MALAWI GOVERNMENT

DEPARTMENT OF LANDS, VALUATION AND WATER

GRAVITY FED
RURAL PIPED WATER SCHEMES

Design Engineer's Manual

REPUBLIC OF MALAWI

GRAVITY FED
RURAL PIPED WATER SCHEMES

Design Engineer's Manual

DLVW

FOREWORD

It is now widely recognised that a good water supply is one of the vital factors in the advancement of rural communities in the developing world.

It is also the participation of the Community in the process of solving their own problem, which ensures the success of the project and develops local responsibility.

This Design Engineer's Manual and the Rural Water Operator's Handbook, which goes with it are a record of the techniques which have evolved out of experience in the development of Self-Help piped water projects in Malawi over the past 16 years. First written in 1977, it has been revised and re-structured in 1983. It has been compiled for the guidance of engineers who design Gravity Fed Rural Piped Water Systems.

CONTENTS

Design of Gravity Fed Rural Piped Water Projects

Outline

There are three major steps in the design of the Gravity Flow Rural Piped Water Projects.

1. **Preliminary Report:**

   This is drawn up in response to a specific request. Using data available in the design office, and a site visit, the engineer puts together this overall view of the proposed projects. The Preliminary Report will be used to judge the feasibility, and priority status of the project.

2. **Preliminary Design:**

   Using data gathered in the Preliminary Report, along with aerial photographs, topographic maps, and census information, the engineer lays out the design in detail.

3. **Final Design:**

   Until this point the project has existed only on maps and photographs. To complete the Final Design, the engineer takes the Preliminary Design into the field, to inspect and survey critical sections, adjusting the Preliminary Design as necessary.

1. PRELIMINARY REPORT

Introduction:

The Preliminary Report serves as a basis to judge the feasibility, and priority status of a proposed project. The information included will be used in the Preliminary Design. (This is particularly true of the site visit data). The following is an outline for the report, it represents the minimum amount of information which should be compiled. Other relevant facts and comments should be included, unique to each individual project.

1.1 Sources of Information:

1.1.1 Topographical Maps of the Area; 1:50,000:

These maps are available in the design office. Additional copies can be purchased from the Department of Surveys.

D.O.S.	D.O.S.
P.O. Box 120	P.O.Box 349
Lilongwe	Blantyre.

1.1.2 Aerial Photographs:

These are optional at this stage of the design, however they do provide some insight into the project area, and they will be essential in later design stages. A nationwide set of aerial photographs is kept at the D.O.S. in Blantyre, and another set is at the Land Husbandry office in Capital City, Lilongwe. Either of these can be used for consultation. Photographs can be ordered from the D.O.S.in Blantyre. When ordering photos it should be kept in mind that these are overlapping for stereoscopic viewing.

An order for one set provides enough photos for two project layouts. Normally two complete sets are ordered. These are then used as: office copy, field copy, field office copy, and a final fair copy, which is handed over to maintainance when the project is commissioned.

1.1.3 Census Maps and Census Data Books:

Maps and books are available in the design office. Additional copies of either can be purchased from the National Statistical Office.

N.S.O.
P.O. Box 333
Zomba

1.1.4 Hydrological Data:

Flows are to be measured during a site visit. On most streams this is carried out using a "V" notch weir, as this is the most suitable method for the types of sources employed in the Projects. Dry Season Flow is the most critical measurement here.

1.1.5 Related Projects:

An effort should be made at this point to determine whether or not any other development projects are planned for the proposed project area. This may include intensive agriculture programmes, Rural Growth Centres, N.R.D.P. or D.R.I.M.P. road construction, and any other projects which will effect the construction of the water project, and the eventual consumtpion.

1.1.6 Site Visit:

See the site visit report form.

1.2 Compiling the Data:

1.2.1 Water Quantity:

Possible source streams are identified on the topographical maps. The engineer should compare catchment areas to determine which streams are most likely to give good year round flows. Once possible sources have been located a programme should be made to visit the streams, and measure the flows. A "V" notch weir is normally used for this measurement. Flows should be determined during the driest part of the year. (This is usually October in the south and November in the north). Flow data will then be reviewed by the hydrology section; a 1 in 5 year drought flow will be calculated, this 1 in 5 figure will then be used for design purposes.

Note: When using the "V" notch weir, water should flow freely through the "V", do not allow standing water downstream to impede the flow. Readings are made from the upstream face of the weir. Include date, and accurate description of measurement site, with the flow data.

1.2.2 Water Quality:

Wherever possible intakes should be sited within forest reserves, above all cultivation and habitation. If this requirement cannot be met then some form of treatment will have to be considered. Two measurements are important for determining what type of treatment may be necessary.

The first, a bacteriological analysis will provide and indication of the level of pathogens. (Normally faecal coliform is measured directly). The second test, a turbidity analysis, helps to determine the type of pretreatment necessary.

1.2.3 Project Area:

1.2.3.1 Topographical Considerations:

The elevation of the intake, and the terrain of the retriculation area are the overriding Factors in determining the extent of the project area. Lack of a suitably elevated and protected source, or steeply undulating terrain are both limiting factors on the eventual size of the project. Large rivers, or ridge lines often serve as natural borders for the project. The topographical maps are useful in identifying any of these physical boundaries.

1.2.3.2 Population:

The number of people who can be served by the project, is another limiting factor. The current population of a proposed project are can be obtained from census information. The design population, is a projected population, based on either agricultural potential, or on estimated growth rates. (See population section in Preliminary Design).

1.2.3.3 Political Boundaries:

Local communities are organized under both Traditional Authorities, and District Government. These organization structures are used for the coordination of the self-help work. It is important to take into consideration both T.A., and District boundaries when determining the project area.

1.2.3.4 Existing Projects:

The boundary of an existing project makes a very suitable boundary for a new project.

1.2.4 Existing Water Supply:

Where do people find water currently? Is there a great deal of travel involved in collecting water? What is the quality of the water? Is it perennial? These questions can best be answered after a site visit. The answers will be used in assigning priorities to the project.

1.2.5 Local Enthusiasm:

This may be difficult to gauge in some cases, however, if the people know of nearby projects, it is not unuaual for them to be extremely eager to start their own project.

1.3 Submission of Report:

The Preliminary report should be assembled in the following order:

1. Identify the project. (Project name, district)
2. Nature of project request. (D.D.C., inter departmental).
3. Area to be served. (Attach map with boundaries shown).
4. Current population. (Explain how figure was derived).
5. Agricultural potential of land, people/sq.km. arable land.

6. Potential population of project area. (Ag. pot. x arable land)
7. Area growth rate estimate.(National Stat. Office).
8. Include complete site visit report form.
9. Further investigations necessary.
10. Comments and recommendations.
11. Name of person compiling report and date of submission.

SITE VISIT REPORT

Project:.............
Name:................
Date:................

Intake and Top Section:

1. Map references for proposed intake sites, including alternative sites.

2. Type of intake anticipated: small weir, large weir, rock foundation, infiltration gallery.

3. Pipe routing difficulties: river bed exit, river crossings, erosion hazards, rocky soil, etc.

4. Vehicle access to top section.

5. Stream flows. (Include date and location of measurement point).

6. Flood hazards. (Estimate highest flows).

7. Water quality of source stream. Is there any

chance of upstream habitation or cultivation? Are there heavy sediment loads during the rainy season? If bacteriological contamination is suspected make arrangements for collection of samples and testing.

General Information:

1. What is the general quality of the land? Good or poor agriculturaly? Is a large perecentage of the land unsuitable for agriculture?

2. What are the present sources of water?

3. What are possible alternative sources of water? Are shallow wells feasible? Do existing boreholes provide water year round? Is the borehole water saline?

4. Have there been any population shifts in the past few years?(Shifts which would not show up in the census data or on the aerial photos)

Facilities:

1. What are the road conditions in and out of the project area? Are bridges subject to washouts?

2. Is petrol and diesel available near the project?

3. Locations for stores and offices.

2. PRELIMINARY DESIGN:

Introduction:

In this stage of the design the project water demand is determined; pipe routes and tanks are located; pipes sizes, flows, and tank capacities are calculated. Although this is a preliminary design, subject to final design changes, major alterations to this are seldom necessary.

