1.0 INTRODUCTION

1.1 Background Information

Irrigation is an artificial application of water to the soil through various systems of tubes, pumps, and sprays. Irrigation is normally used in areas where rainfall is inconsistent or dry conditions or drought is expected (Frenken, K. (2005)).

Irrigation can also be defined as the process of supplying water, in addition to natural precipitation, to field crops, orchards, vineyards, or other cultivated plants. Irrigation water is applied to ensure that the water available in the soil is sufficient to meet crop water needs. The role of irrigation is to improve production and the effectiveness of other inputs.

Irrigation has the following purposes:

- Providing insurance against short duration droughts
- Reducing the hazard of frost (increase the temperature of the plant)
- Reducing the temperature during hot spells
- Washing or diluting salts in the soil Softening tillage pans and clods
- Delaying bud formation by evaporative cooling
- Promoting the function of some microorganisms

It has also been found to have the following benefits:

1. Increase in Crop Yield
2. Protection from famine
3. Cultivation of superior crops
4. Elimination of mixed cropping
5. Economic development
6. Hydro power generation
7. Domestic and industrial water supply

The following are considered to be the objectives of irrigation:
• To Supply Water Partially or Totally for Crop Need
• To Cool both the Soil and the Plant
• To Leach Excess Salts
• To improve Groundwater storage
• To Facilitate continuous cropping
• To Enhance Fertilizer Application- Fertigation

According to Frenken, K. (2005), irrigation systems can be classified as hereunder:-

1.1.1 Surface Irrigation- Surface irrigation methods use the soil surface to spread water across a field or orchard to the plants being irrigated, and include furrow, border or flood irrigation and basin irrigation.

1.1.2 Sprinkler Irrigation - In this type of irrigation water is applied to all field by means of rotating sprinklers or mini-sprinklers connected to a pressurized pipe system

1.1.3 Micro- Irrigation - In micro irrigation water is applied to the plants through emitters so that water leaves the emitter as a droplet. Water is supplied to the emitters through a network of mainline and literal pipelines that are normally made of plastics.

1.1.4 Drip Irrigation - Depending on how the emitters are placed in the plastic polyethylene distribution line, the drip mode can be further delineated as a line source or a point source. The line source type emitters are placed internally in equally spaced holes or slits made along the line. Water applied from the close and equally spaced holes usually runs along the line and forms a continuous wetting pattern.

1.1.5 Localized Irrigation
Water is spread in low pressure, through a piped system and supplied to each plant.

1.1.6 Lateral Move Irrigation
Water is spread through a series of pipes, each with a wheel and a set of sprinklers, which are rotated either by hand or with a purpose-built mechanism.
1.2. Site Analysis and Inventory

Kirinyaga County can be divided into three ecological zones; the lowland area that lies between 1158 m to 2000 m above sea level, the midland area that lie between 2000m to 4000m above sea level and the highland area that lies between 4800m to 6800m above sea level.

The lowland area is characterized by gentle rolling plains that cover most of kirinyaga South district. The upper midland area covers the lower areas of Kirinyaga West and Kirinyaga East districts.

The highland area covers the upper areas of Kirinyaga West, Kirinyaga East and Kirinyaga Central districts and the whole of the mountain area of the county.

The county has a tropical climate and an equatorial rainfall pattern. This climatic condition is influenced by the county’s position along the equator and its position on the wind ward side of Mt Kenya. It has two rainy seasons, the long rains which occur from March to May and the short rains which occur from October to November. The long rains average 710 mm while the short rains average 640 mm. The amount of rainfall declines from the high altitude on the slopes of Mt. Kenya towards the Semi-arid zones in the eastern part of Kirinyaga South district. The temperature ranges from a mean of 8.1\(^\circ\)C in the upper zones with high attitude to 30.3\(^\circ\)C in the lower zones with low attitudes during the hottest season.

Kirimara Irrigation Scheme is an irrigation scheme in Kirimara, which is a location in Mwea Division of Kirinyaga County. This can be considered to be in Kirinyaga South District. I identified the problems that the farmers in this scheme were undergoing during my fieldwork attachment.

The proposed scheme is to be designed such that to accommodate a total of about 1,200 farmers and provide for a future expansion of about 20%. The scheme is to get water from River Nyamindi. The crops to be grown will be horticultural crops such as tomatoes, French beans, some vegetables as well as bananas.

In addition, farmers will use the water for their domestic needs. Below is a map showing Kirinyaga District/County Annual Rainfall in millimeters (mm).
Figure 1: map of kirinyaga district annual rainfall in millimeters
1.3 Problem Statement and Problem Analysis

Kirimara Irrigation Scheme is an irrigation scheme that is yet to be established inorder to help farmers go on with their farming activities even when there is shortage of rains. I came to know about this scheme and identified the problem that they were undergoing during my fieldwork attachment at the Ministry of Water and Irrigation.

Due to the recent climate change, irrigation has become of importance to many farmers in most places in Kenya.

Farmers have also gained interest in growing crops in and out of seasons whereby it has been a great challenge since there are only two seasons of rainfall:- long rains that come from April to May and short rains that come between the months of October to November. The residents of the area therefore desperately need a water intake structure that will help supply water for their irrigation activities as well as for their domestic use.

They also lack the skills to come up with an intake structure that will last for long, hence the reason why I have decided to design for them an intake structure that will satisfy their needs. In most cases, farmers use sacks filled with soil to divert water from a river. This kind of a structure is not effective and in most cases will fail when the river swells, hence the need for a well designed intake structure whose main consideration will be the design of a diversion weir.

1.4 Hypothesis

The designed diversion weir will help to raise and abstract water that will be enough to cater for the needs of the farmers in Kirimara Irrigation Scheme.

The design will also help to cater for the present and future irrigation needs of the farmers, that is, the 20% allowance put during the design will ensure that in future, farmers do not experience water shortage when they increase in number.
1.5. Objectives

1.5.1 Overall Objective

The overall objective of this project was to design a diversion weir for Kirimara Irrigation Scheme.

1.5.2 Specific Objectives

The specific objectives were:

- To identify the most suitable site for the diversion weir
- To determine water demand including crop water requirements and domestic uses
- To prepare detail design calculations and design drawings for the weir and the bill of quantities.

1.6. Statement of scope

The design process will involve design calculations and preparation of the bill of quantities of the materials to be used in the weir construction.
2.0 LITERATURE REVIEW

2.1 Introduction

Weir is a structure constructed at the head of canal, in order to divert the river water towards the canal so as to ensure a regulated continuous supply of silt free water with certain minimum head into the canal.

A weir can also be defined as a solid obstruction put across a river to raise its water level and divert water into a canal (low head structure).

The types of weir and its use depend upon the topography, geology, discharge, river morphology etc. If the major part or the entire ponding of water is achieved by a raised crest and smaller part or nil part of it is achieved by the shutters then it is called weir.

