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Design Manual

for

Rural Water Supply in Bhutan

Prepared by Diederik Prakke
Contributions by Ugyen Rinzin, Wouter Jan Fellinga, Stephen Peterson, and others
December 1998

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Table of content

Foreword

This manual presents a comprehensive overview of all current technical design issues for rural water supply in Bhutan. Therefore, the content is too wide to cover in one single training program. Rather this manual should be used as a source book in different technical training courses and informal skills upgrading events. The manual may also be used as a reference during design, and for (self-)study to upgrade capacity in the area of technical design and its linkages to survey and implementation. As such the manual is relevant to all technical staff in the RWSS program: The vital linkages to survey and implementation need to be understood by surveyors, masons and plumbers, the normal design and rehabilitation issues by all (D)PHE polytechnic diploma-holders, and the more advanced ('special' design) topics by designers.

Over the years the focus of the RWSS program has shifted from hardware only to both hardware and software, and in the future PHE shall pay even more critical attention to enhancing sustainable management through working in partnership with communities. However, though it should play a serving role, this trend does not make technology unimportant. The better the technology, the less of a burden the operation and management poses on the communities. Enhanced knowledge and capacity in technical areas are therefore of great importance, also in view of the decentralisation policies of the royal government. To this end this manual discusses both conventional and 'special' designs, and presents a number of exercises in the topics discussed.

It is my sincere hope that this manual will contribute to further improvements in technical quality of the government support to the RWSS program.

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Diederik Prakke
Technical Officer (RWSS)

This Design Manual has undergone limited review and editing, and may therefore still contain unclear explanations, sub-optimal choices, or even mistakes. For these I take full responsibility and apologise in advance.

Abbreviations

BPT	= Break Pressure Tank
CDF	= Continuous Demand Flow (DDD/86400)
CDF_{large}	= CDF multiplied by a factor > 1 (normally 1.5)
CWR	= Clear Water Reservoir, be it a stone masonry tank or an FCR
DDD	= Daily Design Demand
DF	= Design Flow
$DF_{upper} = DF_1$	= Design Flow to upper (first) sub-scheme
DPHE	= District Public Health Engineering Section
FCR	= Ferro Cement Reservoir
FHL	= Frictional Head Loss
FHL_{factor}	= Frictional Head Loss Factor in m/100m (= cm/m)
HDP	= Head Density Polyethylene, the most common pipe material
HGL	= Hydraulic Grade Line, line representing the residual head in a ground distance – elevation diagram
GI	= Galvanised Iron, pipe material used in structures, rocky areas, and gully crossings
IPT	= Intermediate point (a station in a pipe section)
NF	= Natural flow
$NF_{lower, 20mm}$	= Natural Flow to lower sub-scheme, using a 20mm class V HDP pipe
$NF_{n, 20mm}$	= Natural Flow to sub-scheme n, using 20mm HDP pipe
PHE/HD	= Public Health Engineering Unit, under the Health Division
RH	= Residual Head or Pressure Head
RH_{act}	= Actual Residual Head (not to be confused with calculated RH)
RH_{calc}	= Calculated Residual Head (often erroneously referred to as actual RH)
RL	= Relative Level, the elevation of a point as compared to another
SF	= Supply Flow, the continuous flow to one or more sub-schemes (not to be confused with the safe yield, though the SF -may at the most- be designed to be equal to the SY)
S_{factor}	= Supply Flow divided by CDF
SH	= Static Head (Vertical drop between a point and the above tank)
SY	= Safe Yield
TEE	= Junction in a pipeline
TF	= Tap Flow
TTF	= Total Tap Flow, the flow to all taps

Units

cm	= centimetre
l	= litre
l/(cd)	= litres per person per day
lps	= litres per second
lpd	= litres per day
m	= metre
s	= second

1 Introduction

This manual presents a comprehensive overview of current technical design issues for rural water supply in Bhutan. The objective of the manual is to enhance the sustainability of RWS schemes in Bhutan, through improved design. To this end the manual can be used as a resource book in training course development, as a reference document during actual design, and as a tool for study.
The sub-chapters of this Introduction discuss the main points of attention for design, as well as its critical linkages with survey and implementation. The second chapter presents definitions and hydraulic theory required for the rest of this manual. Chapter three presents normal design, firstly for spring protection (and small stream) schemes, and subsequently (and more extensively) for gravity flow water supply schemes. After this design chapter, follows chapter four with a discussion of some common technical misconceptions, which are particularly relevant to overcome in rehabilitation design.
Chapter five then discusses 'special' designs, designs that differ from current standard design practices Such 'special' designs are relevant to make large or scattered schemes easier to operate and manage, and sometimes to save considerable cost, in schemes which would be practically unfeasible with a normal design. The 'special' designs have been simplified (in comparison to literature and earlier drafts of this document), to minimise critical and complicated features in implementation, but still need more than average attention during construction. As a means to communicate these technical instructions to the implementers an 'Implementation guideline' is proposed.
The last chapter presents a large number of exercises on all subjects discussed in the earlier chapters. Th Annex lists a few suggestions are regarding the content of training courses to further improve design and its linkage to survey and implementation.

1.1 Three main points

In design the most crucial and difficult components are:

1. The **placing of BPT's** (Preventing excessive pressure, to prevent bursting of pipes and wear and leakage of taps)
2. The selection of the **reservoir size** (The required size is much smaller than the total daily demand!)
3. **Pipe size** design (The common practice of over-designing is not only expensive but can also hamper the water distribution. When a major length of pipe is replaced in a rehabilitation, this should not necessarily be designed the same size as before!)

Designing starts after the detailed technical survey is done. In designing it is important that the three issues listed above are well looked into.

1.2 Survey-Design-Implementation linkages

The objective of this Manual is to enhance the design capacity of staff, both for conventional designs and so called special design This, however, is only worthwhile if at the same time survey and implementation are suitable and correct, and in accord with the design Currently the differences between survey, design and implementation are often large.

Therefore, firstly, survey should further improve: The better the survey fits and reflects the physical layout of a settlement, the more appropriate the design can be, and the less reason there is for the implementers to divert from the plan. Secondly implementers need more knowledge when and why following the design is particularly relevant, as well as practical instructions on how to read drawings and implement accordingly. Only then will the full benefits of good design be harvested so that schemes pose the minimal operation and maintenance requirements on communities.

1.2.1 Survey: Accuracy of RL reporting

Often the abney level surveys exaggerate the vertical drop by a factor two. In most cases exaggeration is observed, hardly ever underreporting. This can result in the design of BPT's, that are technically not required, and in the selection of smaller pipes than needed. Several factors may contribute to this over-reporting: Over-reporting of the measured pipe length (which affects the vertical drop calculated later), non-adjustment of the abney level before use, over-reporting of the angle. To overcome these structural problems, survey with both an abney level and an altimeter is highly recommended, whereas re-survey between any two stations is needed if the reported difference in vertical drop between abney level and altimeter is more than 20% (in relative terms) or 100m (in absolute terms). See also Size Pipelines on page 21 and in particular the footnote at the next page.
Other survey issues relate to working in good partnership with communities. Thorough survey meetings or workshops can prevent most requests for additional tapstands, conflicts on tapstand location, and cancellation of tapstands during implementation. So can facilitating higher service levels, which PHE may approve in future. In general, though schemes should be surveyed as small and independent as possible, no beneficiaries should be left unserved between other schemes, unless served by good, private water supply Beneficiaries may be helped in the purchase of good quality spare parts if they want more, or internal water connections. Such facilitation prevents conflict, integrates actual flows in the design, improves the quality of extensions (thus prevent water wastage due to leakage, which could cause shortage), and enhances appreciation, ownership, and good management.

1.2.2 Implementation: Following design

The critical points in design need to be understood by the implementers, so that no harmful deviations from the design are made during implementation. In normal schemes it is often important that especially the higher branch lines in a scheme are not changed for larger ones. If that is done, it becomes very easy for the upper beneficiaries in large schemes to use more water than their share, leaving the other beneficiaries with water shortage. Another important point is the correct placing of BPT's, which is to prevent too high pressures, leading to wearing and leakage from taps, or even the bursting of pipes, and all subsequent technically induced social problems.
In 'special' design schemes the transmission pipeline sizing (that is the pipes above the reservoir(s), is often more critical, and so is the levelling of the reservoirs, especially if the vertical drop between a reservoir and the above tank or intake is little. In such schemes reservoirs and BPT's may also be provided with different levelled outlets, if that is the case the correct levelling and connection from the outlets is crucial. For more details see the chapter on 'special' designs and its section on implementation guidelines.

2 Theory

2.1 Definitions

2.1.1 Pipes

The pipeline from the intake to the reservoir(s) is called the **Transmission Pipeline**, while the pipeline from the reservoir(s) to the taps is called the **Distribution Network**. The distribution network is usually a **Branched System** that branches-out like the roots of a tree

2.1.2 Flows

The flow in a pipeline is called **Continuous Flow** when the water permanently flows out freely at the end of the pipe. In other words, there is continuous flow in pipelines that do not have a bib cock or float valve at the end. In Bhutan, the flow in the transmission pipeline is therefore continuous. Note that in spring protections projects without bib cocks and in **Open Flow** schemes (that are schemes without bib cocks, mostly in high altitude areas) the flow is also continuous.
Between the reservoir(s) and the tapstands the flow is normally **Closed** (meaning that there is a bib cock or float valve at the end of each pipeline. As mentioned above this is not the case in open flow schemes). In the distribution network the flows are variable, depending on the opening and closing of bib cocks and valves. The distribution network should be designed for **Peak-Flow**, which in Bhutan is the accumulated tap-flow of the tapstands served by a distribution pipe, also called **Total Tap-Flow** (TTF). In Bhutan almost all tapstands are designed for a flow of 0.1 lps and therefore:

Total Tap-Flow = Number of Taps * 0.1 lps/tap

Two more terms need to be introduced: Natural flow and continuous demand flow (CDF). The **Natural Flow** is the maximum flow which can run through a given pipeline (which has a certain roughness, inner dia, length and vertical drop). In the transmission pipeline the flow is the natural flow, excepts when the source yield is less than the natural flow (and the pipeline is over-designed, at least for that season).
The **Continuous Demand Flow (CDF)** is the flow that exactly matches the total daily design demand of the beneficiaries. Therefore:

CDF = Daily Design Demand / 86400 lps

In this equation the factor 86400 represents the number of seconds in a day (24 hours/day * 60 minutes/hour * 60 seconds/minute). Furthermore the **Daily design demand (DDD)** is:

DDD = Population * 1.5 Growth Factor * Daily per Capita Demand

The Daily per Capita Demand depends on the type of user: A day-scholar, for example, is designed to use less water than a boarding student, and a rural householder less than an urban dweller. It follows that the safe yield of a source and the natural flow of the transmission mainline should at least be equal to the CDF The safe yield is taken as follows

Safe Yield = 0.8 Safety Factor * Dry Season Measured Yield

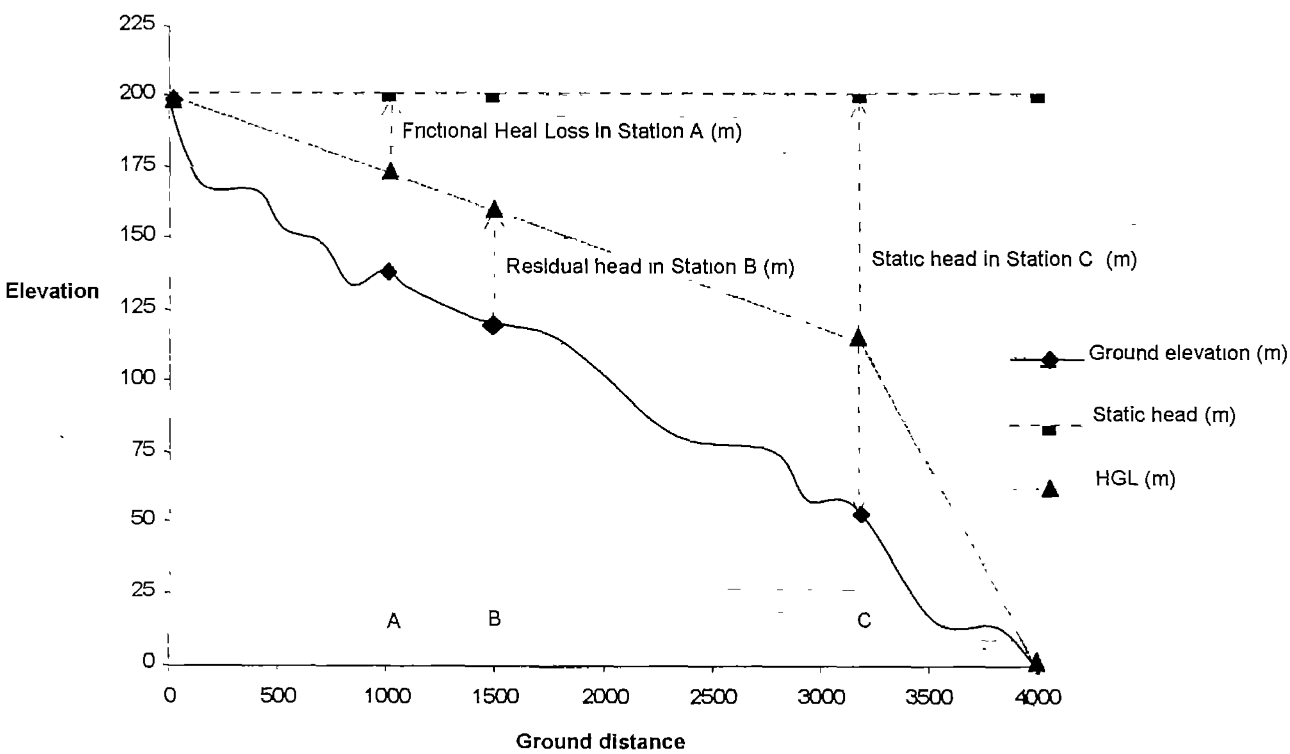
In which the dry season is defined as the months of March, April and May. Note that measurements in any other season, especially the monsoon, cannot be used to guess the safe yield. Some stream which are large in the monsoon season, completely dry up in winter, so that not even a large safety factor can be used to forecast dry season flow

2.1.3 Pressure

The **Vertical Drop** from the top to the end of a pipe (-section) is called the **Static Head**. In other words the static head is equal to the difference between relative level at the top of a pipe and the level RL at the end one is discussing The static head represents pressure or potential energy. Due to friction, this potential energy is transformed into heat and kinetic energy (negligible in RWS in Bhutan) when the water runs. The difference between the static head and the pressure at a given point in the pipeline is called the **Frictional Head Loss**, and the remaining pressure is called the **Residual Head** or **Pressure Head** (neglecting the velocity head). Thus:

Static Head = Frictional Head Loss + Residual Head

In a ground profile drawing one can indicate the static head as a horizontal line starting at the elevation of the top of the pipe. In each point the static head is the difference between the ground level elevation and this line. One can also indicate the residual head in each point as the distance above the ground level. This is always below the static head line, and normally above the ground level (else there is negative pressure, which good design tries to avoid). The line through all residual heads is called the **Hydraulic Grade Line** (HGL, see figure).