2.1 Basic Design Criteria:

2.1.1 Normal designs allow for 8 gallons per capita day, 8 g.p.c.d. (36 lcd). In some designs where there is a shortage of water it is possible to reduce this amount to 6 gpcd (27 l d).

Note: The 1981 Centre for Social Research report, on the Rural Water Supply, listed actual average consumption at 3 gpcd (14 lcd).

2.1.2 Design Flow at the Tap:

To simplify design it is assumed that all taps are open, and that the flow at each tap is 1 gallon per minute (gpm) (0.076 l/sec). This is an artificial design assumption, as it is very unlikely that all taps will be open at one time. Hence, actual flows are between 2 and 3 gpm.

2.1.3 Night Storage Factor:

The service time of the systems runs from about 4 a.m., to 8 p.m., a total of 16 hours. This leaves 8 hours when little or no water is drawn from the system. If sufficient storage is available, then inlet flow to a storage tank, has only to eaqual 16/24 or 2/3 of the daytime outlet flow.

2.1.4 Number of Persons per tap:

This number has evolved over the years, and is now fixed at 120 persons per tap. This allows for 8 gpcd to be received from a tap delivering 1 gpm over a 16 hour service period.

2.1.5 Maximum Walking Distance:

The walking distance to a tap should not normally exceed 500 metres.

2.2 Materials Required:

Item	Source
Topographical Maps	D.O.S.
Aerial Photographs	D.O.S.
Census Maps and Census Books.	N.S.O.
Graph Paper and Dividers	Design Office
Felt Pens and Flow calculators	Design Office

2.3 Villages and Population:

2.3.1 Villages:

A list of all villages in the proposed project area should be drawn up using the census data.

2.3.2 Existing Populations:

For each of the villages listed, determine the latest census population. The current population can then be found by applying an annual growth rate, for the years between the census and the present year.(Annual growth rates for each district, are listed in the

Malawi Census Final Report).

2.3.3 Potential Population:

This is the population which can be supported by subsistence farming. The Ministry of Agriculture provides figures for this. These are typically in the range of 100-300 persons/km^2 of arable land.

2.3.4 Design Population:

The design population is the population to be served, (at design consumption) 20 years from the design date. This may be either the agricultural potential population, or a projected population, found by applying a growth rate to the current population. Normally the agricultural potential figure is used; however, in sparsely settled areas the growth rate figure may be more applicable.

2.3.5 Village Design Population:

In order to obtain a village by village design population, the current population of each village should be multiplied by the ratio (total design population/total current population). This will give a design population for each village.

2.3.6 Water Demand:

From the total design population, the total water requirements of the project can be determined.

2.3.7 Aerial Photographs:

It is useful at this point to mark the village names onto the aerial photos. (Use blue felt tip).

Note: Colours are specified for standardization.

2.4. Tap Locations:

2.4.1 Define Areas:

Instead of trying to plot each tap individually, it is better to define an area of 5 to 10 villages, and determine the number of taps which should be in that area, according to the village design populations.

Note: The census enumeration areas are often useful for this purpose. These areas have well defined boundaries, (streams or rivers) which are easily found on the aerial photographs.

2.4.2 Population Concentrations:

Within each of the areas defined, the population concentrations should be picked out and circled. (Brown felt tip). These concentrations can be identified by locating groups of huts. A magnifying glass or streoscope is useful.

2.4.3 Tap Allocations:

In the design it is best to allow for 110 persons/tap. This will leave 10% of the taps unallocated. The excess will be used to fill the numerous requests which are received once a project starts.

2.4.4 Tap Siting:

Knowing the number of taps allocated for a given area, the Engineer can begin to place taps within the larger population concentrations, combining the the smaller concentrations to share a tap. If a school, health centre, or other institution is in the area, they will be allocated one tap each.

In sparsely settled regions the 500 m criterion should be kept in mind. In low density areas site taps at potential growth points, such as road or path junctions.

Note: Taps should not be sited too close to rivers or dambos.

2.4.5 Plot Tap Sites onto Photos:

When the tap site has been chosen, it should be marked with a distinct red dot.(Red felt tip). The circles around the population concentrations should then be removed. (To remove felt tip ink use methylated spirits and a cloth).

2.4.6 Final Decision on Siting:

The site selection at this stage is preliminary. The villagers will make the final decision on siting. However, careful planning will minimize later changes.

2.4.7 Transfer Taps to Topographical Map:

Once all the taps have been located on the aerial photographs, the tap positions should be marked on the topographical maps. This is a tricky process, and should be done with care. Using the same small areas, which were used to site the taps originally, may be helpful.

2.5 Alignment of Pipelines:

2.5.1 Study the Map:

The Engineer should familiarize himself with the topographical map of the project area.

Ridge lines should be found and followed, large streams and rivers located, and roads in the area should be noted. It is useful to have all these in mind when making alignment decisions.

2.5.2 Criteria for Alignment:

1. Wherever possible lines should be sited on ridges.
2. Minimize the length of piping.
3. Lines should be near to roads when possible.
4. Avoid numerous river crossings.

2.5.3 Joining the Dots:

Keeping in mind the alignment criteria, the dots which represent taps should be joined together. (use pencil). Small lines will lead away from taps towards branchlines, which in turn lead back to larger branchlines, and eventually to mainlines. This begins to resemble a tree with the mainline as the trunk, and the branches leading out to the leaves (taps).

2.6 Tank Sites:

2.6.1 Purpose of Tanks:

1. Break pressure on section of pipeline. (Break pressure tank)
2. Provide storage for night flow.
3. Divide project into independently manageable areas.
4. Control of mainline outflow. (Branch tanks).
5. Sedimentation, or other treatment.

2.6.2 Locating Tanks:

2.6.2.1 Height Over Service Area:

Overall gradient should be between 1:100 and 1:300.

2.6.2.2 Outlet Gradient:

This is an important factor. The outlet gradient from the tank must be steep (1:50 minimum). If the area around the tank is not steep, then the tank should be built above the ground.

2.6.2.3 Break Pressure:

If the tank is to act as a "BP" then the elevation will be determined by the pipe pressure. The overall inlet and outlet gradients, must still be adequate though.

2.7 Calculating the Flows:

2.7.1 One Gallon per minute:

This is where the design assumption that all taps are are open, and deliver 1 gpm becomes useful. Starting from the last tap on a branchline write the flow in each section of pipe, (See sketch G-1) all flows have been shown for the sake of example. When designing omit small flows, showing only the total flow in the larger branches. On branches with 10 or more taps, add 10% to the flow to allow for later tap allocations.

2.7.2 Flows into and out of Tanks:

2.7.2.1 2/3 Storage Factor:

From sketch G-1 the flow into branch "A" is 15 gpm. Usually on a branch of this size a tank would be sited at the head of the line, as shown in sketch G-2. The flow out of Tank "A" is still 15 gpm, but the flow into the tank, only has to be 2/3x15 = 10gpm. This is due to the night storage capacity of the tank.

2.7.2.2 Tanks In Series:

In sketch G-3 a mainline tank T1 has been shown. The flow downstream of branch "A" has been given as 15 gpm. The flow out of T1 will be 10 + 15 = 25gpm. It would be incorrect to calculate the T1 inflow as 2/3 x 25; this would not take into account the fact that the 10 gpm into tank "A" is a 24 hour flow. The proper calculation is (2/3 x 15) + 10 = 20 gpm.

2.7.3 Tank Size:

The tank size is determined by multiplying the tank inlet flow by the 8 hour night storage time. In sketch G-3, tank "A" has an inflow of 10 gpm. The capacity would be calculated as 10 gpm x 60 min/hr x 8 hours this comes to 4,800 gallons. The next standard size above this is 6,000 gallons. (Standard sizes are 50,000; 30,000; 20,000; 15,000; 10,000; 6,000; and 3,000 gallons).