Undersluice is the structure constructed side by the weir for the purpose of flushing the deposited silt by providing opening provided on the weir portion with crest level positioned at lower level than the crest of the weir. It creates comparatively less turbulent pocket of water near intake.

The primary impact of a weir on the river, and indeed its primary function, is the raising of upstream water level above the natural level, as shown in the figure a below:

Figure 2: Raising of water level by a Weir
For this reason, it is very possible to divert water from the main river and pipe it for use in irrigation and domestic use.

2.2 Uses of Weirs

According to the (good practice manual by Charles Rickard, Rodney Day and Jeremy Purseglove 2003), weirs have been constructed and used in England for the following four fundamental reasons:

2.2.1 Water Level Management

Most of the weirs in England and Wales have been constructed with the primary aim of water level management. The impoundment of water is clearly a central function of weirs as by their very nature they raise water levels relative to downstream conditions.

Increased water levels may be required to provide sufficient draft for navigation, to permit the diversion or abstraction of water, or to provide a source of power. Many of the older weirs in England and Wales were constructed in connection with water mills and navigation improvements.

In cases where a river reach serves a navigation requirement, the increase in water levels is often accompanied by the need for controllability of level to ensure that canal banks are not overtopped, and that headroom under bridges is maintained.

This is often achieved by the construction of a weir with a long crest, such that water level variation is small in response to changing flow conditions (the alternative is to have a gated weir that will allow regulation of water level).

Side weirs are frequently used for water level management in navigable waterways.

Weirs are also used to divert water into off-stream reservoirs or diversion channels, for flood defense purposes or as part of a water supply scheme.

In providing raised water levels weirs may also be allowing the continued use of a reach of a river for recreation and amenity.
Weirs are also used to maintain groundwater levels.

2.2.2 Flow Measurement

Weirs also form the backbone of the national hydrometric system, which provides accurate discharge information to facilitate development planning, flood forecasting, planning and development of flood alleviation schemes, and water resources regulation.

Although any weir can be used to provide information on flow rates, weirs not specifically designed with this in mind are likely to provide only approximate data.

In the last fifty years or so, a large number of weirs have been constructed with the sole purpose of monitoring flow conditions in rivers, mostly (until recently) aimed at low to moderate flow conditions, and not high flood flows.

Flow gauging weirs permit engineers and hydrometrists to calculate the discharge in a river reach, monitor it over time and, if real time monitoring is available, to issue flood warnings and to adjust flood control structures in response to changing conditions.

2.2.3 Environmental Enhancement

By raising water levels weirs may offer the opportunity to create wetland and conservation habitats as well as enhance rivers and their surrounding areas.

However, the very fact that the weir creates a barrier in the river may be detrimental to nature conservation, so it is important that all potential impacts are assessed before a decision is made.

Specific advantages of weirs include the prevention of the river channel drying out upstream of the weir, and increased aeration of the river water as it cascades over the weir crest. These can help to develop a rich and diverse environment for both aquatic and terrestrial species.

Weirs also open up options for improving low flow conditions by keeping water depths greater than they otherwise would be, and providing opportunities for water meadows and landscaping. As such, weirs may form an important component of a Water Level Management Plan (WLMP).

Weirs also have a significant impact on the amenity value of rivers, creating or enabling opportunities for enhanced use of the river.

However, care needs to be exercised because the presence of a weir can constitute a barrier in the watercourse thereby preventing the migration of fish upstream and downstream, thus limiting their access to suitable spawning sites as well as reducing the overall biological value of a fishery. Indeed, it can be argued that the ponded water upstream of a weir creates a more homogeneous environment, with lower biodiversity than a natural river. Thus it is not uncommon for weirs to be removed in order to return the channel to a more natural status.
2.2.4 Channel Stabilization

In reaches of river where the channel gradient is steep, and where erosion is an issue, the increased water depths caused by impounding will slacken water surface slopes, reduce and regulate velocities and help to control erosion.

Such weirs are much more common in southern Europe than they are in England and Wales. In this context, weirs are also provided in a reach of channel that has been shortened, so that the gradient in the stream can be maintained at a stable value. Weirs can also be used to create a silt trap, thereby preventing or reducing siltation downstream.
For such use it must be remembered that the effectiveness of the weir will depend on regular removal of the trapped silt, and this will require safe and easy access to the weir for suitable plant and equipment.

### 2.3 Types of Weirs

A weir with a sharp upstream corner or edge such that the water springs clear of the crest is known as a sharp crested weir.

All the other weirs are classed as weirs not sharp crested.

Sharp crested weirs are classified according to the shape of the weir opening such as rectangular weirs, triangular weirs or v-notch weirs, trapezoidal weirs and parabolic weirs.

Weirs not sharp crested are classified according to the shape of their cross-section, such as broad-crested weirs, triangular weirs and trapezoidal weirs.

Sharp crested weirs are useful only as a means of measuring flowing water.

Weirs not sharp-crested are commonly incorporated into hydraulic structures as control or regulation devices, with measurement of flow as their secondary function.

#### 2.3.1 Labyrinth Weir

A labyrinth weir uses a trapezoidal-shaped weir wall geometry (plan view) to increase the weir length. They are versatile structures and can be modified to fit many applications.
2.3.2 Broad-crested Weir

A broad-crested weir is a flat-crested structure, with a long crest compared to the flow thickness. When the crest is "broad", the streamlines become parallel to the crest invert and the pressure distribution above the crest is hydrostatic. The hydraulic characteristics of broad-crested weirs were studied during the 19th and 20th centuries. Practical experience showed that the weir overflow is affected by the upstream flow conditions and the weir.

2.3.3 Sharp Crested Weir (Fayoum Weir)

A sharp-crested weir allows the water to fall cleanly away from the weir. Sharp crested weirs are typically 1/4” or thinner metal plates. Sharp crested weirs come in many different shapes such as rectangular, V-notch and Cipolletti weirs. They are not very accurate or reliable especially when reading and measuring from an orifice.
2.3.4 Combination Weir

The sharp crested weirs can be considered into three groups according to the geometry of weir:

a) the rectangular weir,

b) the V or triangular notch and

c) special notches, such as trapezoidal, circular or parabolic weirs.

For accurate flow measurement over a wider range of flow rates, a combination weir combines a V-notch weir with a rectangular weir. An example is manufactured by Thel-Mar Company and has flow rates engraved along the side of the weir. This is typically used in pipes ranging from 4" to 15" in diameter.

2.3.5 V-notch Weir

The V-notch weir is a triangular channel section, used to measure small discharge values. The upper edge of the section is always above the water level, and so the channel is always triangular simplifying calculation of the cross-sectional area. V-notch weirs are preferred for low discharges as the head above the weir crest is more sensitive to changes in flow compared to rectangular weirs.