2.2 Calculating Pipe flow

The capacity for water flow through pipes depends on:

1 The internal **diameter** of the pipe: The larger the dia, the more flow

2 The **roughness** of the pipe (this is different for HDP and GI)

3. The available pressure head per pipe length between beginning and end of the pipe In the case of gravity flow this is equivalent to the vertical drop or RL difference from the beginning of a pipe to its end

There are formulas to calculate how much water can flow through pipes, but it is easier to use tables, see Chapter 11 1.5 and 11.1.6 (pages 77-82) of the 1998 Revised Standardisation Manual. In the first vertical column you see the flow, beginning with 0.1 lps (the normal design-flow for one tap). In the rows you find the different pipes, beginning with 16mm From 32mm onwards there are two columns per pipe, because there are different classes (as indicated on the pipe with the yellow and green stripes). In the RWSS program in Bhutan we usually use class IV (green print) for the larger pipes, and therefore the column for class V should (almost) never be used. The values in the tables give the Frictional Head Loss Factor (FHL factor) in meters *per 100m of pipe length* belonging to that specific pipe and that particular flow.
The row for 0.2 lps flow, for example, crosses the column for 25mm class V HDP pipe. At the crossing point it says '3.981'. This means that a 100m long pipe of 25mm has a capacity of 0.2 lps if the vertical drop between beginning and end of that pipe is 3.981m. But a two hundred meters long 25mm pipe, with RL difference of 7.962m between beginning and end also has that capacity, because *per 100m* the vertical drop is also 3.981m.

2.2.1 Flow in a single pipe section

This knowledge can be used in two ways, for design of new and rehabilitation projects respectively:

1. You know pipe length, vertical drop and the design flow which you want, and want to select a good pipe or pipe combination (design for **new** pipes) For example: You want a flow of 0.3 lps through a pipe of 330m and a vertical drop of 23m. First calculate the drop per 100m (23*100/330=6.97m). Search in the table in the row for 0 3 flow and look for the value 6.97. You will find that that exact amount is not there: You find 8 435 for 25mm pipe and 1.484 for 32mm. This means that only 25mm pipe is not large enough, because through a 25mm pipe you can only have 0.3 lps if the terrain is steeper than it is in our example. 32mm on the other hand is bigger than required Because 32mm is (more than) large enough, you may design the entire line as 32mm (not advisable if the source is small), or select a good combination of the two pipes.

2 You have a pipe length with its vertical drop and want to know its capacity (for example in a **rehabilitation** project) Let's say our pipe is 40mm class IV HDP pipe. Of course you also know the vertical drop, e.g. 62m over a length of 564m, which comes to 11m/100m In the column "HDP 40mm"we move down searching for the value 11 We find 10.556 and 11.195, for a 1.55 lps and 1.6 lps flow respectively. Our pipe has a vertical drop between those two values, and therefore the flow capacity is also somewhere between the two flows.

Note that you can never say, for example 'The capacity of 32mm HDP pipe is so and so many lps'. You cannot say that in general, because the capacity of a pipe depends not only on its size, but also on the pressure head (for gravity flow the vertical drop) per pipe length!

2.2.2 Flow in a pipe combination

We can also design a (new) combination of pipes for a given flow, or find the natural flow for a given combination of pipes by trial and error (rehabilitation projects).

1. Let's say there is 200m vertical drop between intake and reservoir, while the ground distance is 4000m and the flow we want to have is 0.4 lps.
   - First we calculate the average vertical drop per 100m, which is 5m/100m.
   - Reference to the tables shows that we need to combine 25mm pipe (with a head loss factor of 14 37) with 32mm (with a frictional head loss factor of 2 529)
   - Use the formula

$Length_a$ = (Vertical Drop – $Length_{total}$ * $FHLfactor_b$) / ($FHLfactor_a$ – $FHLfactor_b$)

   In which the FHL_{factor} should be in m/m, and not in m/100m (divide by 100)!
   $Length_{25mm}$ = (200m – 4000m * 0.02529) / (0.1437 – 0.02529) =
   $Length_{25mm}$ = (200m – 101.16) / 0.11841 = 98.84 / 0.11841 = 835 m
   - Calculate the 32mm length 4000 – 835 = 3165 m
   - Check whether this combination leads to the 200m head loss:
   835m * 0 1437m/m = 120m
   3165m * 0.02529m/m = 80m +
   200m
   Round the pipe length off, e.g. to 850m and 3150m, or to 800m and 3200m.

2. If the pipes are given, but the flow is to be found. E.g. 300m of 40mm, followed by 600m of 32mm with a total drop of 85m.
   - For a first trial calculate the average slope. 85 / 900 * 100 = 9.4m/m
   - With only 32mm pipe the flow would be 0.8lps, with only 40mm 1.5lps. So let's see whether combined they give a flow of 1 1lps:
   300m * 0.05593 + 600m * 0.16465 = 17m + 99m = 116m. But we have only 85m vertical drop. The flow will therefore be less.
   - Now try between 0 8lps and 1.1lps, e.g. 0.9lps.
   300m * 0.03857 + 600m * 0.11355 = 12m + 68m = 80m. That's close to 85m So we can conclude that around 0.9lps (maybe a little more) will run though this pipe combination.

2.2.3 Flow in a branched (distribution) network

Calculating the flow in branched pipes follows the same theory. When we calculate the pipes in a new pipeline, we should realise two things:

1. The **residual head at the top** of a section influences the flow.
2. The residual **head at the end** of a pipe is always zero

Residual head influences the flow

In the examples of flow in a pipe combination, we have already taken this into account. If the profile of the first example was as in the first two columns in the table below, then the static and residual head in each of the points would be as in the third and fourth column (see also the drawing on the next page):

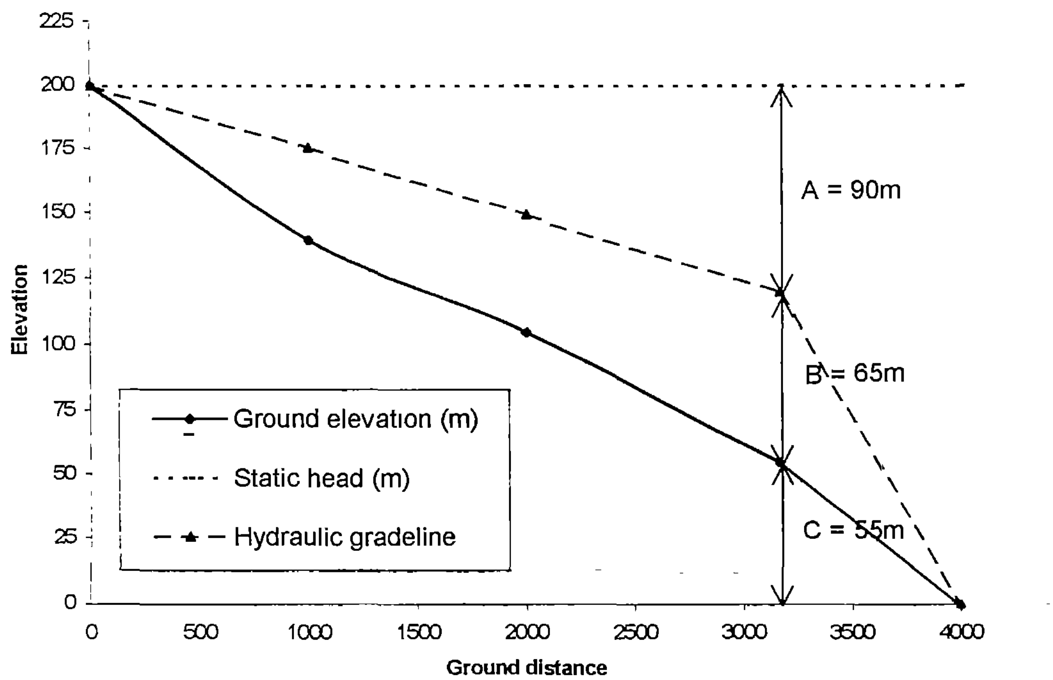
Ground distance	RL	Static head	Residual head
0	200	200 – 200 = 0	0 – 0 = 0
1000	140	200 – 140 = 60	60 – 1000 * 0.02529 = 35
2000	105	200 – 105 = 95	95 – 2000 * 0.02529 = 44
3165	55	200 – 55 = 145	145 – 3165 + 0.02529 = 65
4000	0	200 – 0 = 200	200 – 3165 * 0.02529 – 835 * 0.1437 = 0

At ground distance 3165m the pipe is 55m higher than at the end of the pipeline, while the hydraulic grade line is again 65m above ground level, giving a total available head of 120m. As calculated above this is exactly the frictional head loss over 835m 25mm pipe with a flow of 0 4lps If we forget the residual head, the available head would be only 55m/835m = 6.59m/100m. If that were the case (e.g. if the pipe is cut at that point!) only about 0.26lps could flow through the same 25mm HDP pipe

The graph on the next page illustrates some issues visually:

- Static head is 145m (A+B)
- Residual head 65m (B)
- Elevation above end of the pipe 55m (C)

Available pressure till end of the pipe 120m (B+C)



Residual head at the end of a pipe is always zero

One may *calculate* a pipe combination for a certain flow and at the end (e.g. at a tapstand or at a BPT) have a positive *calculated* residual head In actual fact such a residual head will not happen and the flow will be more (unless the bib cock, control valve, or float valve at the end is not fully open). At first glance this seems nice, because more than sufficient water can flow through this line But, if this happens, the implication is that another line will have less water. In some schemes one tapstand is completely dry when another is opened.

In general over-design of the distribution network makes it less certain that the lower users have sufficient water. Therefore the designer should make the ***calculated* residual head at the end of a line as close to zero as possible** (often by choosing a pipe selection). If the *calculated* residual head at a tapstand is less than 10m or less than $^1/_3$ of the static head, the tapstand control valve need not be adjusted and could in fact be omitted.

Normally over-design of the transmission pipeline does not harm (unless it is very expensive). The designer only has to check that over-design in this pipeline does not lead to negative pressures along the pipeline (because the entire Hydraulic Grade Line will lower). Negative pressure in the pipeline may reduce the flow and lead to sucking in of contamination in case of leakage.

An example may make this clearer.

Station	RL	Dis-tance	Design flow	Design pipe	Design HGL	Calculated RH	Actual flow	Actual HGL	Actual RH	Better design	Actual flow	Actual RH
TOP	1000				1000	0		1000	0			0
		220	0.8	32			1 15			32	0 8	
TEE	960				980	20		961	1			20
		240	0.2	20			0.12			20	0 6	
TAPS	950				950	0		950	0			0
TEE	960											
		290	0 6	32			1.03			190m 32 100m 20	0 2	
END	920				964	44		920	0			0

In this table the four column represent input data: The stations, their elevations, the distances between the stations and the design flow that we require through the respective pipe sections.
The next three columns represent an initial design. Out of these three columns the first gives the chosen pipes, while the second and third column give the HGL and the RH *assuming that only the design flow will flow through the pipe.* In actual fact, however, the pipe capacity of the first design is much larger.
The next columns, columns eight, nine and ten, reflect the actual flow, actual HGL and actual RH that may occur in this pipe, if the continuing all pipe is left fully open, and the preferred flow is into this line (which is likely as it runs steeper down than the line to the two taps). Although the total flow is much more (1.15 lps in stead of 0.8 lps) in the first design, the 0 2 lps flow to tapstands at RL 950 is reduced to 0.12 lps!
The last three columns therefore propose a better design. You can check that the given pipe selection, assuming again full opening of all pipe ends, leads to the flows given in column twelve, and the residual heads as given in column thirteen. Of particular importance is to note that indeed the residual heads at the end of the pipe are zero. If the calculation had shown otherwise, the assumed flow is still differs from the actual flow.

3 Normal Design

The emphasis of this chapter will be on the design of 'normal' gravity flow water supply projects But before discussing that, let's look at Spring Protection Projects. In the near future PHE may add the category 'Small Stream Intake Projects'. As the relevant hydraulic criteria for such projects will be the same (two tapstands), the first below section also pertains to the design of small projects with a stream intake

Spring Protection Projects

See also the instructions on the survey and estimate form

With one tapstand

- Design 16mm pipeline if — vertical drop ≥ 13m/100m
- Design half 20mm and half 16mm if — 13m/100m > vertical drop ≥ 8½m/100m
- Design 20mm pipeline if — 8½m/100m>vertical drop ≥ 4m/100m
- Else design 25mm

Design no bib cock (and no control valve) if total vertical drop is > 80m.
Estimate materials with the help of the estimation form, including reducers.

With two tapstands

Above the TEE point

- Design 20mm pipeline if — vertical drop (from source to TEE) ≥ 13m/100m
- Design half 25mm and half 20mm if — 13m/100m > vertical drop ≥ 8½m/100m
- Design 25mm pipeline if — 8½m/100m > vertical drop ≥ 4m/100m
- Else design 32mm

From the TEE point to each tapstand

- Design 16mm pipeline if the *calculated residual head* (see section 3.1.1) at the TEE plus the vertical drop from TEE to tap ≥ 13m/100m
- Design 20mm pipeline if the *calculated residual head* at the TEE plus the vertical drop from TEE to tap ≥ 4m/100m
- Else design 25mm
  - Design two bib cocks (and control valves) if both taps are within 80m vertical drop below the spring
  - Design one bib cock (and control valve) if one or both tapstands are more than 80m below the spring, but the tapstand with the steepest branch-line, is not more than 80m below the TEE point. To find this steepest branch-line compare how many m/100m drop there is in one branch-line and how much in the other and select the one with most drop. Put the bib cock (and control valve) in this steepest of the two branch-lines, if the Tap is less than 80m below the TEE.
  - Else design two open tapstands and one pipeline control-valve 50m vertically below the TEE in the steepest branch-line.

Gravity Flow Projects

3.1 Check Survey

- Register the project in the project registration book. Give new projects a unique project number. For rehabilitation schemes without number: Reconstruction projects should receive a number starting with that year.
- Completeness. Check for.
    - Drawings
    - Date of source measurement (should be March, April or May)
    - Survey booklet
    - FC test report (or justification of its absence)
- If the survey data are not in order, inform the surveyor immediately and ask for additional data.
- Correctness. Check survey data for common mistakes/suspicious data:
    - RL's at TEE points: Is RL of a TEE copied correctly from previous
    - '100m mistakes' in the RL (e.g. 1802-4=1698)
    - More than 50m/100m vertical drop is unlikely (if you see this in drawing, refer to survey booklet to check)
    - Vertical distance is calculated correctly (sin ∀, not tan or cos)
    - Branch-lines of more than 250m to a single tapstand are uncommon. If you see this in drawing, refer to survey booklet to check (maybe a 0 is added by mistake)
    - Source evaluation. Is safe yield bigger than CDF?
    - Tap spacing. Check whether rural tapstands are not too near to each other. If tapstands are surveyed with less than 100m pipe length and less than 25m drop, reduce the number of tapstands in consultation with the surveyor
- Drawing for designing. Use one of the drawings or make a clear drawing of the scheme, at least A3 size. You may make the drawing vertically to scale. Note:
    - Scheme name, date and your name
    - RL's of tanks, IPT's and TEE's (dotted for additional/reconstruction structures in rehabs)
    - All pipe line lengths (dotted lines for additional/replacement in rehabs)
    - If GI pipe is needed
    - Number of households and beneficiaries per tapstand
- Select IPT's (Intermediate points). IPT's should be prepared as input data at:
    - Every ±100m vertical drop and every ±500m ground distance
    - At all high points (at the first two high points an air release valve can be sanctioned)
    - At low points that are 10m or more lower than the following high point
    - At points in the transmission line above the reservoir where there is a significant change in slope of ground profile (e g. from -3^0 average to -11^0 average).

