.8248 | 2054.1042 | -106098.5456 |
| 4+600.000 | 175.024 | 2048.353 | 210.0288 | 1838.3242 | -104044.4414 |
| 4+620.000 | 162.906 | 1689.772 | 195.4872 | 1494.2848 | -102206.1172 |

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|---|---|---|---|---|---|
| 4+634.054 | 105.675 | 954.191 | 126.81 | 827.381 | -100711.8324 |
| 4+635.000 | 6.87 | 57.648 | 8.244 | 49.404 | -99884.4514 |
| 4+640.000 | 35.844 | 291.078 | 43.0128 | 248.0652 | -99835.0474 |
| 4+645.000 | 35.179 | 271.624 | 42.2148 | 229.4092 | -99586.9822 |
| 4+650.000 | 34.579 | 254.088 | 41.4948 | 212.5932 | -99357.573 |
| 4+655.000 | 33.906 | 237.901 | 40.6872 | 197.2138 | -99144.9798 |
| 4+660.000 | 33.058 | 222.419 | 39.6696 | 182.7494 | -98947.766 |
| 4+665.000 | 32.075 | 206.082 | 38.49 | 167.592 | -98765.0166 |
| 4+670.000 | 31.116 | 190.202 | 37.3392 | 152.8628 | -98597.4246 |
| 4+675.000 | 30.232 | 175.062 | 36.2784 | 138.7836 | -98444.5618 |
| 4+680.000 | 29.313 | 158.867 | 35.1756 | 123.6914 | -98305.7782 |
| 4+685.000 | 28.943 | 144.108 | 34.7316 | 109.3764 | -98182.0868 |
| 4+690.000 | 28.44 | 129.155 | 34.128 | 95.027 | -98072.7104 |
| 4+695.000 | 27.977 | 114.49 | 33.5724 | 80.9176 | -97977.6834 |
| 4+700.000 | 27.894 | 98.38 | 33.4728 | 64.9072 | -97896.7658 |
| 4+705.000 | 26.62 | 75.513 | 31.944 | 43.569 | -97831.8586 |
| 4+710.000 | 25.393 | 52.576 | 30.4716 | 22.1044 | -97788.2896 |
| 4+715.000 | 181.104 | 30.934 | 217.3248 | -186.3908 | -97766.1852 |
| 4+720.000 | 501.419 | 13.289 | 601.7028 | -588.4138 | -97952.576 |
| 4+725.000 | 521.143 | 4.168 | 625.3716 | -621.2036 | -98540.9898 |
| 4+730.000 | 240.447 | 1.467 | 288.5364 | -287.0694 | -99162.1934 |
| 4+735.000 | 119.554 | 2.586 | 143.4648 | -140.8788 | -99449.2628 |

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|---|---|---|---|---|---|
| 4+740.000 | 118.757 | 2.623 | 142.5084 | -139.8854 | -99590.1416 |
| 4+745.000 | 112.986 | 1.435 | 135.5832 | -134.1482 | -99730.027 |
| 4+750.000 | 131.037 | 1.435 | 157.2444 | -155.8094 | -99864.1752 |
| 4+755.000 | 147.042 | 1.432 | 176.4504 | -175.0184 | -100019.9846 |
| 4+760.000 | 133.75 | 1.291 | 160.5 | -159.209 | -100195.003 |
| 4+765.000 | 117.173 | 1.15 | 140.6076 | -139.4576 | -100354.212 |
| 4+770.000 | 123.764 | 1.151 | 148.5168 | -147.3658 | -100493.6696 |
| 4+775.000 | 126.746 | 1.222 | 152.0952 | -150.8732 | -100641.0354 |
| 4+775.880 | 22.554 | 0.227 | 27.0648 | -26.8378 | -100791.9086 |
| 4+780.000 | 107.002 | 1.056 | 128.4024 | -127.3464 | -100818.7464 |
| 4+800.000 | 557.797 | 4.685 | 669.3564 | -664.6714 | -100946.0928 |
| 4+820.000 | 625.938 | 4.229 | 751.1256 | -746.8966 | -101610.7642 |
| 4+840.000 | 680.742 | 3.943 | 816.8904 | -812.9474 | -102357.6608 |
| 4+860.000 | 691.027 | 3.956 | 829.2324 | -825.2764 | -103170.6082 |
| 4+880.000 | 607.951 | 4.451 | 729.5412 | -725.0902 | -103995.8846 |
| 4+900.000 | 649.572 | 6.876 | 779.4864 | -772.6104 | -104720.9748 |
| 4+920.000 | 559.086 | 12.689 | 670.9032 | -658.2142 | -105493.5852 |
| 4+940.000 | 953.514 | 62.624 | 1144.2168 | -1081.5928 | -106151.7994 |
| 4+960.000 | 834.573 | 237.229 | 1001.4876 | -764.2586 | -107233.3922 |
| 4+980.000 | 119.617 | 482.861 | 143.5404 | 339.3206 | -107997.6508 |
| 5+000.000 | 130.886 | 719.002 | 157.0632 | 561.9388 | -107658.3302 |
| 5+020.000 | 140.06 | 909.177 | 168.072 | 741.105 | -107096.3914 |