2.3.6 Minimum Energy Loss Weir

The concept of the Minimum Energy Loss (MEL) structure was developed by Gordon McKay in 1971. The first MEL structure was the Redcliffe storm waterway system, also called Humpybong Creek drainage outfall, completed in 1960 in the Redcliffe Peninsula in Queensland, Australia. It consisted of a MEL weir acting as a streamlined drop inlet followed by a 137 m long culvert discharging into the Pacific Ocean. The weir was designed to prevent beach sand being washed in and choking the culvert, as well as to prevent salt intrusion in Humpybong Creek without afflux. The structure is still in use and passed floods greater than the design flow in several instances without flooding.
The concept of the Minimum Energy Loss (MEL) weir was developed to pass large floods with minimum energy loss and afflux, and nearly-constant total head along the waterway. The flow in the approach channel is contracted through a streamlined chute and the channel width is minimum at the chute toe, just before impinging into the downstream natural channel. The inlet and chute are streamlined to avoid significant form losses and the flow may be critical from the inlet lip to the chute toe at design flow. MEL weirs were designed specifically for situations where the river catchment is characterized by torrential rain falls and by very small bed slope. The first major MEL weir was the Clermont weir, if the small control weir at the entrance of Redcliffe culvert is not counted. The largest, Chinchilla weir, is listed as a "large dam" by the International Commission on Large Dams.

Figures b, c and d below show classification of weirs by shape:

![Rectangular Weir](image)

Figure 3 : Rectangular Weir
Figure 4: Triangular Weir or V-notch

Figure 5: Trapezoidal Weir
Figure 6: Weir type cross-sections (good practice manual by Charles Rickard, Rodney Day and Jeremy Purseglove-2003)
3.0 THEORETICAL FRAMEWORK

3.1 Design Consideration of Diversion Weir

The design of weir includes computing the elevation of weir crest, length of weir, computing the forces acting on the weir and checking the safety of the weir from all aspects like overturning, sliding, crushing etc. They all are explained in the following articles.

3.1.1 Elevation of Weir Crest

There are various factors that affect the elevation of the crest, but in our case, diversion of water is the purpose and the height should be sufficient to pond the water at a level that can facilitate design flow in the intake. The height of the weir is governed by the height of intake sill, depth of intake orifice and depth of the river at the intake site.

3.1.2 Length of Weir

The length of the weir depends upon the width of the waterway at the intake site. Crest length should be taken as the average wetted width during the flood. The upstream and downstream should be properly examined for the protection consideration. Rise in water level on the upstream of the structures after construction of the weir is called afflux. Fixation of afflux depends on the topographic and geomorphologic factors. A high afflux shortens the length of the weir but increases the cost of the river training and river protection works. For alluvial reaches it is generally restricted to 1m but for mountainous region it may be high. The water way must be sufficient to pass high floods with desired afflux. A weir with crest length smaller than the natural river width can severely interfere the natural regime of flow thus altering the hydraulic as well as the sediment carrying characteristics of the river.
3.2 Forces acting on Weir

The main forces which are acting on the weir when it will be operation are: Water Pressure, Uplift Pressure, Slit Pressure and Weight of the weir.

![Diagram of forces on the weir]

3.2.1 Water Pressure

It is the major external force acting on the weir. This is called hydrostatic pressure force and acts perpendicular on the surface of the weir and its magnitude is given by:

\[ P = 0.5 \times \gamma \times H^2 \times b \]

\[ \text{........................................................................................................... (3.1)} \]

Where, \( \gamma \) = Unit weight of water, \( H \) = Depth of water, \( b \) = Width of The Weir surface. This pressure force acts on \( H/3 \) from the base.
3.2.2 Uplift Pressure

Water seeping through the pores, cracks and fissures of the foundation material, seeping through the weir body itself and seepage from the bottom joint between the weir and its foundation exerts an uplift pressure on the base of the weir. The uplift pressure virtually reduces the downward weight of the weir hence acts against the dam stability. The analysis of seepage is done using Khosla's Theory. Khosla's Theory is the mathematical solution of the Laplacian equation and it is easy and accurate method for seepage analysis.

3.2.3 Silt Pressure

The silt gets deposited on the upstream of the weir and exerts the horizontal and vertical pressure as exerted by the water. So, flushing of the silt should be done regularly to reduce its effect of destabilizing the weir. It is done by the use of undersluice gate. The silt pressure is given by the relation:

\[ P_{\text{silt}} = 0.5 \times \gamma_{\text{sub}} \times H^2 \times K_a \]  

Where, \( \gamma_{\text{sub}} = \) Submerged unit weight of silt; \( H = \) Depth of silt deposited and \( K_a = \) Coefficient of Active earth pressure and is given by,

\[ K_a = \frac{1 - \sin \theta}{1 + \sin \theta} \]

where, \( \theta = \) Angle of internal friction of silt

The silt pressure force also acts at a height of \( H/3 \) from the base.

3.2.4 Weight of Weir

The weight of weir and its foundation is the major stabilizing/ resisting force. While calculating the weight, the cross section is split into rectangle and triangle. The weight of each along with their center of gravity is determined. The resultant of all these forces will represent the total
weight of weir acting at the C.G. of weir. Simply, when the sectional area of each part is multiplied by unit weight of concrete, weight of that part is obtained. The weir is designed with oggee profile for spilling over its length. Hence weight is calculated by knowing its section and multiplying by its unit weight.

3.3 Modes of Failure & Criteria for Structural Stability of Weir

3.3.1 Overturning about the toe

If resultant of all the forces acting in the weir passes outside, the weir shall rotate and overturn about the toe. Practically, this condition will not arise because the weir will fail much earlier by compression. The ratio of resisting moment to the overturning moment about the toe is the factor of safety against overturning and it should greater than 1.5 for safety.

3.3.2 Compression or Crushing

While designing the weir section it should be so design that the resultant should pass through middle 3\textsuperscript{rd} part of the section to avoid the possible tension on the weir section. The section should be totally in compression. So, weir should be checked against the failure by crushing of its material. If the actual compressive stress may exceed the allowable stress, the structure material may get crushed. The vertical combine stress at the base is given by

$$\sigma_{\text{Min/Max}} = \frac{\sum V}{B} [1 \pm 6 \times \frac{e}{B}]$$  

Where \(e = \frac{B}{2}-x\), \(x = \frac{\sum M}{\sum V}\), e = eccentricity of the resultant force from the centre of the base.

3.3.3 Sliding

Sliding will occur when the net horizontal force above any plane in the weir or at the base of the weir exceed the frictional resistance developed at that level. Factor of safety against the sliding is measured as Shear Stability Factor (SSF) and is given by:
$$SSF = \frac{\mu \times \sum Y + Bq}{\sum H}$$ (3.5)

Where, $\mu$ = Coefficient of friction; $q$ = Average shear strength of the joint.

For safety against sliding, SSF should be greater than 3.5. To increase the value of SSF, attempts are always made to increase the magnitude of $q$, which is achieved by providing the stepped foundation, ensuring the better bond between the dam base and rock foundation etc.

### 3.4 Protection Work for Weir Structure

The weir should be well protected from the flowing river to avoid creep effect.