3.2 Recognise (potentially) 'Special' Designs

Before you do the actual layout, check whether this scheme qualifies for a 'special design' (for which expertise of PHE/HD may be required). It may if:

- Large in number of tapstands (more than 20 tapstands)
- Large in number of beneficiaries (more than beneficiaries)
- Large in area (highest and lowest tapstand vertically more than 500m apart)
- Scattered (more than 200m vertical drop between two adjacent tapstands and/or more than 500m ground distance between two adjacent tapstands)

3.3 Layout - Place BPT's

Placing reservoir(s) and BPT's should preferably be done together with the surveyor. Such ***layout design should also be done in rehabilitations***: Do not blindly copy the old design! The old designs often had too few BPT's, leading to too high pressures, leading to bursting, tapstand leakage and finally pipe cutting In such cases just repair of the pipes doesn't solve the problem!
For inserting BPT's the static pressure criteria are:

Static Pressure Criteria	**Normal maximum**	**Absolute maximum**
Tapstand	60m	80m
Closed BPT	60m	100m
Medium duty GI pipe	150m	180m
Class IV HDP pipe	60m	80m
Class V HDP pipe	100m	120m

The 'Absolute maximum' should be applied only if doing so reduces the number of BPT's needed in a scheme For example· In a scheme which was surveyed to have 130m vertical drop between the reservoir and the last tapstand, you save one BPT by not rigidly applying the 'Normal maximum' of designing one BPT 60m below the reservoir and another one 10m above the last tapstand. By extending toward the 'Absolute maximum' one BPT can be saved, and the only BPT can be designed somewhere in the middle between the reservoir and the last tapstand.
Note that the limiting factor is the smallest. If for example a BPT is put in a GI pipeline, the absolute maximum pressure it should be designed at is 100m, although the pipe could have a 180m pressure. If on the other hand the BPT appears in a class IV HDP pipe, the absolute maximum design pressure should be 80m, although the float valve in the BPT could safely bear 100m.
Also note that the maximum pressure for HDP class IV and class V differs, while at this stage in the design process one does not know which class of pipe will be chosen However, in the smaller dia's (25mm and below) only class V is available, while for the larger sizes (32mm and above) standard design is class IV. Therefore, it is practically definite that for flows unto 0.2lps (two tapstands) class IV will be used, while for flows over 0.6lps (six tapstands) class IV will be designed. For flows between these values the pipe class is uncertain, but to be quite safe one can assume class IV for flows over 0.33lps, and class V for smaller flows.

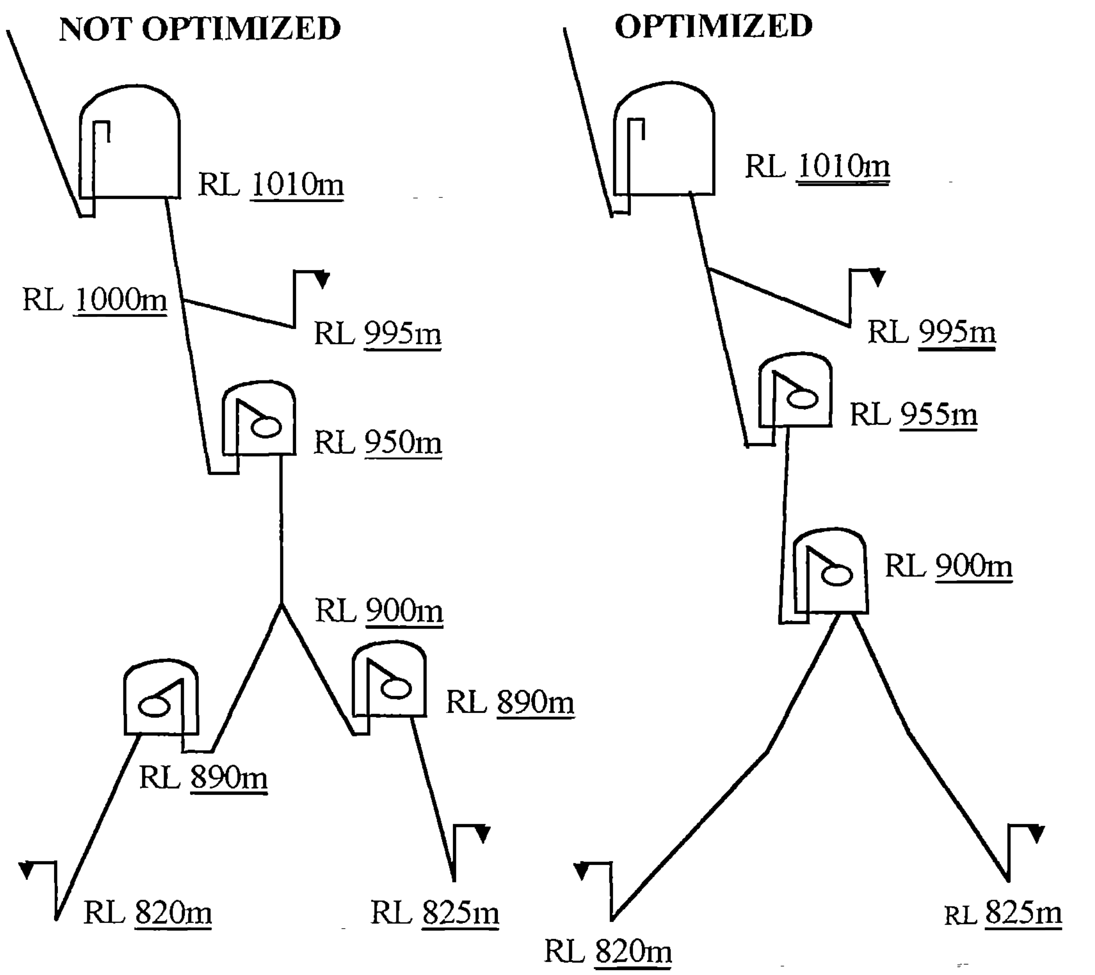
Procedure to locate tanks

- If CWR is proposed ≥20m above the first TEE or TAP discuss with the surveyor whether lowering the reservoir is possible
- Calculate the total vertical drop between CWR and last tapstand
- Divide by 75m and round the number you then find off to the nearest higher number This is the number of sections that you first will try to split the (e.g. 515m : 75m = 6.67 ⇒ 7)
- See where BPT's would come, designing:
  - More than average pressure on the lower BPT's (*not* on the lower tapstands) where you expect that the pipe will be ≤25mm (which implies class V HDP pipe, with a design strength for 100m pressure), that is where the flow is < 0.33lps
  - Less static head on the higher BPT's and the last tapstand (in view of possible future extension of the scheme), that is where the design flow is ≥ 0.33lps
- If a surveyed TEE falls just above a proposed BPT, and if therefore a separate BPT is required in both branch-lines, consider:
  - Lowering the TEE-point in consultation with the surveyor (who knows whether this is feasible) until 10m below the BPT, and/or
  - Raising the BPT until 10m above the TEE
- If a BPT is proposed less than 10m above a TEE, and the slope to the below two branch-lines is very different (so that preferential flow into one branch-line may be expected), and/or if one of the branch-lines is over-designed (in a rehabilitation), consider.
  - Lowering the TEE-point in consultation with the surveyor (who knows whether this is feasible) until 10m below the BPT, or
  - Raising the BPT until 10m above the TEE, else, if this is problematic
  - Design separate outlets from the BPT to the two branch-lines
- If a BPT is proposed less than 10m above a TAP, and the slope to the tap and the ongoing pipeline is very different (so that preferential flow to either the tap or the ongoing pipeline can be expected), and/or if one of the lines is over-designed (in a rehabilitation), consider:
  - Raising the BPT until 10m above the TAP, and serving the TAP from a TEE, else, if raising is problematic
  - Design separate outlets from the BPT to the TAP and the ongoing pipeline
- If a BPT is proposed in a flat area, just after a profile change, consider raising the BPT 5-10m into the steeper area above the flat area (to prevent the need for a large pipeline and the possibility of air locking

Note length of pipeline above and below inserted tanks, *by looking the elevations up in the field book* (not by linear interpolation)

See on the next page an example of conventional and improved BPT placing.

Example of conventional and improved BPT placing



3.4 Size Reservoir

In rehabilitations do not blindly copy the size of the original reservoir, which may be either too large or too small Steps to calculate the size of a new or reconstruction reservoir.

1. Calculate the **Daily Design Demand** (DDD). Assume a growth factor of 1.5 (in the design period of 20 years) and a demand of:

   - Villagers 45l/p/d
   - Day-scholars 10 l/p/d
   - Boarders and officers + family 65l/p/d
   - BHU 1000l

Note I: Larger supply (e.g. 100l/p/d) may be applied in semi-urban areas and large schemes

Note II: If the daily design demand, calculated with the above per capita standards, is bigger than the daily supply, and no alternative sources are available at reasonable cost, lowering the per capita demand can be considered in consultation with PHE/HD.

2. Establish the **Supply flow**
    - Calculate the **natural flow** of the transmission pipeline *(you do not know this before designing the transmission pipeline)*[1]
    - Calculate the dry season **safe yield**
    - As **supply flow** select the smaller value of these two

3. Fill out the below **Table**.
    - The **period supply** is the supply flow into the number of seconds of that period
    - The **period demand** is the total design daily demand into the period percentage
    - The **period surplus or deficit** is. Period supply – Period demand
    - Fill out the **accumulative deficit or surplus** column. As first value, copy the period surplus/deficit from the first period. The next accumulated deficit/surplus is the above value plus the next row's period surplus or deficit, etc.

Time of the day	Duration of period		Percent of daily demand	Period supply	Period demand	Period surplus or deficit	Accumulated surplus or deficit
	hours	Seconds	%				
5-5½ am	½[2]	900	25				
5½-7 am	1½	6300	0		0		
7-12 am	5	18000	35				
12-5 pm	5	18000	20				
5-7 pm	2	7200	20				
7pm-5am	10	36000	0		0		
	24	86400	100				

4. Compare the largest cumulative deficit with the standard reservoir sizes The reservoir size is the nearest bigger standard size. Take the open BPT storage volume as 300 litre. Also if there is no deficit at all, select open BPT as reservoir.

[1] One should actually optimise the supply flow and CWR (see Reservoir optimisation at page 23 and Over-design at page 25). A guideline is to design for a **low supply flow** (close to CDF) if the transmission line is **longer than two kilometre** or if the **source yield is small or uncertain** (e.g. tsheri cultivation in catchment). Else design for a large flow (unto the entire safe yield or the total tap-flow, whatever is less), resulting in a small reservoir.

[2] Most graphs (in literature from Nepal) give 25% use of the daily demand in the first two hours. We have split the first two hours because of the sometimes-scattered settlement pattern in Bhutan. Fewer beneficiaries per tapstand, cause that sometimes even the 25%-in-two-hours-peak criteria leads to no reservoir requirement, although the supply flow is less than the total tap-flow!
Example: 20 People served by 4 tapstands, and a supply flow of 0.1lps.

- 25%-Daily-demand-in-two-hours ⇒ 0.09lps peak demand flow ⇒ no reservoir.
- 25%-Design-dmand-in-half-an-hour ⇒ reservoir capacity required 160l ⇒ open BPT as reservoir.

Theoretically it is not correct to manipulate the period demand, but to introduce another criteria based on tapsflow, and select the larger value of these two. Such a formula could define the period of time that tapstands can receive tapflow, if a 'reasonable' amount is left open. A formula could define what is 'reasonable': a decreasing percentage if the population is less and if the tapstands are more. PHE had such a formula, but as we did not know how to enter it into the new computer program, PHE has chosen for the above mentioned solution of splitting the period demand.

Example:
Rural population of 80 people, school with 60 day-scholars and 70 boarders, staff quarters with 10 people, a dry season yield of 0.22 lps and a transmission pipeline capacity of 0.21lps

1 DDD = (80 * 45 + 60 * 20 + 70 * 60 + 10 * 60) * 1 5 = 14400 litre
2 Supply flow (which is smaller than natural flow) = 0.18 lps 0.8 * 0.22 lps = 0.18 lps
3 See below

Time of the day	Duration of period		Percent of daily demand	Period supply	Period demand	Period surplus or deficit	Accumulated surplus or deficit
	hours	Seconds	%				
5-5½ am	½	900	25	324	3600	-3276	-3276
5½-7 am	1½	6300	0	972	0	972	-2304
7-12 am	5	18000	35	3240	5040	-1800	-4104
12-5 pm	5	18000	20	3240	2880	360	-3744
5-7 pm	2	7200	20	1296	2880	-1584	**-5328**
7pm-5am	10	36000	0	6480	0	6480	1152
	24	86400	100	15552	14400		

4 6 m^3

Size Reservoir - Quick

The above procedure leads to the same results as the quick method described below.

1. Calculate the daily design demand (DDD) and the CDF (= DDD / 86400):

- Population growth factor = 1.5 (in 20 years)
- Villagers 45l/p/d
- Day-scholars 10 l/p/d
- Boarders and officers + family 65l/p/d
- BHU 1000l

Note I: Larger supply (e.g. 100l/p/d) may be applied in semi-urban areas and large schemes
Note II. If the daily design demand, calculated with the above per capita standards, is bigger than the daily supply, and no alternative sources are available at reasonable cost, lowering the per capita demand can be considered in consultation with PHE/HD.

2. Establish the **Supply flow**:

- Calculate the **natural flow** of the transmission pipeline (you do not know this before designing the transmission pipeline)[3]
- Calculate the dry season **safe yield**
- As **supply flow** select the smaller value of these two

3. Calculate the Supply Factor (S_{factor}) as the Supply Flow (SF) divided by CDF

[3] See footnote previous page and its references about optimising the supply flow and CWR.

Calculate the storage requirement:

- If $S_{factor} > 12$, no storage required
- If $S_{factor} > 1.31$, storage requirement = (0.28 – 0.0417 * SF) * DDD
- If $S_{factor} \geq 1$, storage requirement = (1 – 0.58 * SF) * DDD
- Else, water shortage

4. Compare the storage requirement with the standard reservoir sizes, selecting the next bigger standard size as reservoir, taking the storage capacity of an open BPT as 300 litre. If there is no deficit at all, select open BPT as reservoir

The above procedure leads to the same results as the period supply and period demand calculation (see previous page)

Example:
Rural population of 80 people, school with 60 day-scholars and 70 boarders, staff quarters with 10 people, a dry season yield of 0.22 lps and a transmission pipeline capacity of 0.21lps.