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|---|---|---|---|---|---|
| 5+040.000 | 145.612 | 1047.198 | 174.7344 | 872.4636 | -106355.2864 |
| 5+060.000 | 155.03 | 1199.279 | 186.036 | 1013.243 | -105482.8228 |
| 5+080.000 | 166.314 | 1410.015 | 199.5768 | 1210.4382 | -104469.5798 |
| 5+100.000 | 176.242 | 1631.519 | 211.4904 | 1420.0286 | -103259.1416 |
| 5+120.000 | 183.522 | 1809.756 | 220.2264 | 1589.5296 | -101839.113 |
| 5+140.000 | 190.154 | 1965.573 | 228.1848 | 1737.3882 | -100249.5834 |
| 5+160.000 | 196.604 | 2096.115 | 235.9248 | 1860.1902 | -98512.1952 |
| 5+180.000 | 202.646 | 2207.182 | 243.1752 | 1964.0068 | -96652.005 |
| 5+200.000 | 207.228 | 2288.221 | 248.6736 | 2039.5474 | -94687.9982 |
| 5+220.000 | 210.257 | 2318.986 | 252.3084 | 2066.6776 | -92648.4508 |
| 5+240.000 | 208.126 | 2229.761 | 249.7512 | 1980.0098 | -90581.7732 |
| 5+260.000 | 199.491 | 2016.904 | 239.3892 | 1777.5148 | -88601.7634 |
| 5+280.000 | 186.912 | 1728.925 | 224.2944 | 1504.6306 | -86824.2486 |
| 5+300.000 | 171.688 | 1394.083 | 206.0256 | 1188.0574 | -85319.618 |
| 5+320.000 | 155.875 | 1082.626 | 187.05 | 895.576 | -84131.5606 |
| 5+340.000 | 144.502 | 878.08 | 173.4024 | 704.6776 | -83235.9846 |
| 5+360.000 | 138.402 | 727.45 | 166.0824 | 561.3676 | -82531.307 |
| 5+380.000 | 131.796 | 547.243 | 158.1552 | 389.0878 | -81969.9394 |
| 5+400.000 | 122.226 | 366.333 | 146.6712 | 219.6618 | -81580.8516 |
| 5+420.000 | 203.384 | 190.136 | 244.0608 | -53.9248 | -81361.1898 |
| 5+440.000 | 283.966 | 55.078 | 340.7592 | -285.6812 | -81415.1146 |
| 5+460.000 | 138.884 | 2.229 | 166.6608 | -164.4318 | -81700.7958 |

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|---|---|---|---|---|---|
| 5+470.265 | 0 | 0 | 0 | 0 | -81865.2276 |
| Total | | | 0 | 0 | -81865.2276 |

Table 25 Appendixes B

| STATION | offset | center | 0ffset | slope | Terrain |
|---|---|---|---|---|---|
| 0+000.000 | -25 | 1767.5 | 25 | -0.64 | Flat |
| 0+020.000 | -25 | 1767.417 | 25 | -2.72 | flat |
| 0+040.000 | -25 | 1767.333 | 25 | -2.72 | flat |
| 0+060.000 | -25 | 1767.25 | 25 | -2.72 | flat |
| 0+080.000 | -25 | 1767.167 | 25 | -2.72 | flat |
| 0+100.000 | -25 | 1767.083 | 25 | -1.9 | flat |
| 0+120.000 | -25 | 1767 | 25 | -3.61 | rolling |
| 0+140.000 | -25 | 1766.917 | 25 | -2.3 | flat |
| 0+160.000 | -25 | 1766.834 | 25 | -3.44 | rolling |
| 0+180.000 | -25 | 1766.75 | 25 | -2.07 | flat |
| 0+200.000 | -25 | 1766.667 | 25 | -1.49 | flat |
| 0+220.000 | -25 | 1766.584 | 25 | -3.41 | rolling |
| 0+240.000 | -25 | 1766.5 | 25 | -3.58 | rolling |
| 0+260.000 | -25 | 1766.417 | 25 | -6.38 | rolling |
| 0+280.000 | -25 | 1766.334 | 25 | -9.14 | rolling |