For this, the **wing wall** is essential to construct. It should be well anchored into the bed. Similarly, to protect the channel bed from being eroded, launching **apron** is used.

To protect the weir body **riprap** (rock or other material used to armor shorelines, streambeds or other shoreline structures against scour water or ice erosion) is usually placed. If both of the banks are rocky no especial protection shall be introduced. Some sorts of works to protect banks and to confine the river at upstream may be required. **Gabion** walls are used as protection works for the banks which ultimately protect the degradation of the weir.

To prevent the seepage effect, **sheet piles** are inserted at the upstream and downstream.
4.0 METHODOLOGY

4.1 Survey

Field work survey was carried out to determine the most appropriate site for the location of the water intake. This area was found to be the most appropriate in that it was a bit higher in elevation compared to areas/fields where it was to supply water. The river width at this section was also narrower compared to the other alternative sites hence reducing the total length of the whole weir structure as well as the total costs to be encountered in its construction. The length was 22m and the depth was 1.5m.

4.2 River flow

The River flows were to be obtained from the Water Resources Management Authority (WRMA). The flows were however not available but since Nyamindi River is perennial, construction of an abstraction point will adequately provide the volume of water for intended purposes. The permitted volume of water per day for the whole scheme by the Water Resources Management Authority(WRMA) was 2430 m$^3$ per day according to a letter by the Authority Ref. no. WRMA/TC/00387(12). This amounts to a discharge of about:-

$$\frac{2430}{24*3600} \text{ m}^3/\text{s}$$

$$= 0.028125 \text{ m}^3/\text{s} \text{ or } 28.125 \text{ l/s}.$$  

WRMA has to limit the amount of water that is to be used by a particular scheme because the river has several schemes, and all of the farmers in this scheme need water hence the equality in sharing.

This is the discharge that was used to design the weir.

The depth of the river was found to be 1.5 m hence this determined the height of the weir body.
4.3 Water Demand

4.3.1 Crop Water Requirement

Introduction
The scheme water requirement is the total amount of water that will be supplied for effective scheduled irrigation. The following primary assumptions have been made in the determination of the scheme water requirements:

- The potential Evapotranspiration is maximum
- The irrigated area is 100% of the effective irrigation area of the scheme as agreed by the members
- The crop is at its peak growth
- The amount of soil water storage is negligible

Crop Water Requirement
The following factors / parameters were considered during the review of the general water requirements:

- Crops and cropping patterns;
- Crop factors (Kc);
- Evapotranspiration and effective rainfall;
- Irrigation efficiencies (for sprinkler irrigation system);
- Irrigation hours per day and no. of settings per day;
- Irrigation days per week;
- Irrigation area.
- \( \text{ET}_{\text{crop}} = \text{ETo} \times K_c \)

Where:

\( \text{ETo} \) = Evapo-transpiration, which is given by: Evaporation from free water surface x adjustment factor (0.75 for highlands above 1100 m.a.s.l and 0.8 for hot and dry low areas below 1100 m.a.s.l)

\( K_c \) = Crop Coefficient taken as 0.9 for most crops
**Crops**

Various crops have been proposed to be produced under irrigation, which include:

- Onions
- Bananas
- Watermelons
- French beans
- Tomatoes

A cropping pattern that ensured all the crops were grown was used.

**Reference Crop Evapotranspiration, ETo**

Values used are those that were obtained from CLIMWAT/CROPWAT softwares and are as given in table 1 below:-

**Table 1: reference crop evapotranspiration**

<table>
<thead>
<tr>
<th>Month</th>
<th>Min Temp °C</th>
<th>Max Temp °C</th>
<th>Humidity %</th>
<th>Wind km/day</th>
<th>Sun hours</th>
<th>Rad MJ/m²/day</th>
<th>ETo mm/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>11</td>
<td>33</td>
<td>68</td>
<td>112</td>
<td>8.9</td>
<td>22.6</td>
<td>4.85</td>
</tr>
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<td>February</td>
<td>11.7</td>
<td>35</td>
<td>60</td>
<td>121</td>
<td>9</td>
<td>23.4</td>
<td>5.39</td>
</tr>
<tr>
<td>March</td>
<td>12.1</td>
<td>36.2</td>
<td>62</td>
<td>130</td>
<td>8.1</td>
<td>22.2</td>
<td>5.45</td>
</tr>
<tr>
<td>April</td>
<td>11.6</td>
<td>34.8</td>
<td>72</td>
<td>104</td>
<td>6.6</td>
<td>19.2</td>
<td>4.5</td>
</tr>
<tr>
<td>May</td>
<td>11.2</td>
<td>33.6</td>
<td>74</td>
<td>78</td>
<td>6.5</td>
<td>18</td>
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<tr>
<td>June</td>
<td>10.5</td>
<td>31.7</td>
<td>72</td>
<td>69</td>
<td>4.6</td>
<td>14.7</td>
<td>3.27</td>
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<td>July</td>
<td>10.2</td>
<td>30.6</td>
<td>70</td>
<td>78</td>
<td>4</td>
<td>14.1</td>
<td>3.17</td>
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<tr>
<td>August</td>
<td>10.3</td>
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<td>61</td>
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<td>21</td>
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<tr>
<td>Average</td>
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<td>108</td>
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<td>19</td>
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Crop Water requirement, ETcrop

The crop water requirement has been determined using the following relationship:

\[
ET_{\text{crop}} = K_c \times E_{\text{T0}} \quad \text{.............................................(4.1)}
\]

\[
= 0.9 \times 4.4
\]

\[
= 3.96 \text{ mm/day}
\]

Effective Rainfall

Not all the rainfall is available for plant use as some is lost through deep percolation, runoff and evaporation.

The effective rainfall for this scheme is calculated using CLIMWAT/CROPWAT softwares and is as given in table 2 below:-

Table 2: Effective Rainfall

<table>
<thead>
<tr>
<th></th>
<th>Rain</th>
<th>Effective rain</th>
<th>Effective rain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mm</td>
<td>Mm</td>
<td>mm/day</td>
</tr>
<tr>
<td>January</td>
<td>13</td>
<td>12.7</td>
<td>0.41</td>
</tr>
<tr>
<td>February</td>
<td>24</td>
<td>23.1</td>
<td>0.825</td>
</tr>
<tr>
<td>March</td>
<td>72</td>
<td>63.7</td>
<td>2.05</td>
</tr>
<tr>
<td>April</td>
<td>294</td>
<td>154.4</td>
<td>5.15</td>
</tr>
<tr>
<td>May</td>
<td>139</td>
<td>108.1</td>
<td>3.49</td>
</tr>
<tr>
<td>June</td>
<td>23</td>
<td>22.2</td>
<td>0.74</td>
</tr>
<tr>
<td>July</td>
<td>7</td>
<td>6.9</td>
<td>0.22</td>
</tr>
<tr>
<td>August</td>
<td>11</td>
<td>10.8</td>
<td>0.35</td>
</tr>
<tr>
<td>September</td>
<td>12</td>
<td>11.8</td>
<td>0.39</td>
</tr>
<tr>
<td>October</td>
<td>108</td>
<td>89.3</td>
<td>2.88</td>
</tr>
<tr>
<td>November</td>
<td>158</td>
<td>118.1</td>
<td>3.94</td>
</tr>
<tr>
<td>December</td>
<td>59</td>
<td>53.4</td>
<td>1.72</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>920</td>
<td>674.5</td>
<td>22.165</td>
</tr>
</tbody>
</table>

average eff. Rainfall = 22.165/12
=1.85mm/day

Net Irrigation Requirement

The net irrigation requirement (NIR) has been determined as follows

\[
\text{NIR} = \text{ET}_{\text{crop}} - \text{Pe} - \text{Ge} - \text{Wb} \text{ (mm/day)} \tag{4.2}
\]