2.7.4 Totalling Flows:

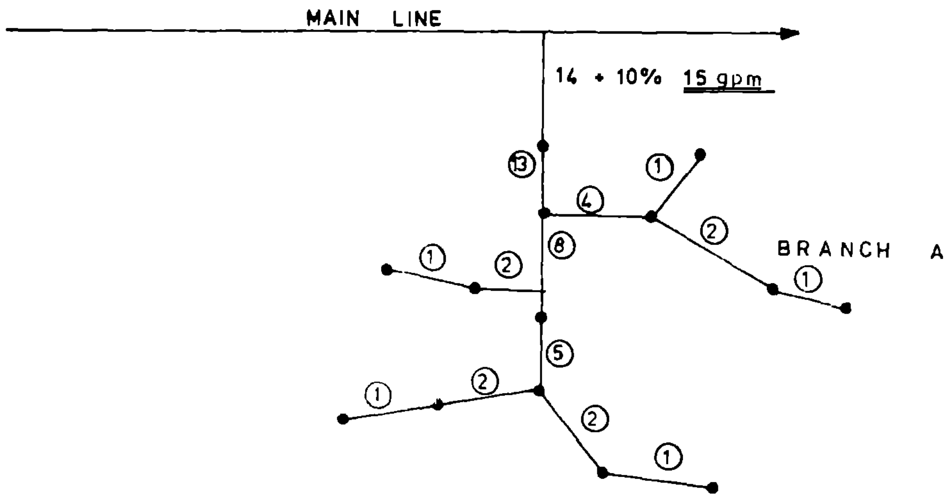
By working back up to the intake or header tank, all the flows in the system can be found. Remember to apply the 2/3 factor where applicable and to add 10% extra flow for additional taps.

2.8 Design of Mainline:

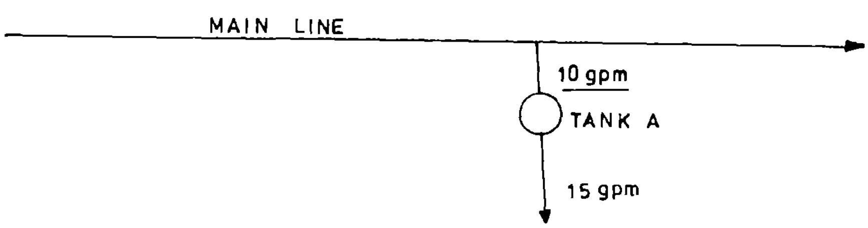
2.8.2.1 Proper Gradient:

The header must be high enough to provide an adequate gradient down to the next tank on the line.

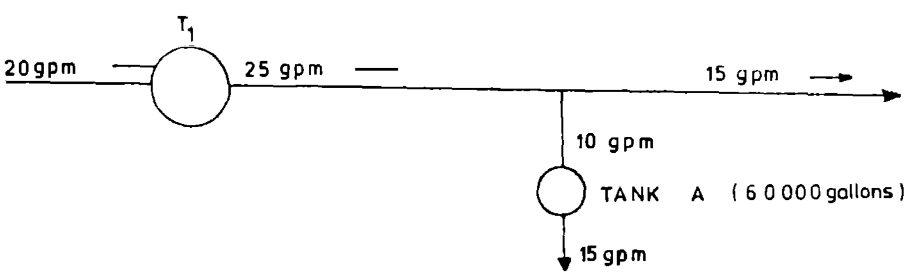
SKETCH G—1



SKETCH G—2



SKETCH G—3



2.8.2.2 Maximum Static Pressure:

The static pressure at the lowest point of the pipeline must not exceed the limits of the piping.

Note: Pressures are allowed to exceed rated capacities by up to 50% for short sections of pipeline.

2.8.3 Plot Ground Profile:

On 1mm:1mm grid graph paper, plot the cross sectional elevations of the proposed pipeline. Horizontal scale should be 1:50,000; vertical scale should be 1:1,000. (Since the map elevations are in feet it is best to show both feet and metres on the vertical scale). The profile can be drawn by using dividers to measure the horizontal distance between contours, plotting a point each time the pipeline crosses a contour line. Notations should be made at all stream and road crossings.

2.8.4 Static Head:

Draw a horizontal line at the elevation of the header tank. This represents the static pressure. Indicate the point of maximum static pressure.

2.8.5 Estimate Pipe Sizes:

On the first segment of mainline (From header tank to mainline tank, or major branchline) determine the overall gradient. (See sketch H-1) From table H-2, estimate the pipe size necessary to provide the proper flow. If a 1:200 gradient is found for the segment of mainline, and if the required flow is 90 gpm, then from table H-2 it can be seen a class 6 pipe of 110mm is too small, and a class 6 125 mm is too large.

A combination of these two sizes will produce the proper flow. (Sketch H1)

2.8.6 Calculate Head Losses and Plot Hydraulic Gradient:

From the estimate made using table H-2 the engineer has an aidea of the pipe sizes necessary. In sketch H-1, it was estimated that a combination of 110 mm and 125 mm, would provide the proper flow. To determine the exact lengths of each size, the Engineer chooses an arbitrary length of 125 mm (perhaps half the total section length), and calculates the head loss through that length, at the design flow (90 gpm). The remaining length of the section would be 110 mm, so the engineer calculates the head loss for the 110 mm. Summing the two head losses, the engineer compares the total head loss with the desired loss. If the calculated loss is too high, then the 125 mm section is lengthened, if too low then the 125 mm is shortened. This process is continued until the calculated loss, matches the desired head loss. When the proper proportions have been determined, the hydraulic gradient is plotted. In lines where there are many small branches, the flow in the main can be averaged. If a branch has a flow of more than 3 gpm, then that branch should act as an end to a calculation section. Often the mainline will reduce in size, at a branch of of this nature.

Note: Flow calculations are normally made using a pipe flow calculator. (Similar to a slide rule). Standard Forms for head loss calculations are to be included in the preliminary design submission).

2.8.7 Available Piping:

2.8.7.1 P.V.C.:

P.V.C. piping is available in the sizes listed in in table H-2. Pressure class 10 (10 bar working pressure), is always used for pipes of 63mm and smaller. For larger size pipes, class 6 can be used if the pressures allow. (Standard classes are 6,10, and 16; however it is possible to specify a class; e.g. class 8, if the order is large enough).

2.8.7.2 Asbestos Cement:

A.C. piping was used in the past, but will probably be superceded in the future, as P.V.C. becomes available in larger diameters. For details on A.C. piping see manufacturer's specifications.

2.8.7.3 Galvanised Steel:

Steel piping is used in exposed sections of line. Steel is available in: $\frac{1}{2}$", $\frac{3}{4}$", 1", $1\frac{1}{4}$", $1\frac{1}{2}$", 2", $2\frac{1}{2}$", 3", 4", 6", all other sizes must be special ordered.