1. DDD = (80 * 45 + 60 * 20 + 70 * 60 + 10 * 60) * 1 5 = 14400 litre; CDF = 0.1667 lps
2. Supply flow = 0.18 lps (Safe yield smaller than Natural flow)
3. SF = Supply flow / CDF = 0.1667 / 0.18 = 1.08
4. (1 – 0.58 * 1.08) * DDD = 0.374 * 14400 = 5380 l/d
5. 6 m^3

3.5 Size Pipelines

Chapter 2 has given the theory of pipe calculation If in rehabilitation small sections of pipe (less than 500m per scheme) need to be replaced, you can simply replace it by the original pipe size, if that was large enough For bigger replacements, or entirely new design, hydraulic calculations should be made. Keep in mind the disadvantages of bad pipe selection:

- Larger flows in some pipes may cause shortages elsewhere
- In over-design the cost of the project increases, as well as the transport labour
- In over-design negative pressures may occur, possibly leading to contamination

For manual design use the design form (for a blank form see annex to this section):

<table>
<tr><th>Station</th><th>RL</th><th>Design Flow</th><th>Ground distance</th><th>Pipe choice</th><th>$FHL_{calc.}$</th><th>$HGL_{calc.}$</th><th>RH_{calc}</th><th>Static head</th></tr>
<tr><td rowspan="2">A1</td><td rowspan="2">B1</td><td rowspan="3">C1</td><td rowspan="3">D1</td><td rowspan="3">E1</td><td rowspan="3">F1</td><td rowspan="2">G1</td><td rowspan="2">H1</td><td rowspan="2">I1</td></tr>
<tr></tr>
<tr><td rowspan="2">A2</td><td rowspan="2">B2</td><td rowspan="2">G2</td><td rowspan="2">H2</td><td rowspan="2">I2</td></tr>
<tr><td rowspan="2">C2</td><td rowspan="2">D2</td><td rowspan="2">E2</td><td rowspan="2">F2</td></tr>
<tr><td rowspan="2">A3</td><td rowspan="2">B3</td><td rowspan="2">G3</td><td rowspan="2">H3</td><td rowspan="2">I3</td></tr>
<tr><td rowspan="3">C3</td><td rowspan="3">D3</td><td rowspan="3">E3</td><td rowspan="3">F3</td></tr>
<tr><td rowspan="2">A4</td><td rowspan="2">B4</td><td rowspan="2">G4</td><td rowspan="2">H4</td><td rowspan="2">I4</td></tr>
<tr></tr>
</table>

Formula's:

Station	RL	Design Flow	Ground distance	Pipe choice	$FHL_{calc.}$	HGL_{calc}	$RH_{calc.}$	Static head
INTAKE	1000	Supply flow	195m	25mm	E1factor (for C1flow) * D1/100	B1	B1-G1	B1-B1
IPT 1	960					G1-F1	B2-G2	B1-B2
CWR	975	Supply flow	30m	20mm	E2factor (for C2flow)* D2/100	G2-F2	B3-G3	B1-B3
TEE 1	960	Total tapflow	60m	25mm	E3factor (for C3flow)* D3/100	B3-F3	B4-G4	B3-B4

Example:

Station	RL	Design Flow	Ground distance	Pipe choice	$FHL_{calc.}$	$HGL_{calc.}$	$RH_{calc.}$	Static head
INTAKE	1000	0.3	195m	25mm	16.5	1000	0	0
IPT 1 Washout	960					983.5	23.5	40
CWR	975	0 3	30m	20mm	7.8	975.7	0.7	25
TEE 1	960	0.6	40m	25mm	12.2	662.5	2.5	0

When estimating **add 10%**[4] **pipe length** after design (in computer design, the computer does this automatically).

3.6 Design

This paragraph and the next apply both to designing manually and designing with the help of a computer, though the practicalities do differ. For manual design (e.g. in rehabilitations that need partly re-design) the design form at the end of this section may be used.

3.6.1 Input

- Prepare the (computer) input, *as per the surveyor's numbering.*
- Also number IPT's and TEE's before each tap.
- Enter input data into the computer, or write them in the data columns of the Design Form making a copy (for easy re-design of sections that you want to review and optimise after initial design)

[4] This percentage may be increased as an incentive not to over-report the measured straight distance between abney-level stations, because such over-reporting distorts the vertical drop calculations, thus leading to faulty design (too small pipes and unnecessary BPT's).

3.6.2 Reservoir optimisation

Optimisation of CWR size and source flow. Rough guideline: Transmission pipelines of more than two kilometres may be designed with a supply flow close to CDF, shorter lines with a supply flow close to the safe yield or total tap flow (whatever is less), unless the yield is uncertain (e.g. tsheri cultivation). Also refer to the section 'Over-design' at page 25, Over-design of the transmission pipeline is especially recommended if:

- Schemes are 'large' (see 'Recognise (potentially) 'Special' Designs' page 16)
- Over-design by 50% costs less than 5% extra in total project cost

3.6.3 Make first design

In the case of computer aided design, the computer will prepare this design for you, in the case of manual design you have to make this first design, making choices and filling out the calculation columns in the Manual Design Form (see end of this section).

3.6.4 Hydraulic check

Check the initial (computer) design for the static head and residual head and flow velocity criteria below (bold printed values in the standardisation manual indicate flow velocities between 0.3 and 3.0 m/s). If the heads or flow velocity is not satisfactory, review the design manually.

	Static Head (SH)		Residual Head (RH)	
	minimum	maximum	minimum	maximum
Intake	0m	-	0m	10m
Open tank (CWR or BPT)	0m	-	0m	10m****
Tank with float valve	10m	100m	0m	10m
IPT ** any pipe SH <20m	-	-	$^{1}/_{3}$ SH	-
IPT ** Class IV HDP pipe SH >20m	-	80m*	10m	60m
IPT ** Class V HDP pipe SH >20m	-	120m*	10m	100m
IPT ** Medium duty GI pipe SH >20m	-	180m*	10m	180m
Tapstand SH <20m	2m	-	0m	10m
Tapstand SH >20m	-	80m	0m	$^{1}/_{3}$ SH***

* Only in closed system (lines ending at bib-cocks or float valves) pipe lines

** In this case 'IPT' can mean any point between intake and last tapstand.

*** If this condition is met, a tapstand control-valve is not required.

**** A residual head of >0m cannot happen at any open point. If such a residual head is *calculated*, this means that more flow can go through the pipe, reducing the heads along the pipe. Therefore, especially in the case of multiple reservoir design or open taps, the line should be redesigned by using smaller pipes and/or increasing the design flow (if you increase the flow, this should also be done in the above lines).

Note that an experience designer may design, check (as discussed above) and optimise (as discussed below) a scheme simultaneously.

Manual Design Form

Station	RL	Design Flow	Ground distance	Pipe choice	FHL_{calc}	$HGL_{calc.}$	$RH_{calc.}$	Static head

When estimating **add 10% pipe length** (this percentage may increase, see footnote page 22)

3.7 Optimise

The aim of reviewing and optimising the design is to make the design.

- Easy to implement (few changes in pipe size, in small schemes few different sizes)
- Easy to operate, in that the flow is naturally controlled (in stead of by valves), to reduce the occurrence of negative pressures and the need for control valves.
- Easy to manage If sources and cost implications allow, the continuous flows in large schemes should be over-designed.
- Cheap

The main two methods to optimise designs are over-designing and practical pipe sizing, which is discussed in the two sub-sections below respectively.

3.7.1 Over-design

You can over-design by increasing the design flow or by leaving a positive *calculated* residual head at the end of a line (tank, tapstand).

Closed lines. *Try not to* over-design in *closed lines* (lines in which the flow is not continuous, that is lines that end at bibcocks or float valves. Normally this applies to all lines in the distribution network). Prevent over-designing by selecting smaller pipes. However, do not redesign in such a way that there is:

- Less than $^1/_3$ static head at TEE points with a static pressure of <20m.
- Less than 10m residual head at TEE points with a static pressure of $\geq$20m

Open lines. Over-designing of *open lines* (the transmission pipeline and lines that end in a tank without float valve or at a tapstand without bibcock) is actually recommended, though one has to think of the cost and source implications. Methods:

- **Increase flow**. If you over-design by increasing the design flow in a certain line, the design flow should be increased in all lines between the above tank or TEE and the below tank or TEE. And if there are other lines above the upper tank or TEE, it is recommended to over-design these lines by *at least* the same quantity, unless the source is insufficient for this purpose, or if this is very expensive.
- **Positive *calculated* residual head** If you over-design by leaving a positive *calculated* residual head at a tank or tapstand, check whether it is possible that a negative head will occur at any higher point. If this is the case, you have to change the design. It is safer to over-design by increasing the design flow.

Notes:

- In the case of open BPT's, it is recommended to over-design the outgoing line(s). Otherwise the BPT may continuously overflow, causing drainage problems.
- In the case of multiple reservoir design it is recommended to over-design 5-10% going up from bottom to top, each time when crossing a point where lines split
- In large schemes or semi-urban areas it is recommended to over-design the supply by some 50% if the cost increase is less than 5%.

3.7.2 Practical Pipe Sizes

- **Round off** the pipe lengths in a pipe combination, at least to 10m, if not to entire roles E.g. if you calculate a combination of 177m 25mm followed by 288m 20mm, then round off to 200m 25mm and 265m 20mm or to 165m 25mm and 300m 20mm
- Design **small sizes of GI** pipes. In the same pipe section, GI pipes should be a size smaller than or the same size as the HDP pipe (except if a stretch of less than 20m of GI is to be put around HDP)
- **Reduce** pipe size **before closed BPT's**

Flow	Pipe before closed BPT
≤ 0.7 lps	20mm class V HDP / ½" GI
>0.7 - ≤2.0 lps	32mm class IV HDP / 1" GI
>2.0 - ≤4.8 lps	50mm class IV HDP / 1 ½" GI

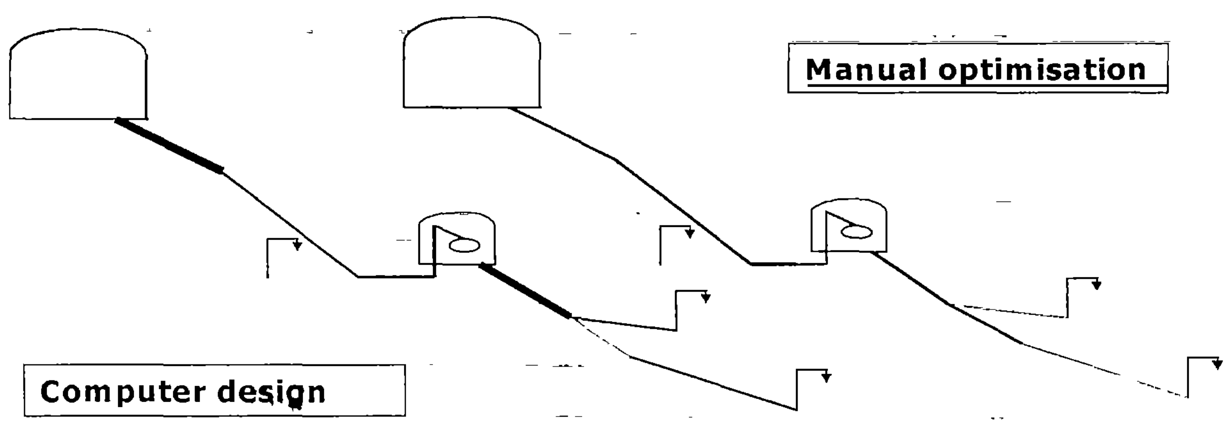
- **Reduce** the pipe size **after tanks**

Static head	Minimum Residual head
<20m	$^1/_3$ SH
>20m	10m

Note that after a tank 32mm HDP is not desirable (1 ½" outlet fittings) If possible reduce to 25mm (1" outlet fittings).

- Keep one size or **decrease pipe sizes in the direction of the flow** in one section between two tanks (except after GI or if pressure compels you).
- **Minimise reductions** in pipe size in one pipe section (apart from the last meters before a closed BPT, which may be smaller)
- Reduce the **number of different pipe sizes** per project, at least in small schemes.
- **Minimise short lengths** (less than 50m) of a different diameter, except just before closed BPT's

Note that it is not always possible to maximise all these suggestions at the same time.



Tapstand control valves may be omitted if

- Calculated residual head at the tapstand is less than one third of the static head
- Static head at the tapstand is less than 10m

3.8 Pipeline valves

3.8.1 Air release valve

Sometimes an air release valves is required on high points, which occur most often in the transmission pipeline, but occasionally also in the distribution network. The need for air release valves (and problems of air or dirt blockage) reduces when there is good pressure in the pipe. Therefore directly after the intake and all tanks the pipeline should be surveyed and implemented as steep down as possible

Estimate for an air release valve after 100m if:

- The vertical drop over the first 100m after a tank is less than 5m

Estimate for air release valves on all but the last highpoint if there are two or more of the following high points after a tank within either of the below criteria.

- High point which is more than 5m above the low point before it
- High point which is more than 1m above the low points before it and the slope between the zero pressure point (intake or tank) and the high point is less than 5m/100m

3.8.2 Washout

At each low point before a high point on which an air release valve is placed, as well as on the low point after the last air release valve.

3.8.3 Pipeline control valve

Normally do not design pipeline control valves: The distribution of flow should be regulated by pipe sizing, or else by tapstand control valves or other valves at the end of a pipe section.

3.9 Drawing

The schematic drawing should follow the layout as in the field: Branches that are to the left in the field, should also branch to the left in the drawing. The longest line ('main line') should be straight down. Note the following.

At the stations:

- RL's of all IPT's, TEE's and structures (underlined)
- Name of households and Number of beneficiaries per tapstand

Along the pipes:

- Lengths of all pipelines (between brackets)
- Type, Size and Class of all pipe lines
- Design flows in all lines

In the project detail box in the right bottom corner:

- Name of project
- Project number
- Geog
- Dzongkhag
- Surveyor and survey date

- Designer and design date
- Drawn by, signature, and date
- Checked by, signature, and date (blank)
- Measured source yield and date
- Present population
- Check schematic drawing
- Check the drawing for completeness and correctness, especially of the pipe design.
- Approval

3.10 Check Design

- Cost. With the 'Health for All' objective cost (per capita) is not a criteria for sanctioning, but it is a proxy- indicator for design quality Crossing of the following criteria is a reason for checking
  - Cost per capita above 2000 Nu for spring protections and rehabilitations
  - Cost per capita and 3000 Nu for new schemes are exceptional, and may be a reason for checking
  - Pipes cost more than 50% of total
  - Cement costs more than 15% of total
- Measured yield Check whether the design source flow is well below the measured yield, as measured in the dry season
- Pressure and BPT layout design: A minimum number of BPT's, yet without crossing the absolute maximum criteria.
- Logical pipe sizing Check for pipe sizing criteria as mentioned under manual design optimisation
- Over-design Check for over-design and whether changes of design flow have been taken into account 'bottom-up' (see design optimisation).
- Sanction, registration and filing correspondence.
- Later correspondence: Of each letter pertaining to a particular scheme (or several schemes), a copy should be filled in the Project file(s).

4 Some technical misconceptions

We have now enough technical understanding to overcome a number of common technical misconceptions.

4.1 Pipe size selection is not engineering

In rehabilitation projects where the population has increased, DPHE staffs often propose to replace existing pipes by larger ones. The proposals, however, are not based on calculations, either because it doesn't come to mind that this would be worthwhile, or because they do not know how to proceed A proper assessment of where the water shortage takes place and can be most economically addressed (supply, storage, and distribution network) is often absent. Not knowing which technical factors are relevant (such as slope, population, number of tapstands, etc), the staffs do not know how much water should flow where and have no starting point for calculations which pipe would have the required capacity

4.2 Over-design is always in the beneficiaries' advantage

As a consequence of the above, the staff has no alternative but to guess pipe sizes, based on their field-experience. They often over-estimate the requirement to be on the 'safe' side. However, apart from the cost, it not always advantageous for the well functioning of the scheme, to over-design certain lines. Generally schemes function well if the transmission pipeline is over-designed, which means that if the source is ample, more water is available and water wastage doesn't lead to shortage elsewhere.
In the command area, however, over-designing the distribution lines causes some tapstands to get more water than planned. This can lead to other tapstands falling dry when these 'advantaged' taps are opened, and generally enhances that a number of tapstands can use more water and in a shorter time than their calculated share, leading to shortage elsewhere, or water shortage later in the day.

4.3 Pipeline control valves can prevent wastage

Often staff and users believe that a well-adjusted pipeline control valve in one branch line can prevent that the users of that line waste water, which causes shortage in the other branches Although flow restriction obviously helps to limit wastage (though preferably by pipe sizing rather than by valves), in closed systems this solution cannot entirely solve the problem
This has to do with the difference between peak-flow and continuous demand flow (CDF). Ideally the pipeline control valve is adjusted to the design flow of the below tapstands, so that the tapstands cannot use more than that total tap flow (peak-flow). However, if the taps are left open for a longer time than assumed by the design, water wastage still happens, maybe causing shortage elsewhere. The control valve cannot be adjusted to make the flow so small that the daily demand of the branch line is just met. If that is done, the tapstands can never be opened simultaneously and still receive the standard tap flow

Example: Branch line with 5 tapstands, with each 6 users.
*The daily design demand of these 30 users is: 2,025litre, while the total tap flow or peak-flow is 0.1 * 5 = 0.5lps*
If we adjust the flow into the branch line to 0.5lps, than in the worst case (all

tapstands permanently open), they use 43,200litre per day; more than twenty times they design demand!