Where,

- \(\text{Pe}\) is effective rainfall (mm)
- \(\text{Ge}\) Ground water contribution (mm)
- \(\text{Wb}\) Stored water contribution (mm), assumed negligible

\[
\text{NIR} = 3.96 \text{ mm/day} - 1.85 \text{ mm/day} - 0 - 0
\]

=2.11 mm/day

Irrigation Efficiencies

The scheme irrigation efficiency has been estimated using the following criteria:

\[
\text{Ep} = \text{Ec} \times \text{Ea} \times \text{Ed} \tag{4.3}
\]

Where,

- \(\text{Ec}\) is conveyance efficiency, 95% for piped system
- \(\text{Ea}\) is application efficiency, assumed 80% for sprinkler irrigation
- \(\text{Ed}\) Distribution efficiency, assumed 95% for piped system

The overall irrigation efficiency is therefore:

\[
0.95 \times 0.95 \times 0.8 = 0.722 \text{ (72%)}
\]
**Gross Irrigation Requirement**

The gross irrigation requirement (GIR) has been estimated using the following formula

\[
\text{GIR} = \frac{\text{NIR}}{\text{Ep}} \quad \text{(assuming 24 hour irrigation on a daily basis)} \quad \text{……………………………...(4.4)}
\]

Where;

\[
\text{Ep} = \text{Project efficiency (taken as 72\% as indicated above)}
\]

\[
\text{GIR} = \frac{2.11}{0.72}
\]

\[
= 2.93 \text{ mm/day}
\]

The scheme water requirement can therefore be calculated as:

\[
\text{Q} = \text{GIR} \times \text{area} \quad \text{………………………………………………………………………………..(4.5)}
\]

Assuming all each farmer is allowed to cultivate 1 acre, total area will be 1200 acres or 1200/2.47 = 485.8 ha

\[
\text{Q} = \frac{2.93 \times 10^{-3} \times 485.8 \times 10^{4}}{24 \times 3600}
\]

\[
= 0.16474 \text{ m}^3/\text{s}
\]

\[
= 164.74 \text{ l/s}
\]

This is based on the fact that all farmers are irrigating their farms at the same time, 24 hrs a day.
4.3.2 Domestic Use

The scheme is being designed to cater for 1,200 farmers and each of these farmers will be allowed to cultivate 1 acre piece of land.

Each farm has approximately six family members. Assuming that each of these members uses 25 l/day, the total amount of water used by all the farmer per second amounts to:-

\[ 1200 \times 6 \times \frac{25}{24 \times 3600} = 2.08 \text{ l/s} \]

Total amount of water for the scheme is 167.74l/s + 2.08l/s

\[ = 169.82 \text{ l/s} \]
5.0 DETAIL DESIGN OF THE INTAKE WORKS

5.1 Introduction

The proposed weir is 22.0 m long and 1.5 m above the river bed. The main weir body and retaining walls are all to be founded on rock and are proposed to be made of reinforced concrete to avoid any shear failure.

The stability analysis for both the weir and the retaining wing walls has been carried out and necessary reinforcement provided while applying a factor safety of 1.5.

The weir site has been provided with protection measures both on the upstream and downstream sides. Protection measures include grouted riprap and tipped apron on the river bed and stone pitching on the river side slopes.

A freeboard of 0.5m m has been added to the retaining wing walls above the weir crest. This has been found to be adequate contain flood flows of up to 20-year return period.

Scouring pipe sluices have been provided within the weir body for continuous silt removal and a sluice gate provided to help in flushing the intake after every major flood event.

Complete drawings of the weir plan as well as the specified sections are drawn into scale and provided separately as the plan of the intake and the respective sections as shown in the plan.
5.2 STABILITY ANALYSIS

Table 3: Specifications for stability checks

<table>
<thead>
<tr>
<th>Item</th>
<th>Weir on sandy gravels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of water</td>
<td>10.00 KN/m³</td>
</tr>
<tr>
<td>Weight of saturated soil</td>
<td>20.00 KN/m³</td>
</tr>
<tr>
<td>Coefficient of neutral pressure</td>
<td>0.50</td>
</tr>
<tr>
<td>Mass concrete unit weight</td>
<td>24.00 KN/m³</td>
</tr>
<tr>
<td>Discharge over weir</td>
<td>28.125 l/s</td>
</tr>
<tr>
<td>Length of weir</td>
<td>22.00 m</td>
</tr>
<tr>
<td>Water depth on weir</td>
<td>0.50 m</td>
</tr>
<tr>
<td>Angle of internal friction of sandy gravels</td>
<td>35 degrees</td>
</tr>
<tr>
<td>Average particle size</td>
<td>1.00 mm</td>
</tr>
<tr>
<td>Weir height</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Water level above weir</td>
<td>0.50 m</td>
</tr>
<tr>
<td>Water level downstream</td>
<td>0.00 m</td>
</tr>
<tr>
<td>Sediment level downstream</td>
<td>0.00 m</td>
</tr>
<tr>
<td>Crest width</td>
<td>0.50 m</td>
</tr>
<tr>
<td>Bottom width</td>
<td>2.00 m</td>
</tr>
<tr>
<td>Base height</td>
<td>0.50</td>
</tr>
<tr>
<td>Downstream slope ( 1:0.8 )</td>
<td>1.25</td>
</tr>
</tbody>
</table>
1. HORIZONTAL FORCES

**Water upstream**

The horizontal pressure at the bottom = (Weir height + water level above weir)\times weight of water

\[ P_1 = (1.50 + 0.50) \times 10 = 20 \text{ KN/m}^2 \]  

(5.1)

The average force over the height = (average of maximum and minimum\times (weir height + water level pressure)

\[ H_1 = \frac{20 + 0.00}{2} \times (1.50 + 0.50) \]

(5.2)

\[ H_1 = 20 \text{ KN/m} \]

The distance to the toe = (weir height + water level above weir) / 3

\[ = \frac{1.50 + 0.50}{3} \]

(5.3)

Distance to toe = 0.67 m

The moment about the toe of the weir = average force over the height \times distance to the toe

\[ = 20 \times 0.67 = 13.4 \text{ KN/m} \]

(5.4)