| | | | | | |
|---|---|---|---|---|---|
| 0+300.000 | -25 | 1766.25 | 25 | -17.81 | rolling |
| 0+320.000 | -25 | 1766.167 | 25 | -12.73 | rolling |
| 0+340.000 | -25 | 1766.084 | 25 | -4.17 | rolling |
| 0+360.000 | -25 | 1766.001 | 25 | -7.95 | rolling |
| 0+380.000 | -25 | 1765.917 | 25 | 28.93 | rolling |
| 0+400.000 | -25 | 1765.834 | 25 | -15.75 | rolling |
| 0+420.000 | -25 | 1765.751 | 25 | -15.76 | rolling |
| 0+440.000 | -25 | 1765.667 | 25 | -10.89 | rolling |
| 0+460.000 | -25 | 1765.584 | 25 | -5.61 | rolling |
| 0+480.000 | -25 | 1765.501 | 25 | -7.15 | rolling |
| 0+500.000 | -25 | 1765.417 | 25 | -5.93 | rolling |
| 0+520.000 | -25 | 1765.334 | 25 | -4.71 | rolling |
| 0+540.000 | -25 | 1765.251 | 25 | -8.51 | rolling |
| 0+560.000 | -25 | 1765.168 | 25 | -7.06 | rolling |
| 0+580.000 | -25 | 1765.084 | 25 | -2.05 | flat |
| 0+600.000 | -25 | 1765.001 | 25 | -5.4 | rolling |
| 0+620.000 | -25 | 1764.918 | 25 | -2.39 | flat |
| 0+640.000 | -25 | 1764.834 | 25 | -0.61 | flat |
| 0+660.000 | -25 | 1764.751 | 25 | 0.27 | flat |

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|---|---|---|---|---|---|
| 0+680.000 | -25 | 1764.668 | 25 | 0.06 | flat |
| 0+700.000 | -25 | 1764.584 | 25 | -0.35 | flat |
| 0+720.000 | -25 | 1764.501 | 25 | -0.62 | flat |
| 0+740.000 | -25 | 1764.418 | 25 | -0.16 | flat |
| 0+760.000 | -25 | 1764.334 | 25 | 3.4 | rolling |
| 0+780.000 | -25 | 1764.251 | 25 | 3.29 | rolling |
| 0+800.000 | -25 | 1764.168 | 25 | 1.31 | flat |
| 0+820.000 | -25 | 1764.085 | 25 | 1.92 | flat |
| 0+840.000 | -25 | 1764.001 | 25 | -5.56 | rolling |
| 0+860.000 | -25 | 1763.918 | 25 | -5.32 | rolling |
| 0+880.000 | -25 | 1763.835 | 25 | -1.1 | flat |
| 0+900.000 | -25 | 1763.751 | 25 | 0.6 | flat |
| 0+920.000 | -25 | 1763.668 | 25 | 0.59 | flat |
| 0+940.000 | -25 | 1763.585 | 25 | -1.81 | flat |
| 0+960.000 | -25 | 1763.501 | 25 | -3.79 | rolling |
| 0+980.000 | -25 | 1763.418 | 25 | -4.82 | rolling |
| 1+000.000 | -25 | 1763.335 | 25 | -7.78 | rolling |
| 1+020.000 | -25 | 1763.252 | 25 | 2.69 | flat |
| 1+040.000 | -25 | 1763.168 | 25 | -15.51 | rolling |