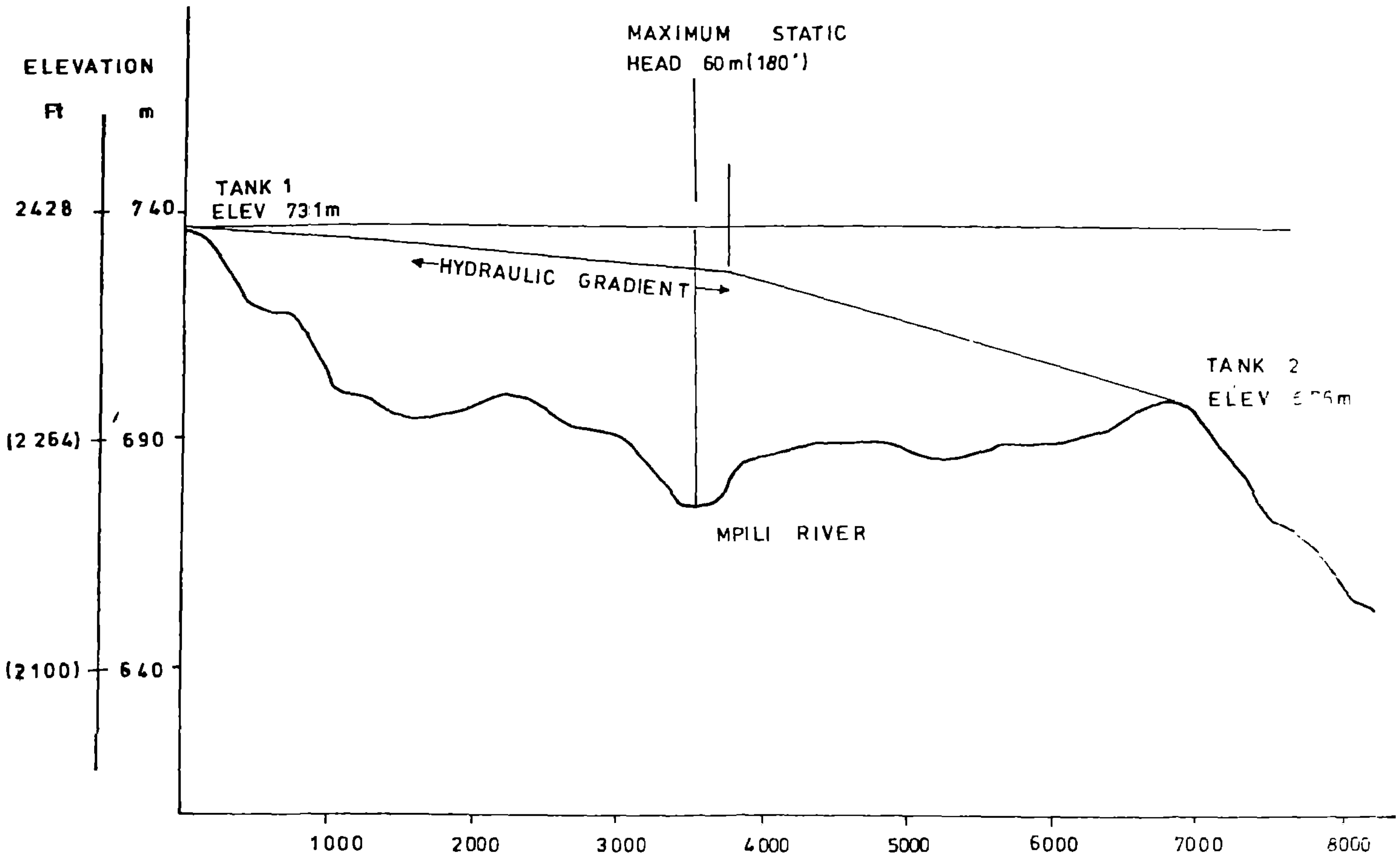
2.8.8 Complete Mainline:

Carry through this process for every segment of mainline. Developing profiles for the entire main.

2.8.9 Branchlines:

2.8.9.1 Label Branches:

On the topographical map, label all "major" branchlines with a letter. Start labelling with "A" and continue through the alphabet. (Major branchlines are those with 10 or more taps).



GRADIENT T1 TO T2 = 1 . 200 ($\frac{35}{7000}$)

ELEVATION LOSS TO T2 = 35 0m (115')

125mm CLASS 6 - 2700m

110mm CLASS 6 4300m

TOTAL LENGTH 7000m

FLOW	90gpm (6 8 1/s)	
PIPE SIZE	125mm CLASS	110mm CLASS 6
LENGTH	2700m	4300m
	1000 2000 3000	4000 5000 6000 7000

LANDS VALUATION & WATER DEPT MALAWI
RURAL PIPED WATER SECTION

EXAMPLE
MAIN LINE
PRELIMINARY DESIGN

2.8.9.2 Ground Profile:

For each major branch, a ground profile should be drawn. This is to the same scale as the previous mainline profile. The starting elevation should be the elevation at the branch from the main. If the branch has a tank at its head, then the profile should show the feeder from the main to the tank.

2.8.9.3 Hydraulic Gradient:

The hydraulic gradient does not start at the ground elevation, for branches from mains. The H.G. is equal to the head in the main at the branch take-off point.

2.8.9.4 Pipe Sizes:

This process is similar to the mainline design process. The engineer should note the elevations of the highest taps, so that the H.G. does not fall below these elevations.

2.8.9.5 Pressure at Taps:

The hydraulic gradient should be designed to descend to the tap elevation when the flow is 1 gpm.

Note: The headloss over the tap unit is negligible at the design flow.

2.8.9.6 Small Branches:

For branches with fewer than 10 taps, the pipe size calculations can be done without profiles. The calculations should take into into account the elevations of all the taps, and also any pronounced topographical features. Normally the final pipe size into the tap is 20 mm.

2.8.10 Marking the Pipe Sizes:

2.8.10.1 Map and Aerial Photos:

The pipe sizes are indicated on the maps, and aerial photographs, by showing the pipelines in various colours. These colours are the primary source of pipe design information for the construction personnel. The following list is the standard colour code.

Yellow	140 mm & Above	(Indicate the pipe size and class along side the pipeline for all pipes)
Pink	125mm	
Light Blue	110mm	
Light green	90mm	
Brown	75mm	
Red	63mm	
Blue	50mm	
Green	40mm	
Orange	32mm	
Purple	25mm	
Black	20mm	
Pencil	12mm & 16mm	

Note: It is important to list the pipe size and class along the pipeline, so that plans can be photocopied without any loss of information.

2.8.10.2 High Pressure Taps:

Many taps are located near to mainlines, if, as usually the case, these mains are of high pressure, then the pipeline to the tap must be designed to limit the flow.

The selection of piping for these taps, is made by the construction Engineer, after the tap has been sited in the field. For ease of identification of these high pressure taps, the design engineer should make a red circle around the red tap mark.

2.8.10.3 Tank Information:

Tank names, elevations, and capacities, should be marked on the maps aerial photographs, and profiles. On the maps and photographs, use black felt tip for the name and size, and brown for the elevation.

2.9 Siting of Control Fittings:

2.9.1 Air Valves:

These are three types of air release valves used on the Rural Piped Water Projects. These are : cast iron double, and single valves, and P.V.C. single air valves. A single air valve has a float, and a small orifice, which will release air while the pipe is under pressure. (They do not release much air when the pipe is filling or emptying). The double air valve, which purges high volumes of low pressure air during filling and draining. The P.V.C. single air valve was developed by the rural water section, as a cheap, easily procured substitute, for the expensive cast iron valves. The following is a list of siting criteria for air valves.

1. All pronounced high points.
2. On A.C.lines a double airvalve every 3km
3. 110 mm P.V.C. and above a single air valve every 3 km.
4. Every abrupt change of gradient.
5. It is possible for a tap to act as an air

valve if it is sited close to, and above the main pipe.

6. Not all air valves can be sited at this stage, extras should be ordered to allow the construction engineer some flexibility.

2.9.2 Sluice Valves and Gate Valves:

For large diameter pipes (greater than 100 mm A.C. or 110 mm P.V.C.), sluice valves should be used. Smaller diameter pipes use gate valves. The sluice valves and gate valves, are both marked with a green cross with a circle around it. (Green felt tip.) Siting criteria are:

1. Tanks, inlets and outlets.
2. Before reducers.
3. On mains immediately down stream of major branches.
4. At the head of all branchlines.
5. On pipes 50 mm and smaller, there should be a valve every 3 km.

2.9.3 Flush Points:

At all significant low points on the main lines, a flush point should be sited. This is normally a "tee" leading to a short 3" steel line, controlled by a 3" gate valve. (See sketch in Final Design).

2.9.4 Float Valves:

These are installed on the inlets tanks, where the flow must stop when the tank is full. Headloss over float valves should be accounted for

2.10 Compiling Project Requirements:

2.10.1 Piping:

1. A.C. pipes should be listed by both size and class. Required lengths are determined from the maps. Add 3% to account for breakages.

2. P.V.C. pipes should be listed by both size and class. Lengths are determined from the maps. Add 3% for all sizes 40 mm and above; 10% for 32 mm; 20% for 25 mm; 30% for 20 mm.

3. Steel pipes are used on all exposed sections. Estimate lengths required for top section and river crossings.
   Label this list as an estimate.