**Sediment upstream**

The horizontal pressure at the bottom = weir height \times coefficient of neutral soil pressure\times (Weight of saturated soil - weight of water)

\[ P_2 = 1.50 \times 0.5 \times (20 - 10) \]

(5.5)

\[ = 7.5 \text{ KN/m}^2 \]

The average force over the height = (average of minimum and maximum pressure) \times weir height

\[ = \left( \frac{7.5 + 0.00}{2} \right) \times 1.50 \]
The distance to the toe = weir height / 3

\[ = \frac{1.50}{3} \quad (5.7) \]

Distance to toe = 0.50 m

The moment about the toe of the weir = average force over the height * distance to toe

\[ = 5.63 \times 0.50 = 2.8 \text{ KNm/m} \quad (5.8) \]

**Water downstream**

The horizontal pressure at the top = - water level downstream * weight of water

\[ P_3 = -0.00 \times 10 = -0.00 \text{ KN/m}^2 \quad (5.9) \]

The average force over the height = (average of minimum and maximum pressure) * water level downstream

\[ = \left( \frac{-0.00 + -0.00}{2} \right) \times 0.00 \]

\[ H_3 = -0.00 \text{ KN/m} \quad (5.10) \]

The distance to the toe = water level downstream / 3

\[ = \frac{0.00}{3} \quad (5.11) \]

Distance to toe = 0.00 m

The moment about the toe of the weir = average force over the height * distance to the toe

\[ = -0.00 \times 0.00 \quad (5.12) \]

Moment about the toe = - 0.00 KNm/m
Sediment downstream

The horizontal pressure at the bottom = sediment level downstream * coefficient of neutral soil pressure * (weight saturated soil - weight water)

\[ P_4 = -0.00 \text{ KN/m}^2 \]  
(5.13)

The average force over the height = (average of minimum and maximum pressure) * sediment level downstream

\[ H_4 = -0.00 \text{ KN/m} \]  
(5.14)

The distance to the toe = sediment level downstream / 3

\[ = \frac{0.00}{3} \]  
(5.15)

Distance to toe = 0.00 m

The moment about the toe of the weir = average force over the height * distance to the toe

\[ = -0.00 \times 0.00 \]  
(5.16)

Moment about toe = -0.00 KNm/m

Total of horizontal moments = 13.4 + 2.8 - 0.00 - 0.00 = 16.2 KNm/m  
(5.17)

2. VERTICAL FORCES

The vertical force = bottom width * base height * mass concrete unit weight

\[ = 2 \times 0.5 \times 24 \]

\[ V_1 = 24 \text{ KN/m} \]  
(5.18)

The distance to the toe = (bottom width) / 2 = 2/2 = 1 m  
(5.19)

Distance to o (toe) = 1 m
The moment about the toe of the weir = vertical force * distance to the toe

\[ = 24 \times 1 = 24 \text{ KN/m} \quad (5.20) \]

**V2 rectangle**

The vertical force = crest width *(weir height - base height) *mass concrete unit weight

\[ V2 = 0.5 \times (1.5 - 0.5) \times 24 = 12 \text{ KN/m} \quad (5.21) \]

The distance to the toe = (bottom width - crest width) + (crest width /2)

\[ = (2 - 0.5) + (0.5/2) = 1.75 \text{ m} \quad (5.22) \]

Distance = to toe = 1.75 m

The moment about the toe of the weir = vertical force * distance to the toe

\[ = 12 \times 1.75 = 21 \text{ KN/m} \quad (5.23) \]

Moment about toe = 21 KN/m

**V3 sloping**

The vertical force = ((bottom width - crest width) /2)* (weir height - base height) *mass concrete unit weight

\[ = ((2 - 0.50)/2) \times (1.50 - 0.5) \times 24 \quad (5.24) \]

\[ V3 = 18 \text{ KN/m} \]

The distance to the toe = (bottom width - crest width) * 2/3

\[ = (2 - 0.50) \times 2/3 \quad (5.25) \]

Distance to toe = 1 m

The moment about the toe of the weir = vertical force * distance to the toe

\[ = 18 \times 1 = 18 \text{ KN/m} \quad (5.26) \]
Moment about toe = 18 KN/m

**Uplift upstream**

The uplift pressure = - (weir height + water level above weir) * weight of water

\[ P_5 = -(1.5 + 0.5) \times 10 = -20 \text{ KN/m} \] (5.27)

The average force = ((uplift pressure upstream + uplift pressure downstream) / 2) * bottom width

\[ = \left( \frac{-20 + 0.00}{2} \right) \times 2 = -20 \text{ KN/m} \] (5.28)

The distance to the toe = bottom width * 2/3 = 2 * 2/3 = 1.3 m (5.29)

Distance to toe = 1.3 m

The moment about the toe of the weir = average force * distance to the toe

\[ \text{Moment about toe} = -20 \times 1.3 = -26 \text{ KN/m} \] (5.30)

**Uplift downstream**

The uplift pressure = - water level downstream * weight water

\[ P_6 = -0.00 \times 10 = -0.00 \text{ KN/m}^2 \] (5.31)

The average force = uplift pressure downstream * bottom width

\[ U_1 = -0.00 \times 2 = -0.00 \text{ KN/m} \] (5.32)

The distance to the toe = bottom width * 2/3 = 2 * 2/3 = 1.3 m (5.33)

Distance to toe = 1.3 m

The moment about the toe of the weir = average force * distance to the toe

\[ = -0.00 \times 1.3 = -0.00 \text{ KN/m} \] (5.34)

Moment about toe = -0.00 KN/m
Total of vertical moments = 24 + 21 + 18 + (-26) + -0.00 = 37 KN/m  \hspace{1cm} (5.35)

3. OVERTURNING

Overturning will be looked at around the downstream the toe of the weir.

There are two different ways of looking at overturning:

a) The vertical compared to the horizontal moments

b) The stabilizing (positive moment (+)) compared to the overturning moments (negative moment(-)).

The ratio should be larger than 1 but for safety reasons taken as 1.5 for a and 1.3 for b.

\[ a. \quad O = \text{Moment over o vertical (eqn. 35)} > 1.5 \quad (5.36) \]

\[ \text{Moment over o horizontal (eqn .17)} \]

\[ O = \frac{37}{16.2} = 2.28 \quad \text{about} = 2.3 \]

The weir is stable against overturning since the ratio is larger than 1.5.