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|---|---|---|---|---|---|
| 1+060.000 | -25 | 1763.085 | 25 | 11.82 | rolling |
| 1+080.000 | -25 | 1763.002 | 25 | -13.44 | rolling |
| 1+100.000 | -25 | 1762.918 | 25 | -19.9 | rolling |
| 1+120.000 | -25 | 1762.835 | 25 | -16.26 | rolling |
| 1+140.000 | -25 | 1762.752 | 25 | -17.13 | rolling |
| 1+160.000 | -25 | 1762.668 | 25 | 18.89 | rolling |
| 1+180.000 | -25 | 1762.618 | 25 | 0 | flat |
| 1+200.000 | -25 | 1762.749 | 25 | 3.86 | rolling |
| 1+220.000 | -25 | 1762.995 | 25 | 7.93 | rolling |
| 1+240.000 | -25 | 1763.241 | 25 | 8.21 | rolling |
| 1+260.000 | -25 | 1763.486 | 25 | 4.28 | rolling |
| 1+280.000 | -25 | 1763.732 | 25 | 4.54 | rolling |
| 1+300.000 | -25 | 1763.978 | 25 | 3.14 | rolling |
| 1+320.000 | -25 | 1764.224 | 25 | 1.98 | flat |
| 1+340.000 | -25 | 1764.47 | 25 | 0 | flat |
| 1+360.000 | -25 | 1764.716 | 25 | 0.17 | flat |
| 1+380.000 | -25 | 1764.962 | 25 | -0.24 | flat |
| 1+400.000 | -25 | 1765.208 | 25 | -0.16 | flat |
| 1+420.000 | -25 | 1765.454 | 25 | 0.78 | flat |

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|---|---|---|---|---|---|
| 1+440.000 | -25 | 1765.7 | 25 | 0.6 | flat |
| 1+460.000 | -25 | 1765.946 | 25 | -28.46 | mountainous |
| 1+480.000 | -25 | 1766.191 | 25 | -28.39 | mountainous |
| 1+500.000 | -25 | 1766.437 | 25 | -10.93 | rolling |
| 1+520.000 | -25 | 1766.683 | 25 | -19.85 | rolling |
| 1+540.000 | -25 | 1766.929 | 25 | -43.97 | mountainous |
| 1+560.000 | -25 | 1767.175 | 25 | 44.08 | mountainous |
| 1+580.000 | -25 | 1767.421 | 25 | 37.67 | mountainous |
| 1+600.000 | -25 | 1767.667 | 25 | 29.63 | mountainous |
| 1+620.000 | -25 | 1767.913 | 25 | 25.87 | mountainous |
| 1+640.000 | -25 | 1768.159 | 25 | 25.86 | mountainous |
| 1+660.000 | -25 | 1768.405 | 25 | 14.26 | rolling |
| 1+680.000 | -25 | 1768.651 | 25 | 12.87 | rolling |
| 1+700.000 | -25 | 1768.896 | 25 | -2.62 | flat |
| 1+720.000 | -25 | 1769.142 | 25 | 1.6 | flat |
| 1+740.000 | -25 | 1769.388 | 25 | 3.87 | rolling |
| 1+760.000 | -25 | 1769.634 | 25 | 2.19 | flat |
| 1+780.000 | -25 | 1769.88 | 25 | -1.92 | flat |
| 1+800.000 | -25 | 1770.126 | 25 | 1.04 | flat |

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|---|---|---|---|---|---|
| 1+820.000 | -25 | 1770.372 | 25 | -3.1 | rolling |
| 1+840.000 | -25 | 1770.618 | 25 | -3.14 | rolling |
| 1+860.000 | -25 | 1770.864 | 25 | -8.09 | rolling |
| 1+880.000 | -25 | 1771.11 | 25 | -5.6 | rolling |
| 1+900.000 | -25 | 1771.36 | 25 | -9.87 | rolling |
| 1+920.000 | -25 | 1771.672 | 25 | 1.78 | flat |
| 1+940.000 | -25 | 1771.988 | 25 | -2.4 | flat |
| 1+960.000 | -25 | 1772.305 | 25 | 5.96 | rolling |
| 1+980.000 | -25 | 1772.621 | 25 | -5.98 | rolling |
| 2+000.000 | -25 | 1772.938 | 25 | -5.3 | rolling |
| 2+020.000 | -25 | 1773.254 | 25 | -5.3 | rolling |
| 2+040.000 | -25 | 1773.57 | 25 | -8.02 | rolling |
| 2+060.000 | -25 | 1773.887 | 25 | -6.87 | rolling |
| 2+080.000 | -25 | 1774.203 | 25 | -5.57 | rolling |
| 2+100.000 | -25 | 1774.52 | 25 | -5.57 | rolling |
| 2+120.000 | -25 | 1774.836 | 25 | -8.72 | rolling |
| 2+140.000 | -25 | 1775.153 | 25 | -18.73 | rolling |
| 2+160.000 | -25 | 1775.469 | 25 | 1.74 | flat |
| 2+180.000 | -25 | 1775.785 | 25 | -2.88 | flat |