If we adjust the flow into the branch line to supply only 2025 litre/day, than that is 0.02lps; in that case not even one tapstand can get a decent flow at the time!

Note that multiple reservoir design makes use of this difference between peak-flow and CDF to make branch lines more independent (see later).

Also note that the adjustment of pipeline control valves is very difficult, firstly because you don't see the result of your adjustment immediately, but more importantly because the flow through a valve fluctuates depending on the pressure. In closed lines the pressure fluctuates, and therefore also the amount of flow through the control valve. Thirdly, closing pipeline control valves often causes negative pressure in the below pipes, which is undesirable

4.4 Reservoir size is independent of supply flow

From seeing DPHE and PHE design of new reservoirs in rehabilitation projects I conclude that sometimes the size is just 'large', and sometimes equal to the total daily demand. Although the last is based on a calculation, it does not accord to the PHE technical criteria. These criteria are that the per capita daily demand of 45litre must be supplied to the design population, that 25% of that should be available in half-an-hour, and 65% in seven hours. This implies that the required reservoir capacity depends on the supply flow.

Example: With a PHE team we recently visited a scheme with 2000 beneficiaries, an existing 23m3 tank and a supply flow of 1.6lps, but a much larger source. Sticking to the 45 per capita criterion, the shortage could be solved in different ways. In the below table the cells give the required supply flow for a given reservoir size in the two peak periods. The required supply flow is calculated as the period demand minus supply from storage, divided by the length of the period. The last column selects the largest required supply flow from the different peaks.

	25% in ½ hour	65% in 7 hours	100% in 24 hours	Flow
23m³	(135,000*25%-23,000):1800=6.0lps	(135,000*65%-23,000):7*3600=2.6lps	135,000.86400=1.6lps	6.0lps
23+5m³	(135,000*25%-28,000).1800=3.2lps	(135,000*65%-28,000):7*3600=2.4lps	135,000:86400=1.6lps	3.2lps
23+10m³	(135,000*25%-33,000).1800=0.4lps	(135,000*65%-33,000).7*3600=2.2lps	135,000:86400=1.6lps	2.2lps
23+20m³	(135,000*25%-43,000)·1800=-5 1lps	(135,000*65%-43,000):7*3600=1.8lps	135,000:86400=1.6lps	1.8lps
23+30m³	(135,000*25%-53,000):1800=-10 7lps	(135,000*65%-53,000):7*3600=1.4lps	135,000:86400=1.6lps	1.6lps

4.5 Extra connections are technically always feasible

This example illustrates the relevance of technical know-how in policy-making, because recently a meeting discussed whether anticipated internal connections should be taken into account when designing. The main issue in this discussion was on policy· Does the program *want* to facilitate the development However, one technical question was also raised Do our current designs already make extra connections technically feasible? PHE applies a population growth factor over the design period of 1 5 and on top of that often over-designs pipelines (the latter is visible as a calculated residual head at a tank or tapstand) Do these factors imply that additional connections from existing schemes will practically never lead to dry tapstands?

In almost all cases the other households will indeed not observe the impact of a few extra tapstands But when it comes to large numbers of new connections compared to the original, as is sometimes the case with internal connections, this is no longer true. The issue here again is one of peak-flow, which has nothing to do with the 1.5 multiplication factor applied to the daily demand (unless there are more then 39 rural users per tapstand, in which case the design tap flow crosses the standard of 0.1lps. However this situation is very uncommon in Bhutan) In other words: The scheme may have a capacity to supply several times the daily demand, but not to supply extra connections.

> *Example: A scheme with 6 tapstands and 30 households with currently an average of 6 people. The transmission line and the entire distribution system is over-designed by 30%. The 6 households served by tap 1 make one internal connection each.*
>
> *With the present population the scheme can supply 45*1.5*1.3(over-design factor)*180(population)=16m³ or 90 litre per capita per day. In the (unlikely) event that all internal connections from tapstand 1 are opened at the time, the average flow would only be *0.1(tap flow)*1.3/6*=0.02lps. In other words:. Although the scheme is over-designed, on average only one fifth of the normal tap flow would come. Of course this means that many internal connections would be dry, while others receive a reduced flow.*
>
> *Note that actually the example is more complicated, because the flow to tap 1 depends on the use by the other tapstands: The more of the other tapstands are closed, the higher the residual head at the TEE point and the more flow to tap 1...*

4.6 Direct connections from above the tank are technically not sound

It is often believed that a connection from above a reservoir is a larger thread to the water security of the other beneficiaries than a connection from below. The argument mentioned is that that tapstand may be left open, permanently draining water But is that different if the connection is from below the tank? Let us imagine a scheme with one tap far from the main command area. Let's see what happens in two cases.

1. *If the single tapstand is left open day and night. In this case, whether the connection is above or below the reservoir, in any case the tap takes away a lot of water and the others may have a shortage.*
2. *If the isolated tapstand is constantly open in the day but closed in the night. In this case the reservoir fills up in the night. If the high tapstand is from below the*

reservoir, in the morning it takes away the incoming water as well as the water stored in the reservoir during the night. If it is connected from above the reservoir, then the high tapstand can take way the incoming water during the day, but it can no longer drain the water that filled the reservoir in the night!

This example shows that almost the opposite is true from what is often believed: Connections from below the reservoir may waste more water and be a bigger thread to the security of others, than taps from above... The main reason why many direct connects are not common is that they require that the transmission pipeline needs to be designed to supply their tap flow, in stead of the much lower CDF

*Example. A community of 120 people, served by 15 tapstands, is situated very far from its large stream source. Three scattered households (with 8 people each), each with a separate tapstands, stand a bit higher above the village. If all are served from one tank, the (long) transmission mainline capacity needs to be 120*1.5*45.86400=0.1lps. If three households are served directly from the mainline, the capacity of that entire line should preferably be 96*1.5*45:86400+3*0.1=0.4lps, but at least 0.3lps.*

Note that 'preference of flow' also relates to this issue. In over-designed branch (and supply-) lines, which cause the residual head at the TEE point to be zero, the water will flow more or entirely into the branch whose pipe is lower at the TEE point itself, or the pipe that is heading in the direction of the flow velocity. For TEE points with pressure, the flow goes more in the pipe with a higher capacity, that is the larger and/or steeper pipe

5 'Special' design

The objective of 'special' designs is to make large or scattered schemes easier to operate and manage, and sometimes to save considerable cost 'Special' designs should be made for schemes which are so large or scattered[5] (but which cannot be split, for lack of independent sources) that the farest households will almost certainly face water problems if a conventional design is applied.
The 'special' designs have been simplified (in comparison to literature and earlier drafts of this document), to minimise critical and complicated features in implementation, but still need more than average attention during construction. As a means to communicate these technical instructions to the implementers an 'Implementation guideline' is proposed.
The basic method to reach the objective of special designs (increased independence of sub-schemes), is to split schemes into sub-schemes, each with a more or less independent supply. And preferably that splitting of flows is done by pipe sizing, rather than by valves, which require knowledge and consensus from the part of the communities involved, which is especially difficult in large schemes with limited available water. Flow regulation by valves also requires a quality of valves that perpetuate the same adjustment (be it in absolute terms or in percentage), even if pressures fluctuate; a feature that some of the valves used by the RWSS program, and definitely the locally available valves, unfortunately do not have. The option of proportional (in stead of fixed) water division by carefully equal levelling of over-designed tank outlets (as proposed in the revised manual Gravity Water Supply schemes, published in Nepal) was also discarded for sensitivity to implementation mistakes.

Categorisation

Initially aim to identification sub-schemes with 5-10 tapstands (later some sub-schemes may be clubbed together). If one or more tapstands are vertically more than 100m below or above the nearest other tapstand, sub-schemes smaller than 5 tapstands can be identified. The Dzongkhag surveyor can be very helpful in this process, because he knows which households are considered as one village.
You may find one or more of the following:

1. Sub-schemes of comparable size below each other (in series)
2. Sub-schemes of comparable size next to each other (parallel)
3. One or a few taps relatively far away from one (or more) larger sub-scheme(s)

The below sections discuss what to do in different cases; if a particular scheme has more than one of the above characteristics, refer to all concerned sections, noting that the options are interdependent! (E.g Designing open flow to a far tapstand below a sub-scheme influences the required flow to that sub-scheme and from the source)! The sections also assume that the safe source yield is at least 1.1 * the CDF of all below

[5] The following criteria indicate in which cases a 'special' design is recommended (for which involvement of PHE/HD at least in design may be required):

- Large in number of tapstands (more than 20 tapstands)
- Large in number of beneficiaries (more than beneficiaries)
- Large in command area (highest and lowest tapstand are vertically more than 500m apart)
- Scattered (more than 200m vertical drop between two adjacent tapstands and/or more than 500m ground distance between two adjacent tapstands)

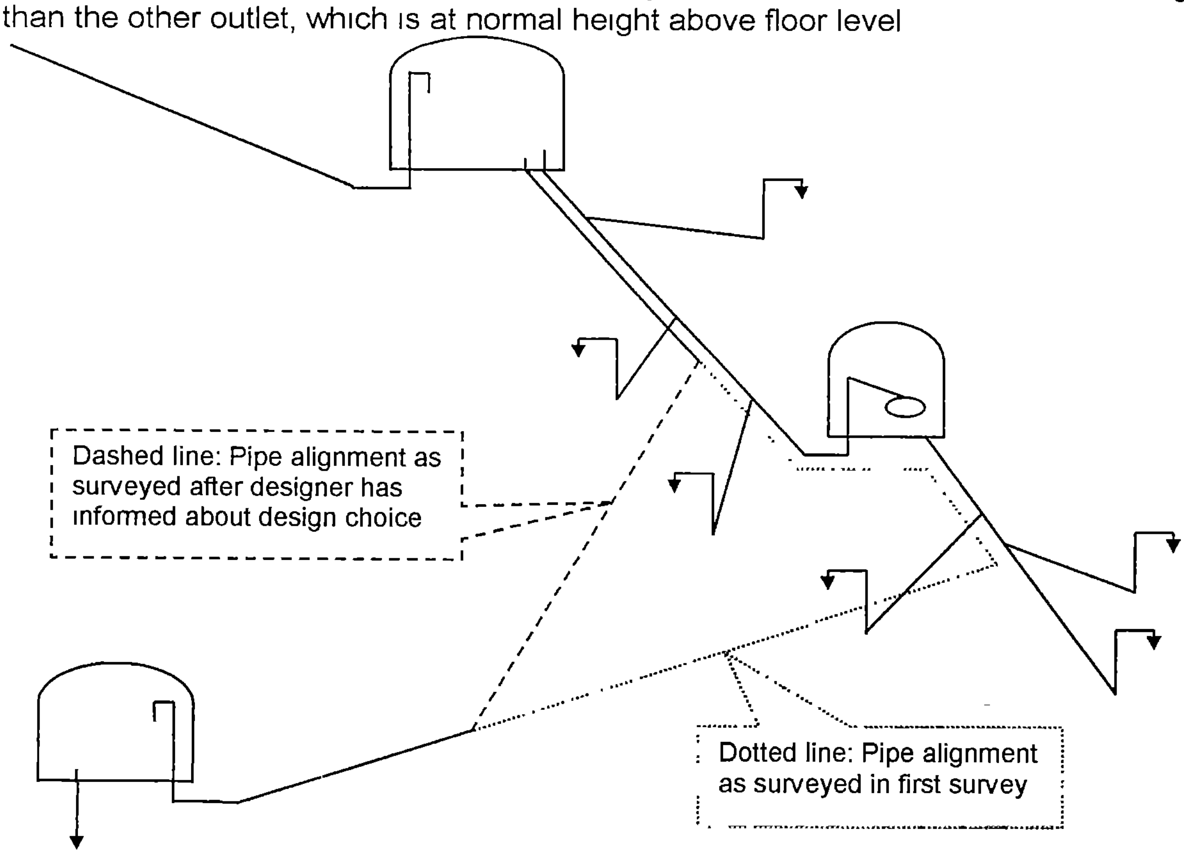
tapstands. If this is not the case with the normal per capita demands, reduce *all* demands accordingly with one and the same percentage. You may also do the reverse. If ample water is available, and especially if the scheme is very large, you may add 50% to all per capita demands before starting design.

Pipe Specifications: Raw material

HDP pipes are named by their outer diameter, such as 32mm class IV etc. The inner diameter of HDP pipes depends on the class (pressure rating), and the raw material Until 1995 all HDP pipes used in RWSS in Bhutan were made from a raw material called 'PP 63' (This is the best material described in Indian Standards Manuals from 1987 and earlier). Since 1995, however, also 'PP 80' is available, a stronger plastic. Pipes of the same strength (class) and outer dia, but made from this material, have a smaller inner diameter. This makes them more difficult to weld and, and this is relevant for the below discussions, makes that more water can flow through the same pipe If pipes from 'PP 80' are used, please realise that the Frictional head loss Factor tables in the July 1998 revised Standardisation manual, and the calculations by the current design program, are no longer valid (actual flows will be more than calculated, especially for the smaller pipes).

5.1 Series

Locate tanks at the top of the sub-schemes, and lead the source flow first into the top reservoir Design two outlets from that first reservoir: One to the tapstands served directly by that tank and one to the sub-scheme(s) below (see below) In most cases the outlet to the distribution line to the nearby sub-scheme should be 10-15cm higher than the other outlet, which is at normal height above floor level



The text boxes in the drawing on the previous page point at an important point regarding schemes in series: After deciding on the clustering into sub-schemes, the designer should ask a surveyor to re-survey the most suitable pipe alignment from the above to the lower reservoir(s). This pipeline will in most cases be shorter than originally surveyed, as it may already branch-off from the main distribution pipeline before it reaches its last tapstand (while during original survey the pipe to the lower sub-schemes went down to that tap, and then bend to the next sub-scheme) See also the section on implementation aspects of 'special' designs, at the end of this chapter.