If the figure could be 2 > 1.5 then the weir would be stable against overturning.

\[ 0 = \text{moment stabilizing} = \text{Moment over o vertical except the moment of uplift} = \text{ (equations. 5.12 + 5.16+ 5.20+5.23+ 5.26)} \]

\[ \text{Moment overturning} = \text{Moment over o horizontal plus the moment of uplift} \quad ( \text{equations. 5.4 + 5.8 + 5.30+5.34}) \]

\[ 0 = 0.00 + 0.00 + 24 + 21 + 18 = 63 =1.49 > 1.3 \tag{5.37} \]

\[ 13.4 + 2.8 + (-26) + 0.00 \quad 42.2 \]

The weir is stable against overturning since 1.49 is greater than 1.3.
4. BEARING PRESSURE ON FOUNDATION

\[ a = \text{all moments over } o \text{ vertical} - \text{all moments over } o \text{ horizontal} \]  \hspace{1cm} (5.38)

\[ \text{all vertical forces (without uplift)} \]

\[ a = \frac{(\text{equations 5.20+5.23+5.26-5.4-5.8-5.12-5.16})}{(\text{equations 5.18+5.21+5.24})} \]

\[ a = \frac{24 + 21 + 18 - 13.4 - 2.8 - 0.00 - 0.00}{24 + 12 + 18} = \frac{46.8}{54} = 0.87 \]

\[ e = \frac{(1/2 * \text{bottom width}) - a}{54} \]  \hspace{1cm} (5.39)

\[ e = \frac{(1/2 * 2) - 0.87}{54} = 0.13 \]

Is \( a \) within the middle 1/3 of the base of the weir body?

Yes as 0.87 is between 0.66 m and 1.33 m

**Bearing pressure on upstream face (t1)**

\[ T1 = \frac{\text{all verticals} - \text{all verticals} \times e}{1000 \times \text{bottom} \div 1/6 \times 1000 \times (\text{bottom width})^2} \]  \hspace{1cm} (5.40)

\[ T1 = \frac{24 + 12 + 18 - (24 + 12 + 18) \times 0.13}{1000 \times 2 \div 1/6 \times 1000 \times (2)^2} \]

\[ = 0.027 - 0.011 = 0.016 \text{ N/m}^2 \]
Bearing pressure on downstream face $t_2$

$$T_2 = \frac{\text{all verticals}}{1000 \times \text{bottom}} + \frac{\text{all verticals} \times e}{1/6 \times 1000 \times (\text{bottom width})^2}$$  \hfill (5.41)

$$T_2 = \frac{24 + 12 + 18}{1000 \times 2} + \frac{(24 + 12 + 18) \times 0.13}{1/6 \times 1000 \times (2)^2}$$

$$= 0.027 + 0.011 = 0.038 \text{ N/m}^2$$

Allowable:

Sandy gravels $t < 1.00 \text{ N/m}^2$

Q. Acceptable?

A. Yes since 0.038 is less than 1

5. SLIDING

Sandy gravels:

Ratio = all verticals minus uplift * tangent of angle of internal friction \hfill (5.42)

All horizontal forces

$$\text{Ratio} = \left( \text{equations 5.18 + 5.21 + 5.24} \right) - \left( \text{equations 5.18 + 5.21 + 5.24} \right) \times \tan 35^\circ$$

Equations 5.2 + 5.6 + 5.10 + 5.14

$$\text{Ratio} = \left( 18 + 21.1 + 8.4 - 20.00 \right) \times \tan 35^\circ$$

$$20 + 5.63 + 0.00 + 0.00$$
DESIGN OF A DIVERSION WEIR

= 19.2/25.6 = 0.75

Allowable : sandy gravels ratio > 1.3

Q. Acceptable?

A. No.

The weir is not safe against sliding effect hence a key is required

**Method 2**

Sandy gravels

Ratio = \( \frac{\text{All horizontal forces}}{\text{All verticals forces minus uplift}} \) \hspace{1cm} (5.43)

Ratio = \( \frac{5.43}{5.2 + 5.6 + 5.10 + 5.14} \)

Ratio = \( \frac{5.18 + 5.21 + 5.24 - 5.28 - 5.32}{20 + 5.03 + 0.00 + 0.00} \)

Ratio = \( \frac{24 + 12 + 18 - 20 - 0.00}{34} \)

= \( \frac{25}{34} \) = 0.73

Allowable : Sandy gravels/coarse sand ratio < 0.4

Q. acceptable?

A. No

As the weir is not safe against the sliding effect a key trench is required since the ratio is greater than 0.73.

Horizontal force (F) in key trench is:
F = (all vertical minus uplift forces) * ratio - all horizontal forces  

\[ F = (24+12+18-20-0.00) * 0.4 - (20+5.03+0.00+0.00) = 13.6 - 25.0 = -11.4 \text{ KN/m} \]

The key trench width (W) should be:

Permissible shear stress (q) in key (mass concrete mix 1:2:4) is 0.25 N/m$^2$

\[ q = \frac{( \text{required horizontal force})}{1000} \times \text{load factor} \times w \]

\[ 0.25 = \frac{(11.4 \times 10^3)}{1000} \times 1.7 \times w \]

The load factor is a safety factor taken for the impact of forces. It is taken as 1.7

\[ W = 77.52 \text{ mm} = 0.08 \text{ m} \]

The key trench depth (D) will be

\[ F = \frac{1}{2} \times T \times \text{permissible compressive stress} \times D \times 1000 \]

\[ 11.4 \times 10^3 = \frac{1}{2} \times 0.25 \times D \times 1000 \]

\[ D = 91.2 \text{ mm} = 0.091 \text{ m} \]

(Gravel: horizontal compressive stress = 0.25 N/mm$^2$)

(Sand: horizontal compressive stress = 0.10 N/mm$^2$)

It can be concluded that only a small key is required to overcome the sliding tendency
6. STRESSES IN CONCRETE

Load factor = 1.7

A. compression

\[
t = \frac{(\text{all vertical forces} - \text{uplift forces} + \text{all verticals} - \text{uplift forces} \times e)}{1000 \times \text{bottom width}} \times \text{load factor}
\]

\[
t = \frac{(24+12+18-20-0.00 + (24+12+18-20-0.00) \times 0.13)) \times 1.7}{1000 \times 2}
\]

\[
t = \frac{(34 + 4.42) \times 1.7}{1000 \times 2}
\]

\[
t = \frac{(0.017 + 0.066) \times 1.7 = 0.14 \text{ N/m}^2}{1000 \times 2}
\]

B. Tensile

\[
t = \frac{(\text{all vertical forces} - \text{uplift forces} - \text{all verticals} - \text{uplift forces} \times e)}{1000 \times \text{bottom width}} \times \text{load factor}
\]

\[
t = \frac{(24+12+18-20-0.00 - (24+12+18-20-0.00) \times 0.13)) \times 1.7}{1000 \times 2}
\]

\[
t = \frac{(34 - 4.42) \times 1.7}{1000 \times 2}
\]

\[
t = \frac{(0.017 - 0.066) \times 1.7 = -0.083 \text{ N/m}^2}{1000 \times 2}
\]

Nominal mix 1:2 : 3 permissible is 1.00 N/m² so tensile stress is within limit

Nominal mix 1:2 : 4 permissible is 0.50 N/m² so tensile stress is within limit

Nominal mix 1:2.5 : 5 permissible is 0.35 N/m² so tensile stress is within limit
C. Shear

\[ T = \text{all horizontal forces} \times \text{Load factor} \]

\[ = \left( \frac{20+5.03+0.00+0.00}{1000} \times \text{bottom width} \right) \times \text{Load factor} \]

\[ = (25.03/2000) \times 1.7 = 0.021 \text{ N/m}^2 \]

Nominal mix 1 : 2 : 3 permissible is 0.05 N/m² so tensile stress is within limit.