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|---|---|---|---|---|---|
| 2+200.000 | -25 | 1776.102 | 25 | 3.53 | rolling |
| 2+220.000 | -25 | 1776.418 | 25 | -4.76 | rolling |
| 2+240.000 | -25 | 1776.735 | 25 | 0 | flat |
| 2+260.000 | -25 | 1777.051 | 25 | 1.54 | flat |
| 2+280.000 | -25 | 1777.368 | 25 | 0.08 | flat |
| 2+300.000 | -25 | 1777.684 | 25 | 0.07 | flat |
| 2+320.000 | -25 | 1778 | 25 | 2.04 | flat |
| 2+340.000 | -25 | 1778.317 | 25 | 3.24 | rolling |
| 2+360.000 | -25 | 1778.633 | 25 | 5.39 | rolling |
| 2+380.000 | -25 | 1778.95 | 25 | 1.92 | flat |
| 2+400.000 | -25 | 1779.266 | 25 | 4.42 | rolling |
| 2+420.000 | -25 | 1779.583 | 25 | -1.18 | flat |
| 2+440.000 | -25 | 1779.899 | 25 | -1.18 | flat |
| 2+460.000 | -25 | 1780.215 | 25 | -1.25 | flat |
| 2+480.000 | -25 | 1780.532 | 25 | -1.25 | flat |
| 2+500.000 | -25 | 1780.848 | 25 | -6.65 | rolling |
| 2+520.000 | -25 | 1781.165 | 25 | 6.65 | rolling |
| 2+540.000 | -25 | 1781.481 | 25 | 5.68 | rolling |
| 2+560.000 | -25 | 1781.797 | 25 | 14.11 | rolling |

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|---|---|---|---|---|---|
| 2+580.000 | -25 | 1782.114 | 25 | 14.1 | rolling |
| 2+600.000 | -25 | 1782.43 | 25 | 12.37 | rolling |
| 2+620.000 | -25 | 1782.747 | 25 | 12.11 | rolling |
| 2+640.000 | -25 | 1783.063 | 25 | 12.3 | rolling |
| 2+660.000 | -25 | 1783.38 | 25 | 14.18 | rolling |
| 2+680.000 | -25 | 1783.696 | 25 | 13.65 | rolling |
| 2+700.000 | -25 | 1784.012 | 25 | 0.54 | flat |
| 2+720.000 | -25 | 1784.329 | 25 | 26.16 | mountainous |
| 2+740.000 | -25 | 1784.645 | 25 | 21.77 | rolling |
| 2+760.000 | -25 | 1784.962 | 25 | 13.29 | rolling |
| 2+780.000 | -25 | 1785.278 | 25 | 22.97 | rolling |
| 2+800.000 | -25 | 1785.595 | 25 | 13.42 | rolling |
| 2+820.000 | -25 | 1785.911 | 25 | 22.76 | rolling |
| 2+840.000 | -25 | 1786.227 | 25 | 23.04 | rolling |
| 2+860.000 | -25 | 1786.544 | 25 | 11.23 | rolling |
| 2+880.000 | -25 | 1786.86 | 25 | 12.92 | rolling |
| 2+900.000 | -25 | 1787.177 | 25 | 10.82 | rolling |
| 2+920.000 | -25 | 1787.493 | 25 | 6.33 | rolling |
| 2+940.000 | -25 | 1787.809 | 25 | 8.28 | rolling |

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|---|---|---|---|---|---|
| 2+960.000 | -25 | 1788.126 | 25 | 5.67 | rolling |
| 2+980.000 | -25 | 1788.442 | 25 | 0.52 | flat |
| 3+000.000 | -25 | 1788.759 | 25 | 23.73 | rolling |
| 3+020.000 | -25 | 1789.075 | 25 | 14.2 | rolling |
| 3+040.000 | -25 | 1789.392 | 25 | 14.37 | rolling |
| 3+060.000 | -25 | 1789.708 | 25 | 5.99 | rolling |
| 3+080.000 | -25 | 1790.024 | 25 | 4.9 | rolling |
| 3+100.000 | -25 | 1790.341 | 25 | 0 | flat |
| 3+120.000 | -25 | 1790.657 | 25 | 9.25 | rolling |
| 3+140.000 | -25 | 1790.974 | 25 | 9.14 | rolling |
| 3+160.000 | -25 | 1791.29 | 25 | 8.94 | rolling |
| 3+180.000 | -25 | 1791.607 | 25 | 3.25 | rolling |
| 3+200.000 | -25 | 1791.923 | 25 | -4.71 | rolling |
| 3+220.000 | -25 | 1792.239 | 25 | -6.12 | rolling |
| 3+240.000 | -25 | 1792.556 | 25 | -2.78 | flat |
| 3+260.000 | -25 | 1792.872 | 25 | -13.84 | rolling |
| 3+280.000 | -25 | 1793.189 | 25 | -14.58 | rolling |
| 3+300.000 | -25 | 1793.505 | 25 | -17.69 | rolling |
| 3+320.000 | -25 | 1793.821 | 25 | -41.97 | mountainous |