Sub-Categorisation

The sub-sections below will discuss the different options that one may choose, in relation to the availability (and nearness) of water. To decide on the options, first a few calculations should be carried out:

- Calculate the safe yield, as 0.8 * measured dry season yield (or 0.5 * measured yield in case of uncertain catchment area management, e.g. tsheri)
- Calculate the Total Tap Flow for the upper sub-scheme (number of taps * 0 1lps)
- Calculate the CDF for all sub-schemes, using the standard per capita demands, or multiplying these by up to 1.5 if the scheme is rather large, or 'semi-urban' In case of water shortage (taking the 10% extra for all lower sub-schemes into account), but no alternative sources, decrease *all* per capita demands with an equal factor
- Calculate the natural flow for the transmission pipeline(s) below the first reservoir for a 20mm class V and 16mm class V HDP pipe (and for GI ½" pipe)
- 'Calculate' whether the transmission pipeline to the first sub-scheme is long or short: We will define it as 'long' if it has more than 2000m HDP pipe and/or 500m GI

Typology

IF **Source near** upper sub-scheme (pipe less than 2000m HDP, and/or 500m GI),
IF $NF_{lower} \leq CDF_{lower}$, THEN
$DF_{upper} = (TTF_{upper} + CDF_{lower}) * 1.1$, AND
$DF_{lower} = CDF_{lower}$, ELSE
IF $(TTF_{upper} + NF_{lower, 20mm}) * 1.1 \leq SY$
$DF_{upper} = (TTF_{upper} + NF_{lower, 20mm}) * 1.1$, AND
$DF_{lower} = NF_{lower, 20mm}$, ELSE
Look under 'Source not near'

IF **Source not near** upper sub-scheme,
IF $(CDF_{upper} + NF_{lower, 20mm}) * 1.1 \leq SY$, THEN
$DF_{upper} = (CDF_{upper} + NF_{lower, 20mm}) * 1.1$, AND
$DF_{lower} = NF_{lower, 20mm}$, ELSE
IF $(CDF_{upper} + NF_{lower, 16mm}) * 1.1 \leq SY$, THEN
$DF_{upper} = (CDF_{upper} + NF_{lower, 16mm}) * 1.1$, AND
$DF_{lower} = NF_{lower, 16mm}$, ELSE
COMBINE SUB-SCHEMES, OR
MAKE SMALL HOLE
$DF_{upper} = (CDF_{upper} + CDF_{lower}) * 1 1$, AND
$DF_{lower} = CDF_{lower}$, OR
INSERT CONTROL BPT 50-100m VERTICALLY BELOW UPPER TANK·

DF_{upper} = (CDF_{upper} + CDF_{lower}) * 1.1, AND
DF_{lower} = $NF_{lower, 20mm (or 16mm)}$, OR
INSERT CONTROL BPT ≤ 50m VERTICALLY ABOVE UPPER TANK:
$DF_{above BPT}$ = (CDF_{upper} + CDF_{lower}) * 1.2, AND
DF_{upper} = $NF_{upper, 20mm (or 16mm)}$, AND DF_{lower} = $NF_{lower, 20mm (or 16mm)}$

The possibilities listed above are further described in the following sub-sections. But first, for completeness, find below what to do if there are more than two sub-schemes.

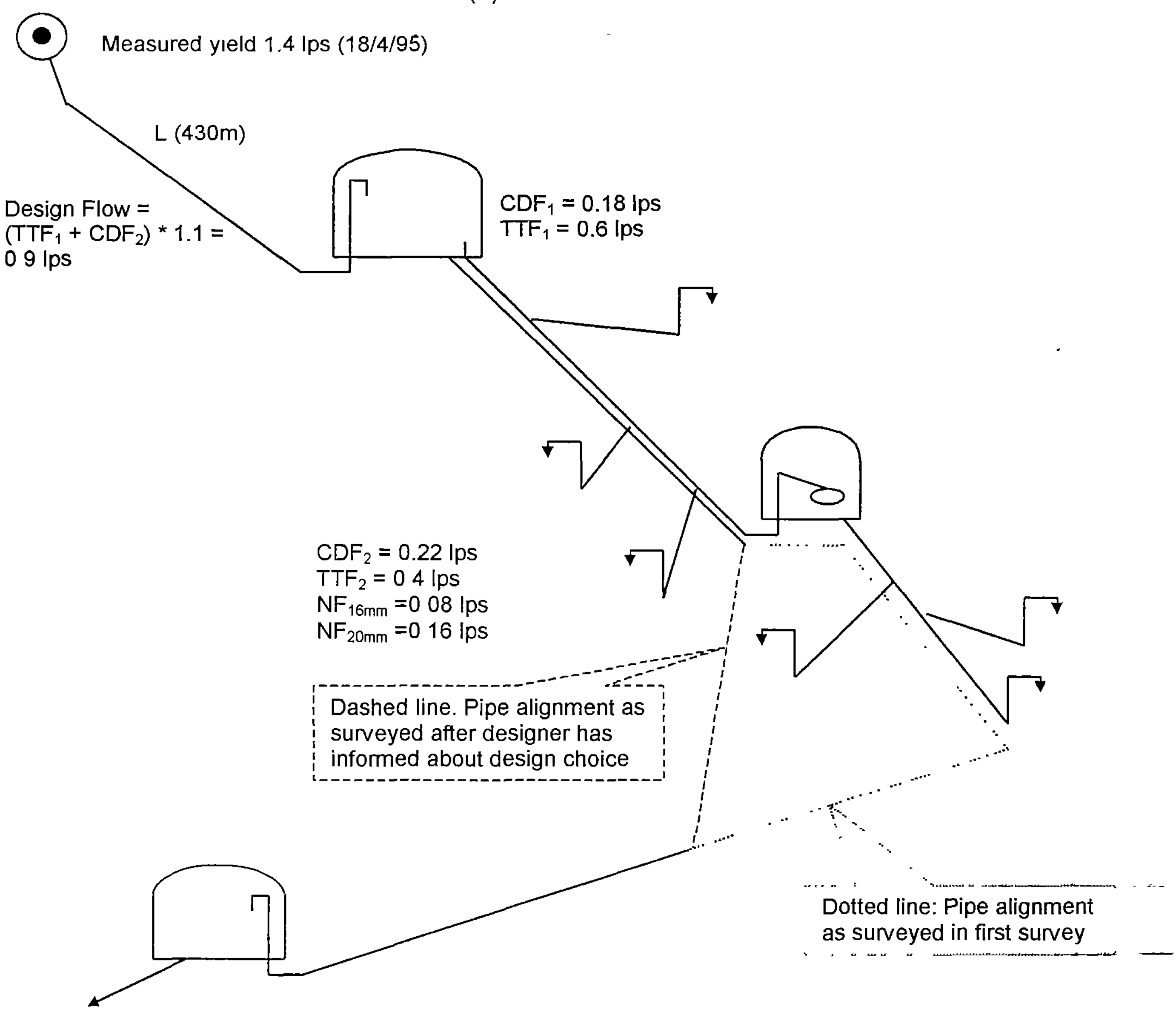
Design Flow (n sub-schemes)

If there are more than two sub-schemes in series, start from the lowest (n).
IF $NF_{n, 20mm}$ ≤ CDF_n, THEN DF_n = CDF_n,
AND DF_{n-1} = (CDF_n + CDF_{n-1}) * 1.1,
AND DF_{n-2} = (DF_{n-1} + CDF_{n-2}) * 1.1, etc, ELSE
IF (((etc (((CDF_1 + CDF_2) * 1 1) + CDF_3) * 1.1, ... + $NF_{n-1, 20mm}$) * 1.1) + $NF_{n, 20mm}$) * 1.1 ≤ SY, THEN DF_n = $NF_{n, 20mm}$,
AND DF_{n+1} = $NF_{n, 20mm}$,
AND DF_{n+2} = ($NF_{n, 20mm}$ + CDF_{n-1}) * 1.1, ...
AND DF_2 = (DF_3 + CDF_2) * 1.1,
AND DF_1 = (DF_2 + CDF_1(or TTF_1)) * 1.1, ELSE
IF (((etc (((CDF_1 + CDF_2) * 1.1) + CDF_3) * 1 1, ... + CDF_{n-1}) * 1.1) + $NF_{n, 16mm}$) * 1.1 ≤ SY, THEN DF_n = $NF_{n, 16mm}$,
AND DF_{n-1} = $NF_{n, 16mm}$,
AND DF_{n-2} = ($NF_{n, 16mm}$ + CDF_{n-1}) * 1.1, ..
AND DF_2 = (DF_3 + CDF_2) * 1.1,
AND DF_1 = (DF_2 + CDF_1(or TTF_1)) * 1 1, ELSE
DF_n = CDF_n
AND DF_{n-1} = (DF_n + CDF_{n-1}) * 1.1,
AND DF_{n-2} = (DF_{n-2} + CDF_{n-2}) * 1.1, ...
AND DF_2 = (DF_3 + CDF_2) * 1.1,
AND DF_1 = (DF_2 + CDF_1(or TTF_1)) * 1.1

5.1.1 Up TTF, down CDF

If the source is large and nearby the first sub-scheme, and the CDF of the lowest sub-scheme is larger than the natural flow of 20mm pipe, we can supply TTF to the upper sub-scheme, and CDF to all the lower sub-schemes. In this case we may well use a 'large CDF'. The per capita demands multiplied by 1.5.

Re-survey:	Re-survey the shortest pipe alignment between the upper and lower reservoir(s) before final design
Design/Estimate:	The upper reservoir has two outlets, of which the outlet to the nearby sub-scheme should be 10-15cm higher than normal: Change this in the threading table!
Implementation guideline:	Communicate very clearly with the implementers the critical points: The outlets from the first reservoir and their levelling, and the pipe size(s) to the lower sub-scheme(s)



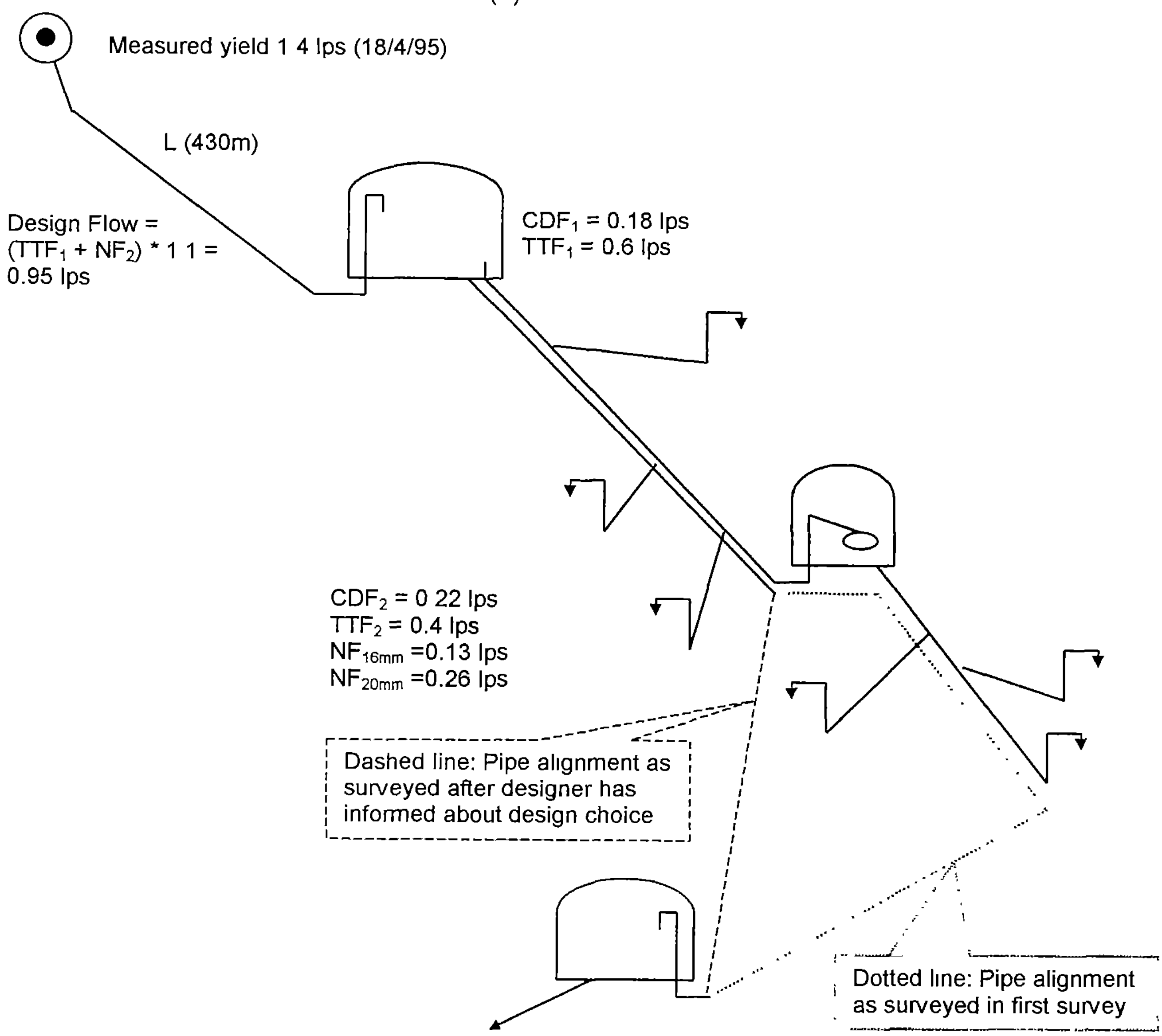
5.1.2 *Up TTF, down NF_{20mm}*

If the source is large and nearby the first sub-scheme, and the CDF of the lowest sub-scheme is smaller than the natural flow of 20mm pipe, we can supply TTF to the upper sub-scheme, and design 20mm to the lowest sub-scheme. If there are more than two sub-schemes, the 'in between' sub-scheme all receive CDF (or $NF_{20mm} - DF_{below}$ in the exceptional case that this is still more than the CDF of the sub-scheme). Also in this case we may well use a 'large CDF': The per capita demands multiplied by 1.5.

Re-survey: Re-survey the shortest pipe alignment between the upper and lower reservoir(s) before final design

Design/Estimate: The upper reservoir has two outlets, of which the outlet to the nearby sub-scheme should be 10-15cm higher than normal: Change this in the threading table!

Implementation guideline: Communicate very clearly with the implementers the critical points. The outlets from the first reservoir and their levelling, and the pipe size(s) to the lower sub-scheme(s)

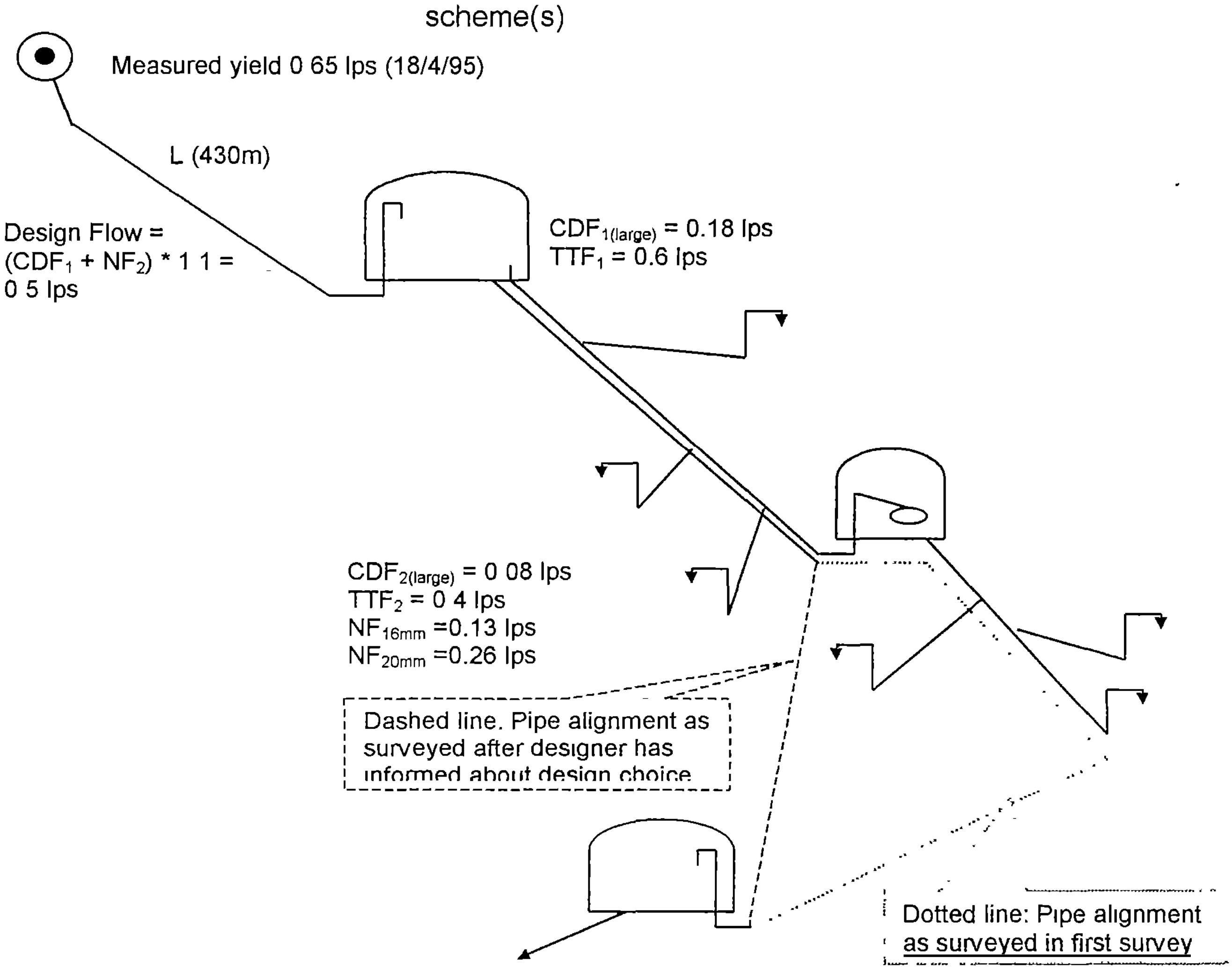


5.1.3 Up CDF, down NF_{20mm}

If the source is quite large and nearby the first sub-scheme, but not large enough to supply TTF to the upper sub-scheme if we supply natural flow 20mm to the lowest sub-scheme (of which the CDF is smaller than the 20mm natural flow), than we can design CDF to all sub-schemes, except for the last which receives a larger flow. We should also choose this option if the source is sufficient to supply TTF to the first sub-scheme on top of the supply to the lower schemes, but it is far away (more than 2000m HDP pipe and/or 500m GI).