2.10.2 Fittings:

1. A.C. fittings; i.e. hydrant tees, short collar or gibalt joints, flange adaptors, saddle pieces, should all be listed. (See sketch K-1 for descriptions and usage).

2. P.V.C. fittings; i.e. tees, reducers, and adaptors. See sketch K-2.

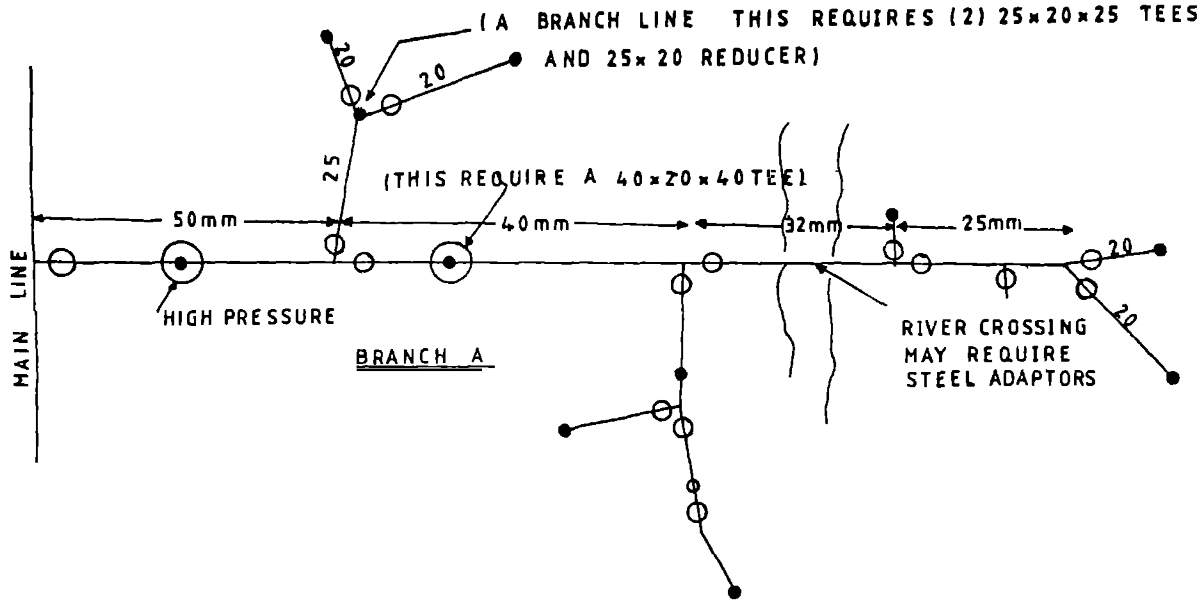
3. Sluice Valves should be tallied, and listed according to size.

4. Gate Valves should be tallied and listed.

5. Tank fittings should be tallied both for each tank and overall. See sketch K-4.

6. Other fittings; i.e. intake and river crossing connectors should be listed.

P. V. C. FITTINGS K - 2



BRANCH A FITTINGS (P V C)etc

REDUCED TEES

50 × 20
50 × 25
40 × 20
40 × 32
32 × 20 111
25 × 20 111

M/F ADAPTORS
(GATE VALVES 2 EACH, STEEL SECTION)

50mm × 1½" — 2
40mm × 1¼ — 2
32mm × 1" — 6
25mm × ¾" — 6
20mm × ½ — 28

REDUCING BUSHES

50 × 40 1
40 × 32 1
32 × 25 11
25 × 20 ~~1111~~

F/F ADAPTERS

20mm × ½ — 14 EACH TAP

TAP UNITS (STAND PIPE) — 14

TAPS — 14 (W/SPARE RUBBER)

GATE VALVES

1½" (50mm) 1
1¼" (40mm) 1
1" (32mm) 11
¾" (25mm) 111
½" (20mm) ~~1111~~ ~~1111~~ 111 (EACH TAP)

2.10.3 Civil Works:

Civil works at the projects should be outlined in the following manner:-

1. List all tanks and their respective sizes.
2. Estimate number of houses or offices to be constructed.
3. List the plant (machinery) required; i.e. cement mixers, vibrators, and rock drills.

2.10.4 Personnel Requirements:

Estimate number of supervisors, and water operators needed, for each phase of construction. Also list number of builders required.

2.10.5 Transport:

Estimate the transport requirements for the project. This should include the number of weeks required for each type of vehicle. (Pipe carriers, flat beds, tippers, land rovers, pick-ups, motor cycles).

2.11 Submission of Preliminary Design:

The following is a check list for submission of the Preliminary Design.

1. Project Population:

   List both current, and design populations. Include calculations.

2. Villages:

   List all villages in the project area. Show current, and design populations for each village.

3. Land Area: Give total project area in km^2. Estimate km^2 of arable land.

4. Population Density: List current, and design populations/Km^2 of arable land.

5. Water Consumption: Give per-capita consumption, for current, and design populations. Also list total project consumption/day.

6. Taps: Give number of taps, as determined by design. (Include the 10% for later allocation).

7. Population/Tap: Show the population/tap, for both current, and design populations.

8. Topographical Maps: Submit completed maps, showing pipe networks and tanks.

9. Profiles: Submit profiles of mainlines, and branch-lines. Include calculations.

10. Lay-Out Plan of Project: This shows lay-out of tanks, and their relation to each other. On lines connecting tanks show design flows. Indicate tank capacities and elevations.

11. List of Piping Requirements: Separate sheets for A.C., P.V.C., and steel piping required.

12. Fittings:

    1. A.C.fittings.
    2. P.V.C.fittings list. (Use form if available).
    3. Sluice valves.
    4. Gate valves.
    5. Air valves, double and single, cast iron or P.V.C.

6. Float valves.
7. Other fittings; i.e. puddle flanges, unions, "V-J" joints.

Note: These fittings include requirements for for tanks, etc.

13. Tanks: List all tanks, include name, size, and elevation. Also calculate total project storage capacity.

14. Houses and Offices: List all proposed houses, and offices to be built. Include location, and purpose of structure.

15. Plant: List requirements.

16. Personnel: Give estimated requirements.

17. Transport: List vehicle weeks required for each type of vehicle.

Note : A detailed transport schedule is required, when actually ordering vehicles.

3. Final Design:

Introduction:

After a project has been approved, the project engineer and his staff, move into the field to begin construction. It is at this point, that the engineer finalizes the design.

There is an enormous amount to organize, in the first few months of a project. However, it is important to allocate time, early on, to complete the final design. Without this, it is likely that progress will be slowed, or that work will be done incorrectly. It is very discouraging for people to excavate at a tank site,only to be told that the site is wrong, and that they have to re-excavate somewhere else. A poorly planned project, has very little chance of maintaining a high level of self-help enthusiasm.

There are five major tasks to complete for the final design.

3.1 Intake and Top Section	Site, Mark, Survey Design.
3.2 Mainlines to Tanks	Mark, Survey, Site Tanks and River Crossings.
3.3 Other Critical Sections	Mark, Survey
3.4 Air Valves, Flush Points, and Mainline Valves	Site, Design.
3.5 Revise Preliminary Design.	

Note: These have been listed in a typical order of priority. (Most projects begin work on the top section).

3.1 Intake and Top Section:

3.1.1 Elevation of Header Tank and Intake:

The Preliminary Design specifies a design elevation for the header tank, this elevation must be established on the ground by levelling. Once the proper elevation has been found, a suitable tank site should be located. (See tank siting 3.2.2). If the chosen site is slightly above, or below, the design elevation the new elevation should be recorded. From the chosen site for the header tank, the survey should continue on to the source stream, the same elevation as the header tank should be found in the stream. A good gradient for the intake-header tank pipeline is 1:50. Knowing this and knowing the distance from the header tank to the stream the engineer can calculate the minimum elevation for the intake. The survey should continue up the stream to locate this minimum elevation.