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|---|---|---|---|---|---|
| 3+340.000 | -25 | 1794.138 | 25 | -31.74 | mountainous |
| 3+360.000 | -25 | 1794.454 | 25 | -31.01 | mountainous |
| 3+380.000 | -25 | 1794.771 | 25 | -2.38 | flat |
| 3+400.000 | -25 | 1795.087 | 25 | -2.36 | flat |
| 3+420.000 | -25 | 1795.404 | 25 | -1.6 | flat |
| 3+440.000 | -25 | 1795.72 | 25 | -27.29 | mountainous |
| 3+460.000 | -25 | 1796.036 | 25 | -23.91 | rolling |
| 3+480.000 | -25 | 1796.353 | 25 | -13.89 | rolling |
| 3+500.000 | -25 | 1796.669 | 25 | -13.4 | rolling |
| 3+520.000 | -25 | 1796.986 | 25 | -11.92 | rolling |
| 3+540.000 | -25 | 1797.302 | 25 | -20.39 | rolling |
| 3+560.000 | -25 | 1797.619 | 25 | -31.36 | mountainous |
| 3+580.000 | -25 | 1797.935 | 25 | 1.2 | flat |
| 3+600.000 | -25 | 1798.251 | 25 | -23.3 | rolling |
| 3+620.000 | -25 | 1798.568 | 25 | -13.42 | rolling |
| 3+640.000 | -25 | 1798.884 | 25 | 15.43 | rolling |
| 3+660.000 | -25 | 1799.201 | 25 | -10.09 | rolling |
| 3+680.000 | -25 | 1799.517 | 25 | -10.2 | rolling |
| 3+700.000 | -25 | 1799.834 | 25 | -10.67 | rolling |

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|---|---|---|---|---|---|
| 3+720.000 | -25 | 1800.15 | 25 | -8.68 | rolling |
| 3+740.000 | -25 | 1800.466 | 25 | -7.77 | rolling |
| 3+760.000 | -25 | 1800.751 | 25 | -6.51 | rolling |
| 3+780.000 | -25 | 1800.968 | 25 | -6.49 | rolling |
| 3+800.000 | -25 | 1801.154 | 25 | -10.32 | rolling |
| 3+820.000 | -25 | 1801.339 | 25 | -11.57 | rolling |
| 3+840.000 | -25 | 1801.525 | 25 | -15.16 | rolling |
| 3+860.000 | -25 | 1801.71 | 25 | -10.87 | rolling |
| 3+880.000 | -25 | 1801.895 | 25 | -6.92 | rolling |
| 3+900.000 | -25 | 1802.081 | 25 | -7.7 | rolling |
| 3+920.000 | -25 | 1802.266 | 25 | 2.37 | flat |
| 3+940.000 | -25 | 1802.452 | 25 | 11.34 | rolling |
| 3+960.000 | -25 | 1802.637 | 25 | -11.2 | rolling |
| 3+980.000 | -25 | 1802.823 | 25 | -20.17 | rolling |
| 4+000.000 | -25 | 1803.008 | 25 | 70.24 | escarpment |
| 4+020.000 | -25 | 1803.194 | 25 | 69.77 | escarpment |
| 4+040.000 | -25 | 1803.379 | 25 | -5.4 | rolling |
| 4+060.000 | -25 | 1803.565 | 25 | -4.6 | rolling |
| 4+080.000 | -25 | 1803.75 | 25 | -18.94 | rolling |