(In exceptional cases the second lowest scheme also receives more than CDF, if $NF_{20mm} - DF_{below}$ is still more than the CDF of the second lowest sub-scheme). Also in this case we may use a 'large CDF' (the per capita demands multiplied by 1.5), but not if that necessitates us to use 16mm, while the source is a stream.

Re-survey:	Re-survey the shortest pipe alignment between the upper and lower reservoir(s) before final design
Design/Estimate:	The upper reservoir has two outlets, of which the outlet to the nearby sub-scheme should be 10-15cm higher than normal: Change this in the threading table!
Implementation guideline:	Communicate very clearly with the implementers the critical points: The outlets from the first reservoir and their levelling, and the pipe size(s) to the lower sub-scheme(s)



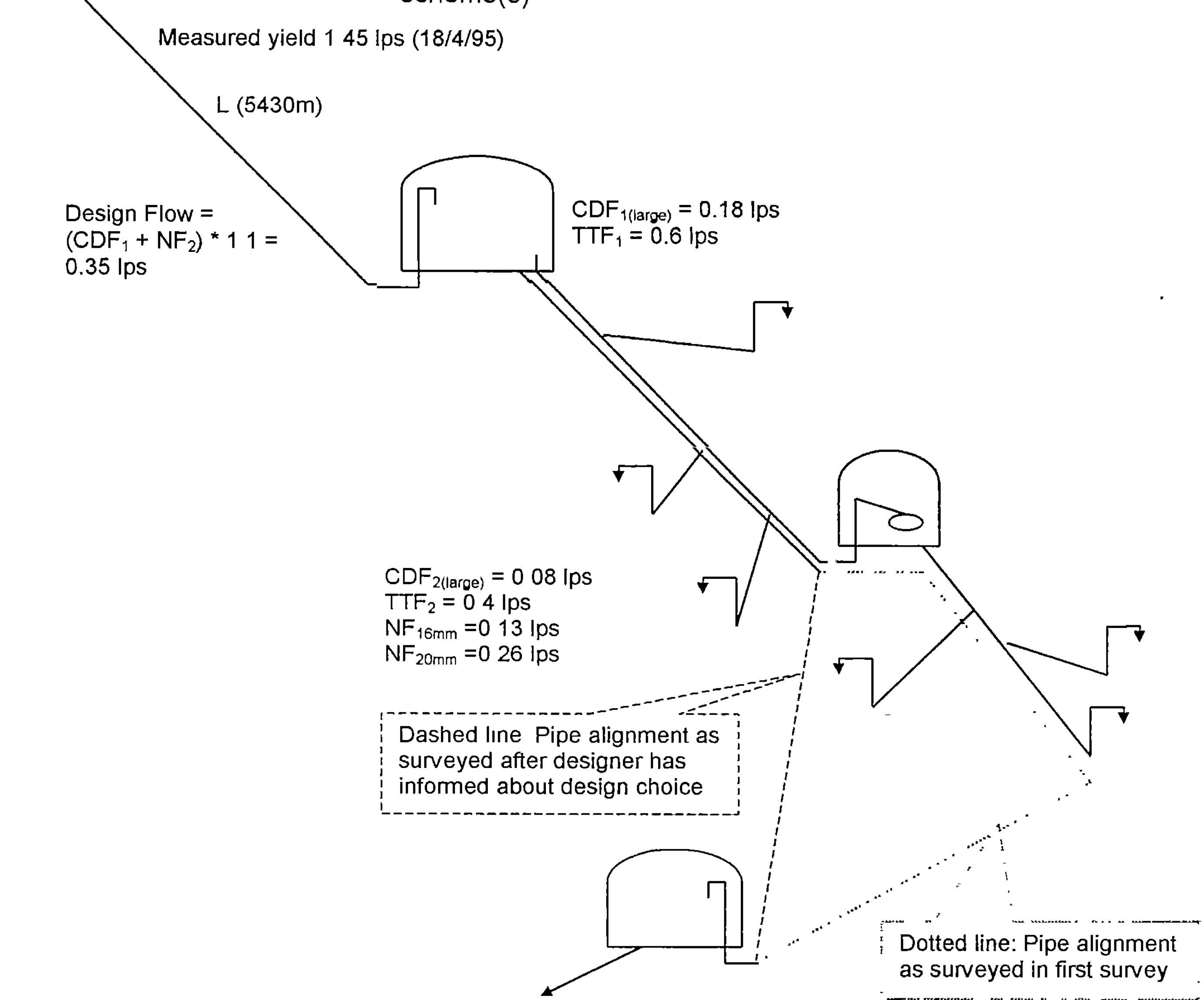
5.1.4 Up CDF, down NF_{16mm}

We go for the option of 16mm to the lower sub-scheme(s), if the safe source yield is not large enough (or if the source is very far away) to supply natural flow 20mm to the lowest sub-scheme(s) and CDF to the higher sub-schemes. (Under this arrangement, the second lowest scheme also receives more than CDF, if $NF_{20mm} - DF_{below}$ is still more than the CDF of the second lowest sub-scheme). If still possible, we may also in this case use a 'large CDF': The per capita demands multiplied by 1.5.

Re-survey: Re-survey the shortest pipe alignment between the upper and lower reservoir(s) before final design

Design/Estimate: The upper reservoir has two outlets, of which the outlet to the nearby sub-scheme should be 10-15cm higher than normal: Change this in the threading table!

Implementation guideline: Communicate very clearly with the implementers the critical points: The outlets from the first reservoir and their levelling, and the pipe size(s) to the lower sub-scheme(s)

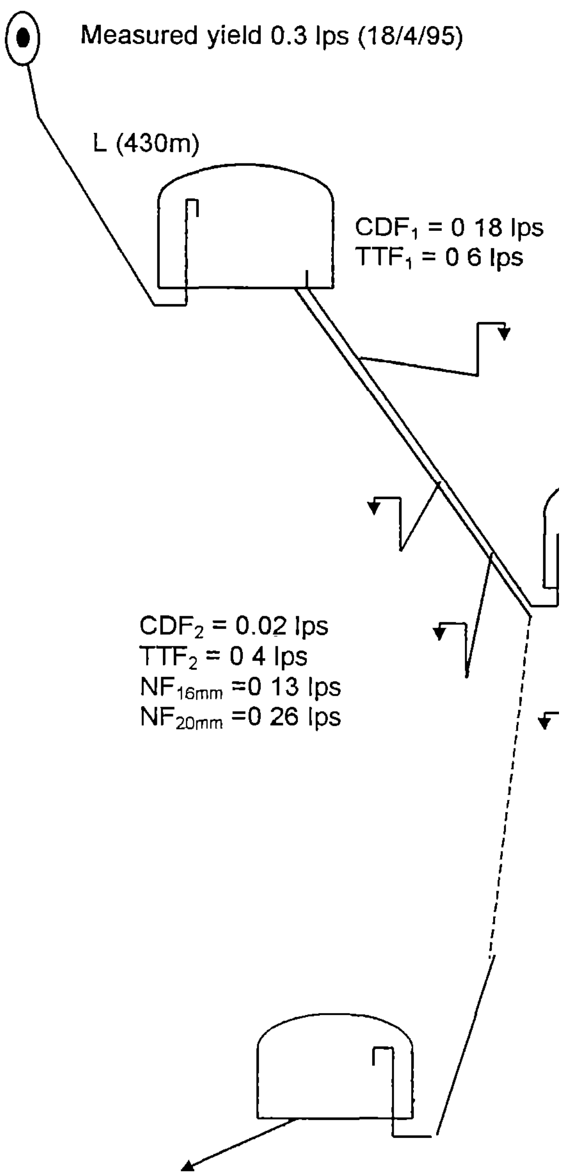


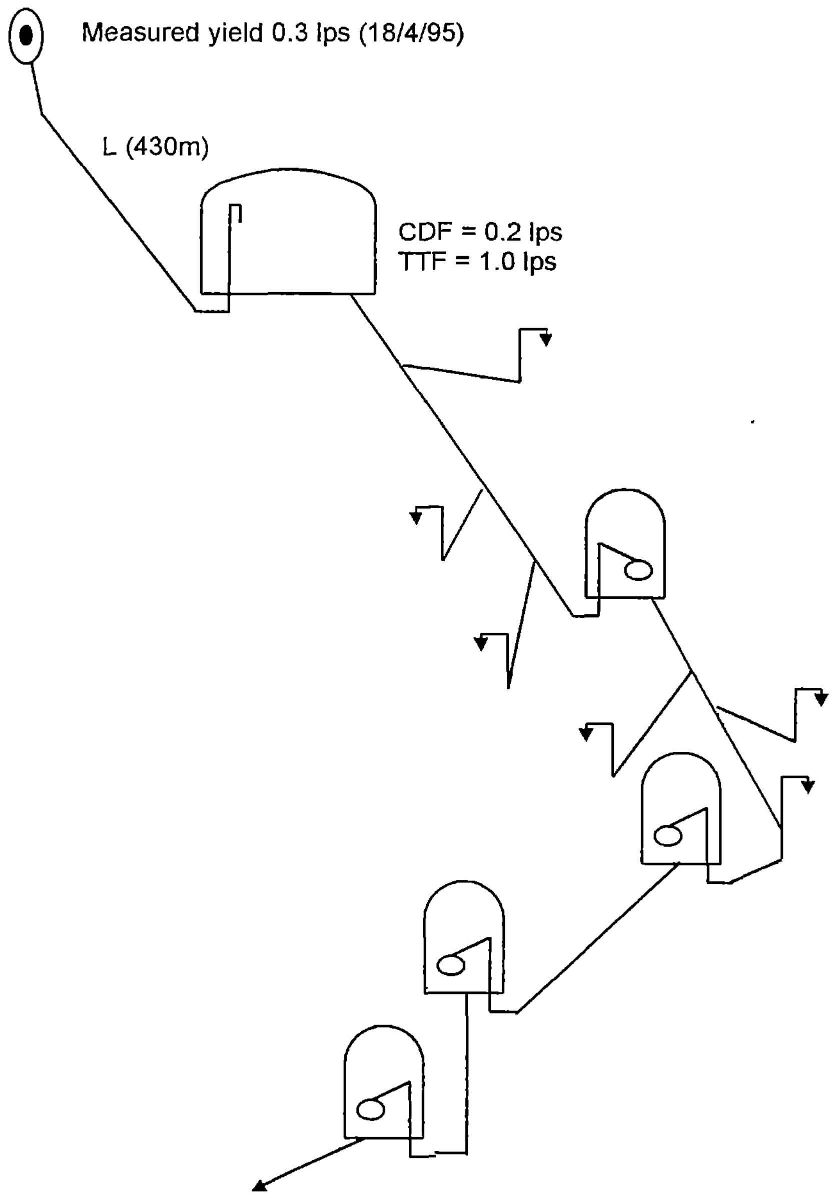
5.1.5 Little (or far) source

Below you will find some options for projects with sub-schemes where the water is insufficient (or the source too far away) to supply CDF to the upper, and natural flow (even using 16mm) to the lower sub-scheme(s). The options are not numbered, because they are all options for the same situation (insufficient water for flow control by pipe size). Basically we have the options of combining sub-schemes (making people more interdependent again), or to taking measures to regulate the flow, which can be done by a smaller outlet than normal, with valves, or by proportional water division over well-levelled, over-designed outlets (not preferred).
As in other options above, it is advisable to multiply the CDF by 1.5 if possible.

Less sub-schemes

Make bigger clusters, like in 'normal' design, as in the right below example.





Small hole (in overflow)

A smaller hole than the normal 1" (or larger) outlets, will allow a smaller amount of water to flow to the lower sub-scheme(s), even if the pipe capacity of the pipe below is much larger The flow through such a hole can be approximated as:

$$\mathbf{Q = 0.7 * A * \sqrt{(g * h)}} \qquad \text{Units: } [m^3/s] = [m^2] * \sqrt{(m/s^2 * m)}$$