Notes on Surveying:

The Preliminary Design elevations, are based on contour information from the topographic maps. For the siting of tanks, and intakes, this information is not accurate enough. The relative heights of the intake, and tanks, are determined from surveys. Although the design of the system only requires relative heights, it is seldom that an entire project is surveyed. At some point the surveyed lines must tie back into the map contours. For this reason it is best to start survey from existing bench marks, so that all surveyed elevations are based on the same datum as the map. Bench-marks are located along most main roads (M & S class).

The BMs are indicated on the maps with a small arrow, and a notation such as C9/M/5. The 1:50,000 maps show only every fifth BM. Benchmark elevations, and locality sketches, can be obtained from the D.O.S. If no benchmarks can be located in the area, then the survey should start from a point, where the contour elevation can be read accurately; i.e., where a contour line crosses a road junction or stream crossing. All surveys to tanks should be closed.

3.1.2 Siting the Intake:

Starting from the minimum elevation, which was determined by surveying, the engineer should move upstream looking for a possible intake. The following criteria should be considered:-

1. Will adequate dry season flow pass the site? Does some flow go through other channels or below ground?

2. Is there a natural formation, which will accommodate a small intake structure?

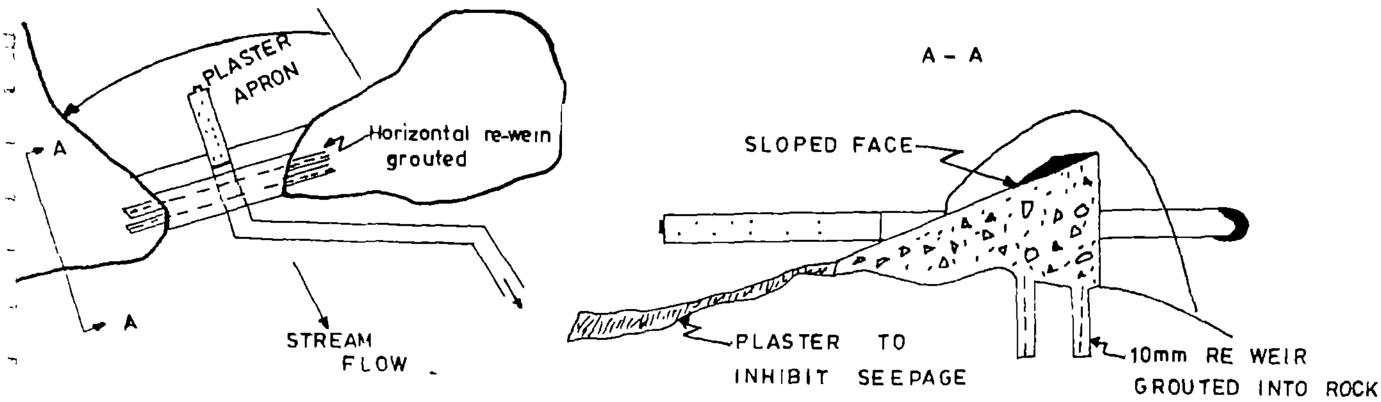
3. Can the pipe leave the stream bed immediately downstream of the intake? Are the pipes going to be exposed to the force of flood flows?

4. Is there a good foundation into which to key the intake? Will there be seepage under, or around the intake?

A perfect intake will never be found. Compromises must be made, to provide a reliable flow at a reasonabl cost.