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|---|---|---|---|---|---|
| 4+100.000 | -25 | 1803.935 | 25 | -13.35 | rolling |
| 4+120.000 | -25 | 1804.121 | 25 | -7.37 | rolling |
| 4+140.000 | -25 | 1804.306 | 25 | 1.23 | flat |
| 4+160.000 | -25 | 1804.492 | 25 | 0 | flat |
| 4+180.000 | -25 | 1804.677 | 25 | -11.25 | rolling |
| 4+200.000 | -25 | 1804.863 | 25 | 11.2 | rolling |
| 4+220.000 | -25 | 1805.048 | 25 | -7.46 | rolling |
| 4+240.000 | -25 | 1805.234 | 25 | -5.13 | rolling |
| 4+260.000 | -25 | 1805.419 | 25 | -1.35 | flat |
| 4+280.000 | -25 | 1805.605 | 25 | -0.74 | flat |
| 4+300.000 | -25 | 1805.79 | 25 | -0.73 | flat |
| 4+320.000 | -25 | 1805.975 | 25 | -16.89 | rolling |
| 4+340.000 | -25 | 1806.161 | 25 | -27.07 | mountainous |
| 4+360.000 | -25 | 1806.346 | 25 | 27.01 | mountainous |
| 4+380.000 | -25 | 1806.532 | 25 | -22.41 | rolling |
| 4+400.000 | -25 | 1806.717 | 25 | -21.11 | rolling |
| 4+420.000 | -25 | 1806.903 | 25 | -20.29 | rolling |
| 4+440.000 | -25 | 1807.088 | 25 | -14.49 | rolling |
| 4+460.000 | -25 | 1807.274 | 25 | -13.69 | rolling |

| | | | | | |
|---|---|---|---|---|---|
| 4+480.000 | -25 | 1807.459 | 25 | -7.67 | rolling |
| 4+500.000 | -25 | 1807.644 | 25 | 1.5 | flat |
| 4+520.000 | -25 | 1807.83 | 25 | -3.42 | rolling |
| 4+540.000 | -25 | 1808.015 | 25 | 4.49 | rolling |
| 4+560.000 | -25 | 1808.201 | 25 | 5.11 | rolling |
| 4+580.000 | -25 | 1808.386 | 25 | 2.34 | flat |
| 4+600.000 | -25 | 1808.572 | 25 | 2.44 | flat |
| 4+620.000 | -25 | 1808.757 | 25 | 3.87 | rolling |
| 4+640.000 | -25 | 1808.943 | 25 | 1.09 | flat |
| 4+660.000 | -25 | 1809.128 | 25 | 2.31 | flat |
| 4+680.000 | -25 | 1809.314 | 25 | 1.32 | flat |
| 4+700.000 | -25 | 1809.499 | 25 | 2.98 | flat |
| 4+720.000 | -25 | 1809.684 | 25 | 5.61 | rolling |
| 4+740.000 | -25 | 1809.87 | 25 | 4.73 | rolling |
| 4+760.000 | -25 | 1810.055 | 25 | -0.42 | flat |
| 4+780.000 | -25 | 1810.241 | 25 | 2.19 | flat |
| 4+800.000 | -25 | 1810.426 | 25 | -5.32 | rolling |
| 4+820.000 | -25 | 1810.612 | 25 | -2.69 | flat |
| 4+840.000 | -25 | 1810.797 | 25 | 2.01 | flat |

| | | | | | |
|---|---|---|---|---|---|
| 4+860.000 | -25 | 1810.983 | 25 | -7.1 | rolling |
| 4+880.000 | -25 | 1811.168 | 25 | -4.97 | rolling |
| 4+900.000 | -25 | 1811.354 | 25 | -5.79 | rolling |
| 4+920.000 | -25 | 1811.539 | 25 | -6.45 | rolling |
| 4+940.000 | -25 | 1811.724 | 25 | -9.1 | rolling |
| 4+960.000 | -25 | 1811.91 | 25 | 9.8 | rolling |
| 4+980.000 | -25 | 1812.095 | 25 | 9.8 | rolling |
| 5+000.000 | -25 | 1812.281 | 25 | 9.8 | rolling |
| 5+020.000 | -25 | 1812.466 | 25 | 8.29 | rolling |
| 5+040.000 | -25 | 1812.652 | 25 | 9.99 | rolling |
| 5+060.000 | -25 | 1812.837 | 25 | 10.36 | rolling |
| 5+080.000 | -25 | 1813.023 | 25 | 9.23 | rolling |
| 5+100.000 | -25 | 1813.208 | 25 | 11.42 | rolling |
| 5+120.000 | -25 | 1813.393 | 25 | 4.91 | rolling |
| 5+140.000 | -25 | 1813.579 | 25 | 8.76 | rolling |
| 5+160.000 | -25 | 1813.764 | 25 | 4.26 | rolling |
| 5+180.000 | -25 | 1813.95 | 25 | 3 | Flat |
| 5+200.000 | -25 | 1814.135 | 25 | 5.92 | rolling |
| 5+220.000 | -25 | 1814.321 | 25 | 1.84 | flat |