Nominal mix 1 : 2 : 4 permissible is 0.25 N/m² so tensile stress is within limit.

Nominal mix 1 : 2.5 : 5 permissible is 0.17 N/m² so tensile stress is within limit.

The pipe diameter at the intake chamber is 400mm for the intake pipes and 150 mm for the scour pipe. This size of pipe is believed to convey the required discharge to the farmers.

A silt gate is also provided to ensure that the amount of silt deposited upstream of the weir is minimal.

A concrete mix of 1:2:4 should be used since it’s within limits of compression and tensile stresses.

Steel reinforcement bars of diameter 16mm are used and spaced at 200mm centre to centre and are put in both directions.

A screen is provided at the intake chamber entrance to filter off any unwanted material that the water may be carrying.
5.3 BILL OF QUANTITIES

Volume of the intake

Weir body \(= \frac{1}{2} \times 1 \times (0.5+2) \times 22 + 0.5 \times 2 = 28.8 \text{ m}^3\)

Upper apron \(= 2 \times 0.2 \times 22 = 8.8 \text{ m}^3\)

Lower apron \(= 3.5 \times 0.2 \times 22 = 15.4 \text{ m}^3\)

Wing walls \(= (2 \times 8.5 \times 0.3 \times 2) + (4 \times 0.2 \times 0.2 \times 2) = 10.52 \text{ m}^3\)

Keys \(= 0.08 \times 0.091 \times 22 \times 3 = 0.48 \text{ m}^3\)

Inlet chamber \(= 0.8 \times 0.2 \times 2 \times 3 + 0.2 \times 2 \times 0.2 = 1.04 \text{ m}^3\)

Inlet chamber cover \(= 0.5 \times 0.5 \times 0.1 = 0.025 \text{ m}^3\)

Total volume \(\approx 65 \text{ m}^3\)

Concrete mix is 1:2:4

Unit weight of concrete is 24KN/m² and 10 N make 1Kg

Hence total weight of concrete used is \(= \frac{65 \times 24 + 10^3}{10} = 156,000 \text{ Kg}\)

Cement = \(1/7 \times 156,000 = 22,286 \text{ Kg/50} = 446 \text{ bags}\)

Sand = \(2/7 \times 65 = 18.6 \text{ m}^3\)

Ballast = \(4/7 \times 65 = 37.2 \text{ m}^3\)
### Table 4: BoQs

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit cost (Kshs)</th>
<th>Total cost (Kshs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cement</td>
<td>Bags</td>
<td>450</td>
<td>1,250</td>
<td>562,500</td>
</tr>
<tr>
<td>2 Sand</td>
<td>m³</td>
<td>18.6</td>
<td>2,800</td>
<td>52,080</td>
</tr>
<tr>
<td>3 Ballast</td>
<td>m³</td>
<td>37.2</td>
<td>4,500</td>
<td>167,400</td>
</tr>
<tr>
<td>4 GI pipes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 mm diameter</td>
<td>No.</td>
<td>2</td>
<td>50,000</td>
<td>100,000</td>
</tr>
<tr>
<td>150 mm diameter</td>
<td>No.</td>
<td>1</td>
<td>25,000</td>
<td>25,000</td>
</tr>
<tr>
<td>5 Reinforcement bars</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y10</td>
<td>6m</td>
<td>300</td>
<td>1000</td>
<td>300,000</td>
</tr>
<tr>
<td>Y16</td>
<td>6m</td>
<td>150</td>
<td>2,500</td>
<td>375,000</td>
</tr>
<tr>
<td>6 Binding wires</td>
<td>Kg</td>
<td>200</td>
<td>300</td>
<td>60,000</td>
</tr>
<tr>
<td>7 Screens(0.5m by 0.5m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine screen</td>
<td>No.</td>
<td>1</td>
<td>2,500</td>
<td>2,500</td>
</tr>
<tr>
<td>Coarse screen</td>
<td>No</td>
<td>1</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>8 Labour</td>
<td>Days</td>
<td>60</td>
<td>1,500</td>
<td>90,000</td>
</tr>
<tr>
<td>9 Contingencies</td>
<td>Kshs.</td>
<td>30,000</td>
<td>30,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td></td>
<td></td>
<td></td>
<td>1,786,480</td>
</tr>
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</table>
6.0 DISCUSSION

A survey that was carried out helped in knowing the diversion weir dimensions. At the point where the weir is to be constructed, the river is 22m wide and 1.5m deep hence the weir to be constructed is 22m long and 1.5m high.

The scheme demand was calculated by calculating the gross irrigation requirement and then multiplying the value obtained, in this case 2.93 mm/day with the total area of the scheme that will be put under irrigation, which is 485.8 ha. This yielded a value of 167.74l/s. Domestic use yielded an amount of 2.08l/s, assuming all the 1200 farmers had a family of about six people and the sum of both was approximately 170l/s. This value is much more greater than the authorized amount by WRMA which is 28.125l/s.

I therefore used the authorized discharge of 28.125l/s to design my diversion weir. This discharged helped in selection of pipe sizes to be used as off take pipes. To satisfy this demand, I used two 400 mm pipes at intake chamber for off take and a 150 mm pipe for scour. All the pipes were galvanized steel. To ensure that all the farmers got water equally, the calculated amount was divided into six parts and each part was allocated about 8 hours of irrigation after each and every day.

The designed weir was checked for stability by calculating the moments about the toe and it was found to be stable against water pressure, silt pressure, uplift and overturning. It was however not safe for against sliding and therefore a key with dimensions of 0.08m by 0.091 meter was to be included in the design.

The bill of quantities revealed that about 1.786 million shillings will be needed to construct the designed weir.
7.0 CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

The objectives of the project were met since I was able to identify a site suitable for the weir construction, dimension the weir whose calculations revealed it was stable, calculate and come up with the scheme demand hence make recommendations on how farmers are to share the water and calculate and come up with a bill of quantities.

7.2 RECOMMENDATIONS

The calculated water demand was approximately 170 l/s whereas the authorized amount by WRMA is 28.125l/s. The calculated amount was however based on the assumption that all farmers were irrigating at the same time, 24 hours a day.

I therefore recommend that this amount be divided into 6 parts. Three of the parts will be irrigating same day for 8 hours each then skip a day for the remaining fields. This will ensure that each farmer gets water as is desired.

I also recommend that the following activities will be carried out by the farmers regularly to ensure that the scheme is in proper condition to serve the intended purpose:-

- Flush out the accumulated silt
- Stir up the accumulated silt
- Clean the trash screens
- Grease the movable metal parts
- All the concrete and steel parts with defects should be repaired
8.0 REFERENCES


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