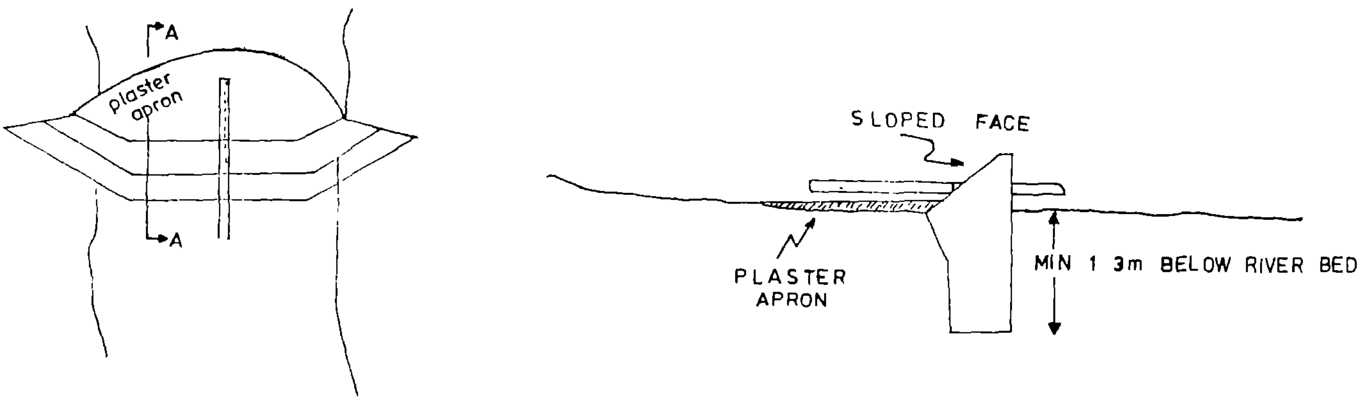
— L – 1 —

INTAKE WEIR WITH ROCK FOUNDATION



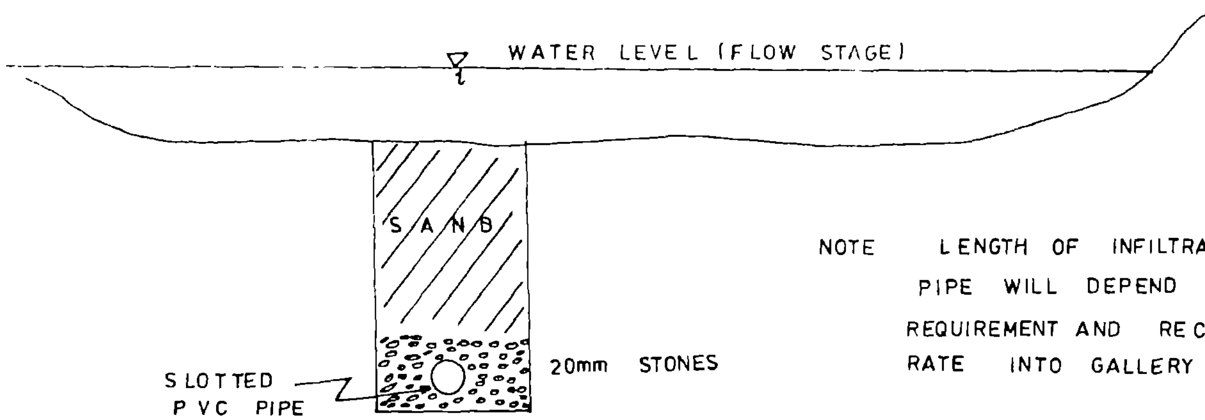
— L – 2 —

INTAKE WEIR WITHOUT ROCK FOUNDATION



— L – 3 —

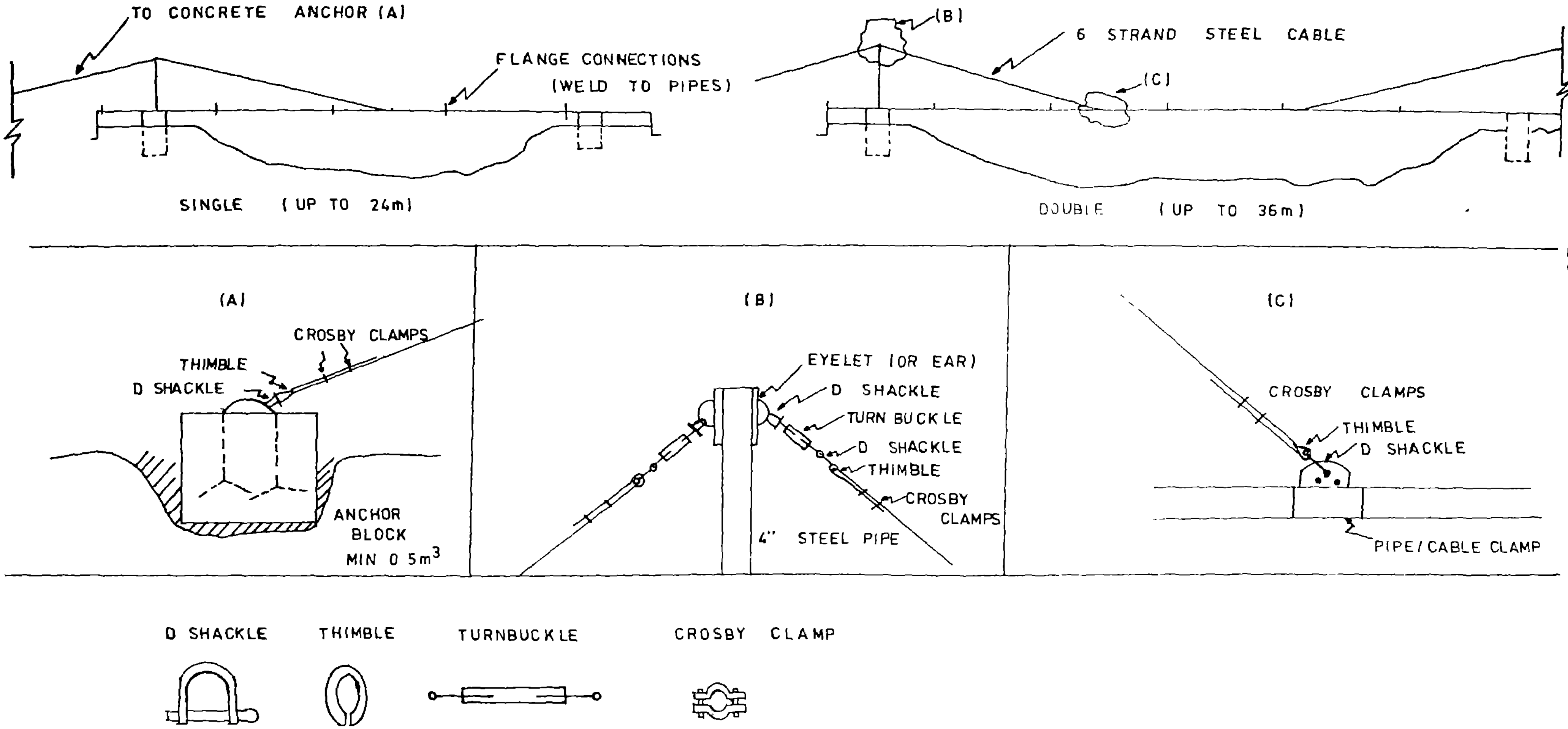
INFILTRATION GALLERY



NOTE LENGTH OF INFILTRATION PIPE WILL DEPEND ON FLOW REQUIREMENT AND RECHARGE RATE INTO GALLERY

CABLE CROSSINGS

NOTES MAXIMUM SPANS ARE BASED ON MAX 12m SPAN WITHOUT VERTICLE SUPPORT



3.1.3 Design of Intakes:

3.1.3.1 Rock Foundations:

The best intake is a small intake! If a natural weir can be found, it should be used, adapting it as necessary. Usually a small concrete weir is built. This should be keyed into the rock. The upstream side of the weir should be sloped at about 60° to create a scour effect. (See sketch L-1).

3.1.3.2 No Rock Foundation:

If a suitable rock foundation cannot be found, then the weir should have a 4' (1.3m) deep foundation below the river bed. Also an apron should be constructed upstream, extending from the weir about 6' (2m). (See sketch L-2).

3.1.3.3 Infiltration Gallery:

In streams carrying a high sediment load, it may be possible to lay inlet pipes below the river bed. It is possible in this fashion to ensure flow, even when a conventional intake would be blocked by sediment. (See sketch L-3).

3.1.4 Top Section Line:

The line from the intake to the header tank is usually the most exposed line on the project. The engineer should take special care when marking out this line. All exposed areas should be steel, with concrete pillars where necessary. Erosion protection measures are essential.

3.1.5 List of Fittings and Pipes:

List all fittings, and pipes, required for the intake, and top section line. (Order all steel bends well in advance of needs).

3.2 Mainlines to Tanks:

3.2.1 Survey Mainlines:

3.2.1.1 Marking the lines:

There are two methods used for marking lines. The first utilizes the aerial photographs, correlating features on the photographs to the actual features on the ground, and using these to guide the route. The second method makes use of a prismatic compass. The bearing of the proposed line is taken from the map, and this bearing is followed throughout the length of the line (or segment of line). Often a combination of these methods works best. For either method the line is marked with pegs placed at 100' (30 m) intervals.

3.2.1.2 The survey:

Chain, and survey, all the mainlines after they have been marked (and cleared if necessary). Chainage markers should be labelled,and placed every 300 m. (These should be semi-permanent, so that they last throughout the construction period. These chainage markers are in addition to the line pegs, which were set out when marking the line).

3.2.2 Tank Site Selection:

The mainline surveys are continued to all the mainline tanks.

At the design elevation, the engineer should look for a suitable site, this site will have: enough level area for tank construction, proper outlet gradient. vehicle access (if possible), and finally the land must be available; i.e., not somebody's garden. If the tank must be moved up or down the new elevation must be recorded on all design materials, (maps, profiles, and photos).

3.2.3 River Crossings:

While marking out mainlines, the engineer should choose where the line should cross rivers. This may involve shifting the line several hundred metres to find a suitable site. The following list gives the criteria, for the various types of crossings.

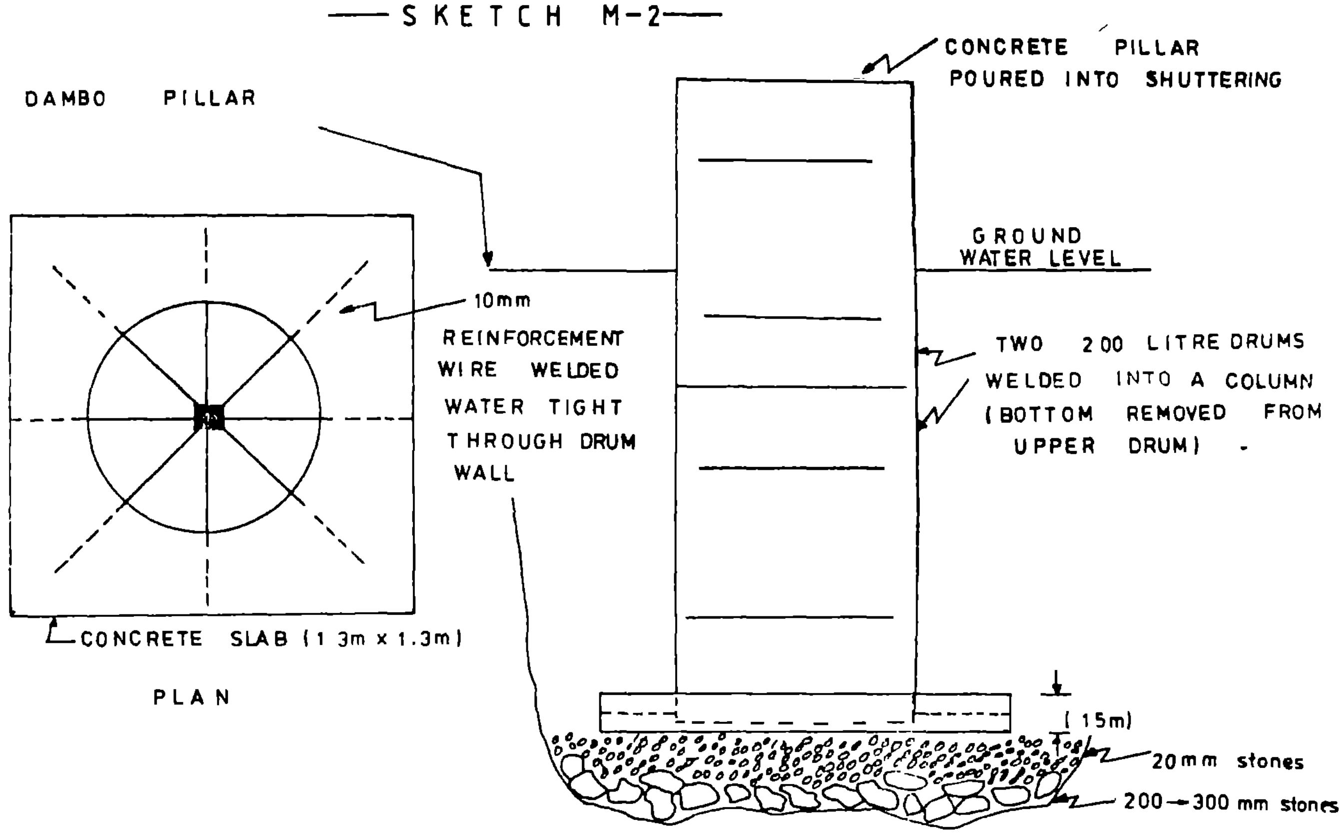
3.2.3.1 Under the River Bed: (Usually the least expensive alternative)

1. Straight river course, little bank erosion.
2. Stable river bed not subject to scour.
3. Bed material of sand or soil which can be excavated.
4. Possible to divert dry season flow for construction.