| | | | | | |
|---|---|---|---|---|---|
| 5+240.000 | -25 | 1814.506 | 25 | 4.48 | rolling |
| 5+260.000 | -25 | 1814.692 | 25 | 3.04 | Rolling |
| 5+280.000 | -25 | 1814.877 | 25 | 3.13 | Rolling |
| 5+300.000 | -25 | 1815.063 | 25 | 3.39 | Rolling |
| 5+320.000 | -25 | 1815.248 | 25 | 0.4 | Flat |
| 5+340.000 | -25 | 1815.433 | 25 | -2.18 | Flat |
| 5+360.000 | -25 | 1815.619 | 25 | -2.18 | Rolling |
| 5+380.000 | -25 | 1815.804 | 25 | -2.18 | Rolling |
| 5+400.000 | -25 | 1815.99 | 25 | -2.18 | Rolling |
| 5+420.000 | -25 | 1816.175 | 25 | -2.18 | Rolling |
| 5+440.000 | -25 | 1816.361 | 25 | -2.18 | Rolling |
| 5+460.000 | -25 | N/A | 25 | -2.18 | Rolling |
| 5+470.265 | -25 | N/A | 25 | | |

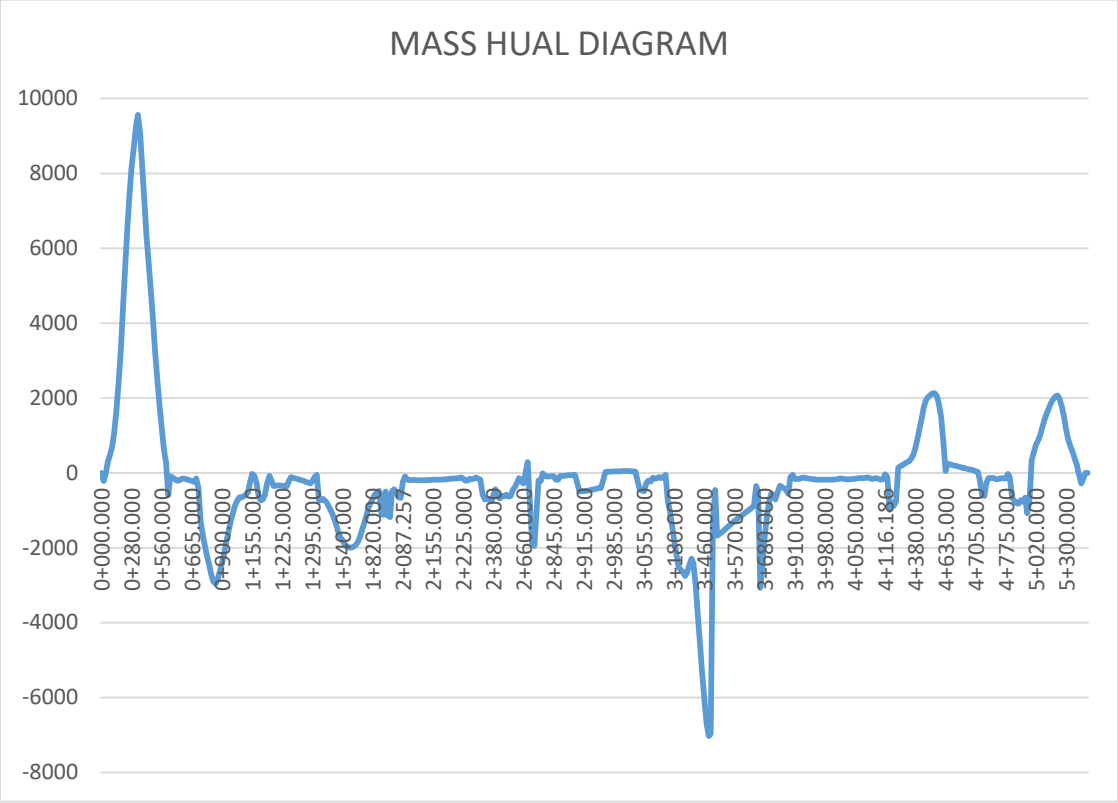



*Figure 14 mass haul diagram*

## References


1. ERA manual 2013
2. Survey engineering I
3. Survey engineering II
4. Highway I
5. Highway II
6. Transportation engineering
7. Output of software (eagle point)