3.2.3.2 Over River on Simple Pillars:

1. Straight river course, little bank erosion.
2. Solid banks, good foundation for pillars.
3. Short span, 12 m or less. (It is not advisable to have pillars in the river bed).

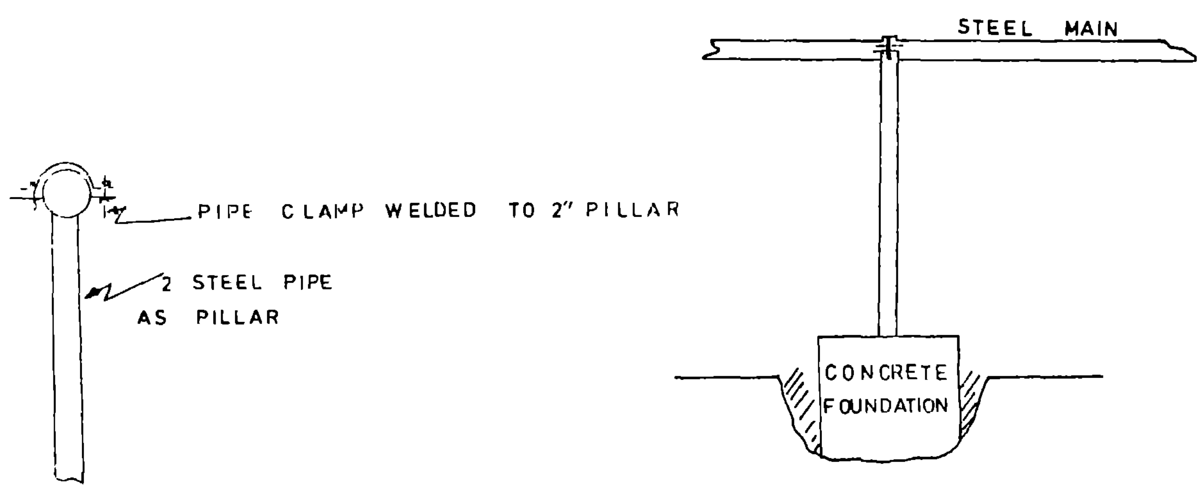
—SKETCH M-2—



THIS DAMBO PILLAR IS USED TO CONSTRUCT CONCRETE PILLARS IN PLACES WITH HIGH WATER TABLES THE DRUMS PROVIDE A WATER TIGHT SHUTTERING FOR THE CONCRETE PILLAR. THE BOTTOM SLAB DISTRIBUTES THE LOAD TO PREVENT SETTLEMENT

—SKETCH M—3—

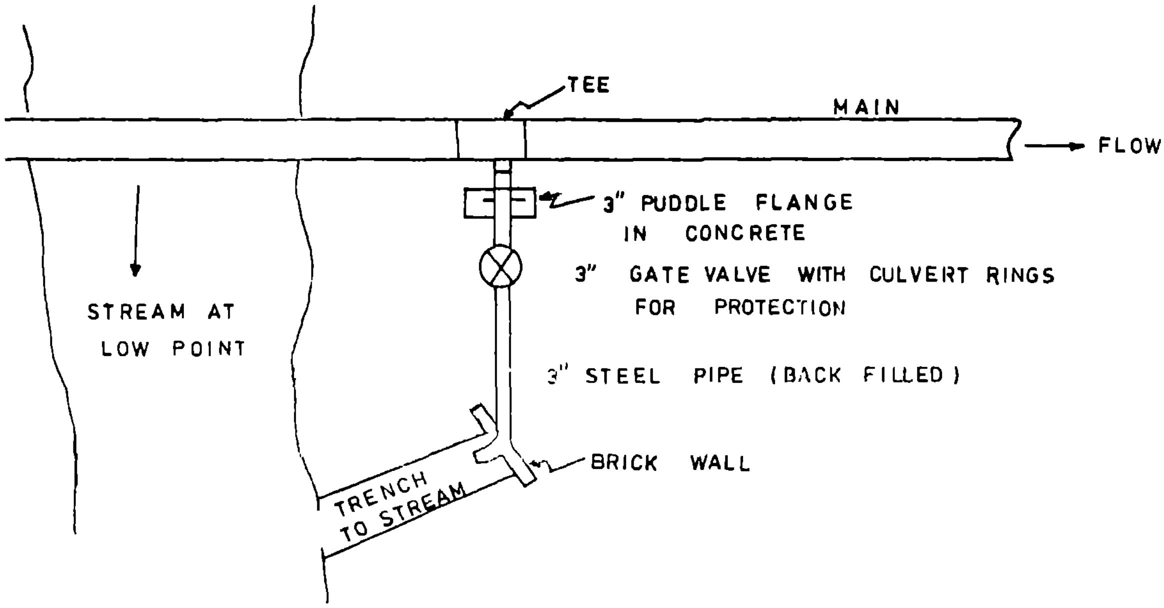
STEEL PILLAR WITH PIPE CLAMPS



THIS ARRANGEMENT CAN BE USED IN PLACE OF A TALL CONCRETE PILLAR ONLY THE BOTTOM (0·7m) NEEDS TO BE CONCRETED

—SKETCH N—1—

LAYOUT OF FLUSHPOINT



3.2.3.3 Over River with Cable Crossing:

1. Straight river course, little bank erosion.
2. Solid banks, good foundation for pillars.
3. Span between 12 and 36 m.

Special designs are shown in sketches M-1, M-2, and M-3.

3.3 Critical Sections of Lines:

In places along the line where the elevation must be known accurately a survey should be carried out. (This pertains to branchlines which were not surveyed previously). The following is a list of some of the places an engineer would want to survey.

1. High pressure points.
2. Low pressure points, where the hydraulic gradient comes very close to the ground.
3. Outlet gradients from tanks should be checked, they should be steeper than 1:50.
4. Any other place, where the engineer feels the accuracy of the topographical maps is not sufficient.

3.4 Site Fittings:

3.4.1 Air Valves:

High points, as determined by the mainline profile, should be surveyed in detail. The engineer should determine the highest point, marking it on the ground, and on his maps and profiles.

3.4.2 Flush Points:

Low points, as determined by the mainline profile, should be marked for flush points. The engineer should sketch how the flush point will lie, showing the location of the valve, flush pipe, and drainage trench. See sketch N-1.

3.4.3 Mainline Valves:

Both sluice, and gate valves, should be sited by the engineer if they are on mainlines. (Branchline valves are usually sited by other staff).

List all fittings required for these controls.

3.5 Revise Preliminary Design Data:

3.5.1 Maps and Aerial Photos:

Show all changes including: pipelines, tank sites, intake site(s), Air valves, and flush point sites. Give date of revision.

3.5.2 Profiles:

Surveyed data should be plotted onto a profile. Show clearly that this profile is a final design and that it supercedes all others.

3.5.3 Fittings List:

Check lists from preliminary design, against those from final design, order to offset any shortages.