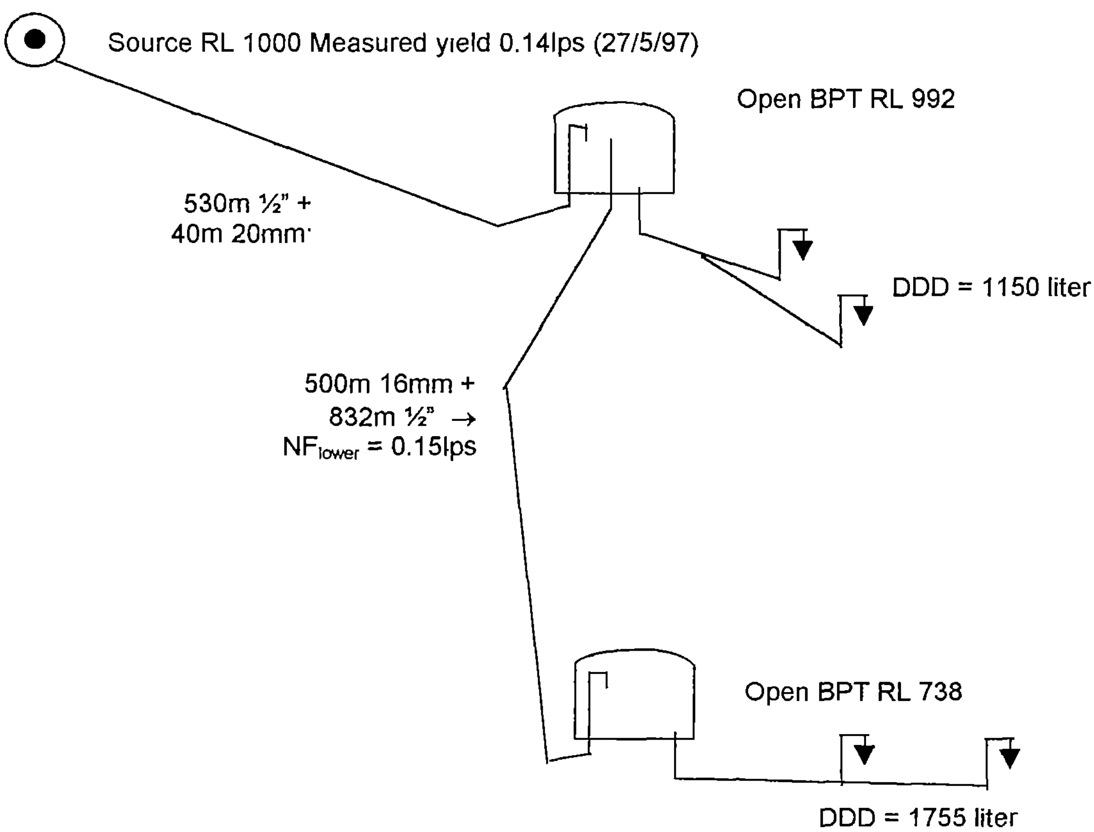
In which 'A' is the surface area of the hole in m^2, that is $(\pi * D^2) / 4$, 'g' the gravitational acceleration (which may be taken as $9.7 m/s^2$, though actually it depends on the RL), and 'h' the height of the water column above the hole, also in meters. This height depends on how full the tank is, and how high below floor level the hole is made.
In most cases that the natural flow to the lower sub-scheme(s) is unacceptably large, the upper sub-scheme is also small, and the tank from which the nearby peak-flow and the below continuous flow split, is an open BPT, or else a 1½m³, or 2½m³ FCR. In such cases the lower sub-scheme may be served from the overflow of the upper tank, and the hole should be made 2cm below the normal outlet to the nearby sub-scheme. Given the thickness of soling etceteras, this means **in a BPT 18cm from the lower end of the pipe** (and 38cm in the mentioned FCR's), and 52 below the end of the overflow (122cm below the overflow TEE in the other two tanks). Combined with larger tanks, the 'small hole' option is not attractive, since the water level (and therefore the flow to the lower scheme) than changes even more. **Co-ordinate with central stores!**
Note that the function of the hole is to secure that at least only a small amount of water reaches the lower sub-scheme, so that the lower beneficiaries even receive *some* water if the upper sub-scheme wastes water, and the open BPT (tank) never overflows. Although we prefer to supply CDF_{lower} even if the upper tank is empty (only 2cm water layer over the hole), this can in most cases not be done. This is because we also wish that at least CDF_{upper} remains for the upper sub-scheme if the open BPT (tank) is three-fourth full. If this is not the case the upper sub-scheme is in a disadvantaged position, and may have water shortage when taps are opened for longer than it takes to empty the BPT storage. This would encourage the upper beneficiaries to store water in private tanks, by leaving their tap(s) running.
The below table shows the amount of water from different sizes of holes, if the tank is practically empty or three-fourth full.

	Tank empty (h=0.02m)		BPT ¾-full (h=0 40m)		1½ or 2½m³ FCR ¾-full (h=0.92)	
	lps	lpd	lps	lpd	lps	lpd
3mm	0.0022	189	0 0098	844	0.0148	1279
4mm	0.0039	335	0.0174	1500	0.0263	2274
5mm	0.0061	524	0.0271	2343	0.0411	3554
6mm	0.0087	754	0.0391	3374	0.0592	5117
7mm	0.0119	1027	0 0532	4593	0.0806	6965
8mm	0.0155	1341	0.0694	5999	0.1053	9097
9mm	0.0196	1698	0.0879	7592	0.1333	11514
10mm	0 0242	2096	0 1085	9373	0.1645	14214

Consider the following example:

- Safe yield = 0.11lps
- Natural $flow_{16mm}$ between the sub-schemes = 0.15lps
- Upper 17 rural beneficiaries (DDD_{upper} = 1150 liter, CDF_{upper} = 0.013lps)
- Lower 26 rural beneficiaries (DDD_{lower} = 1755 liter, CDF_{lower} = 0.020lps)

Obviously flow control by pipe sizing is ruled out, but there is sufficient water to supply 1.5 times CDF. To make the lower beneficiaries less dependent on good behaviour by the upper sub-scheme beneficiaries, we make a hole 18cm above floor level in the upper BPT. We wish to guarantee a supply of $CDF_{lower, large}$ (0.03 lps) to the lower sub-scheme. Only a 12mm or larger hole (not shown in the table) could guarantee such a flow, even if the upper taps are left open constantly, and the height of the water layer above the hole is only 2cm. But this is not the only criteria we have to look at: Let us also check that the hole is not so large that the tank is too easily drained and leaves too little for the upper beneficiaries.
The hole should at the most leave the entire supply flow (0.11lps) minus CDF_{upper} (0.03lps) through when the BPT is three-fourths full (thus 0.08lps). Thus the largest hole can be 8mm, and since this is smaller than the largest hole of 12mm, we select 8mm.



Finally we should check whether the tanks are large enough. As available flow take the situation of ¾th filling of the upper tank (thus in our example 0.07lps to the lower sub-scheme, and to the upper 0.11- 0.07 = 0.04lps). For the upper tank the capacity available should be taken as ¾th (in our case 318 * ¾ = 238 litre)
For the actual calculations refer to Size Reservoir at page18.

Extra BPT above upper tank: Small hole (high outlets)

Another option, especially if the ¾th-full criteria cannot be met, while still supplying CDF_{large} to the lower sub-scheme, is to design an additional open BPT a little above the upper sub-scheme From this BPT to the first tank design parallel lines
This BPT should have raised outlets, the outlet to the 'no-control' pipeline should be 45cm (in stead of 5cm) above floor level (making it 60cm long), and the control outlet should be 50cm above floor level (thus 65cm long). The hole in the control outlet(s) should be made 5cm above floor level (45cm below the top and 20cm above the bottom end of the pipe). Provide the hole to the sub-scheme(s) with the highest DDD.
The below table shows the amount of water from different sizes of holes. Note that the flow now no longer fluctuates depending on the use of either of the sub-schemes.

Yield	3mm	4mm	5mm	6mm	7mm	8mm	9mm	10mm
In lps	0.0098	0.0174	0.0271	0.0391	0.0532	0.0694	0.0879	0.1085
In lpd	844	1500	2343	3374	4593	5999	7592	9373

Choose a hole size through which the CDF (if possible multiplied by 1.5) can flow, and if there is more yield divide the 'extra water' roughly proportionally. However, realise that a hole has a tendency to be drilled too large; therefore over-design less to the control sub-scheme(s) than to the no-control sub-scheme.

Design/Estimate: The open division BPT has two (or more) outlets, of which the outlet to the not-controlled sub-scheme should be 40cm longer than normal (thus 60cm long), and the control outlet(s) 45cm longer (thus 65cm long): Change this in the threading table! The hole should be made 20cm from the bottom of the pipe!

Implementation guideline: Communicate very clearly with the implementers the critical point: The outlets from the open division BPT and that the hole should be on the lower half of the outlet pipe (else it may be fitted upside down, and leave little water through)

Below find a descriptive example related to parallel schemes.

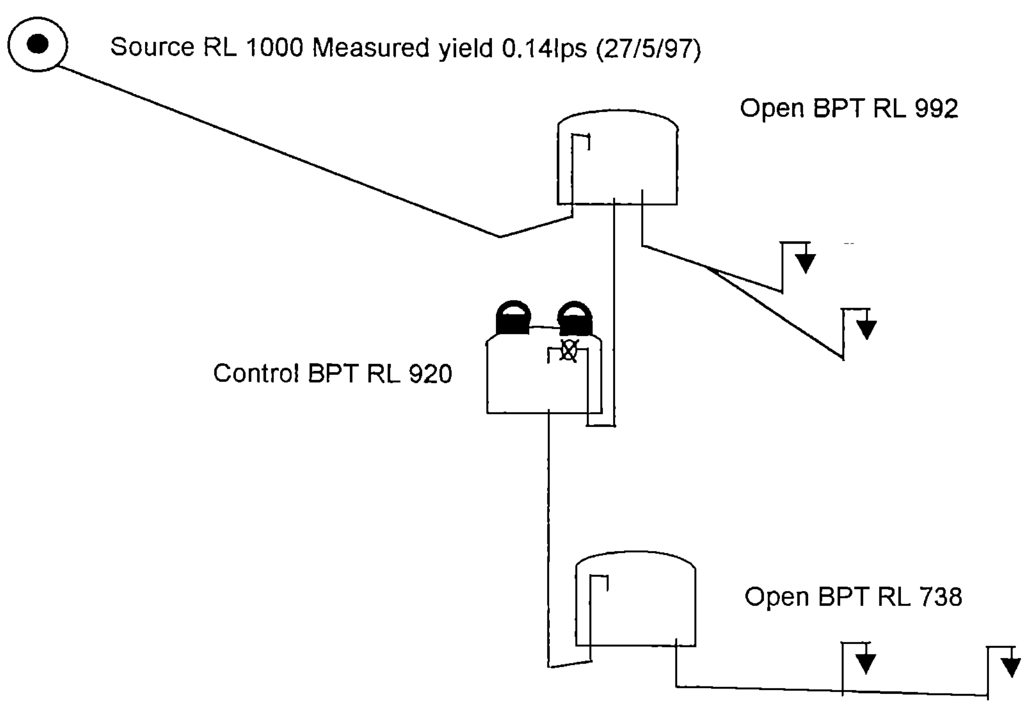
- Safe yield = 0.11lps
- Natural $flow_{16mm}$ between the sub-schemes = 0.15lps
- Upper 37 rural beneficiaries (DDD_{upper} = 2500 liter, CDF_{upper} = 0.029lps)
- Lower 56 rural beneficiaries (DDD_{lower} = 3800 liter, CDF_{lower} = 0.044lps)

Obviously flow control by pipe sizing is ruled out, but there is sufficient water to supply 1.5 times CDF. We design a BPT at the surveyed TEE point and make a hole 20cm above floor level in the 65cm long outlet. We will connect the lower sub-scheme to this pipe, because its DDD is the largest. If we divide the safe yield proportionally, the lower sub-scheme should receive (0.11 : (0.029 + 0.044)) * 0.044 = 0.066lps. We look select 6mm.

Extra BPT below upper tank: Control valve

Between the upper and lower sub-scheme(s), we may design a control BPT some 50-100m below the upper tank, to adjust the continuous flow to the lower sub-scheme(s) Note that the same cannot be done from the control valve in the outlet of the upper tank for a technical reason· The water layer above that valve fluctuates by 350% (for a BPT) to 500% (for $6m^3$ and most larger reservoirs) when the tank is empty or full. Therefore the flow would fluctuate considerably under one and the same adjustment (see also 'small hole'), making it very difficult for the beneficiaries to understand and agree on an acceptable division.
If you consider this option, note that three disadvantages remain: The adjustment is relatively skilled work, the adjustment may lead to conflict, and the valve may dis-adjust spontaneously (although this is less likely with a more or less constant pressure). If you nevertheless choose for this option, if still possible, design for a 'large CDF': The per capita demands multiplied by 1.5.

Re-survey:	Re-survey the shortest pipe alignment between the upper and lower reservoir(s) before final design
Design/Estimate:	The upper reservoir has two outlets, of which the outlet to the nearby sub-scheme should be 10-15cm higher than normal: Change this in the threading table! The BPT is without float valve, but with a valve on the inlet (design as open, but add one valve). Also add two padlocks for the control BPT
Implementation guideline:	Communicate very clearly with the implementers the critical points. The outlets from the first reservoir and their levelling, and the adjustment of the control valve in the control BPT (see also example of internal management agreement). The latter needs to be communicated and practised extensively with the caretaker(s) and VHDC members



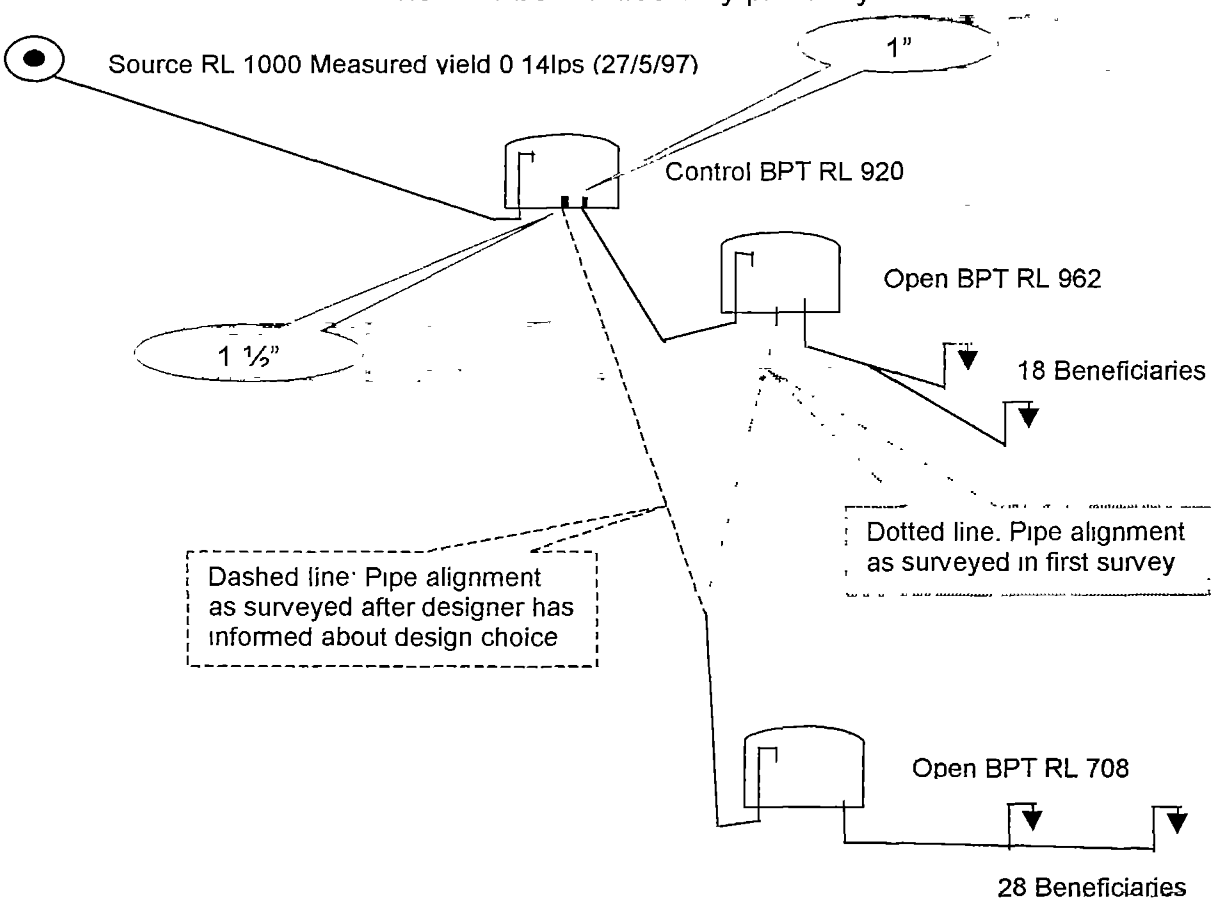
Extra BPT above upper tank: Proportional

Locate an open control BPT at any place above the upper reservoir (not too far above, because the flows split from the BPT, and if it is far this means a lot of parallel pipe). The sizes of the equal levelled outlets determine per which ratio the continuous flows will be divided. The principal is to divide water proportionally over even levelled outlets. As long as the water layer above these outlets is thin, the amount of water flowing into each outlet is proportional to its dia. A 2" outlet, for example, has double the circumference of a 1" outlet, and if these pipes are the only two outlets from a tank, they would receive $^2/_3$ (66%) and $^1/_3$ (33%) of a small flow respectively (whereas, if the flow is large, they would receive $^6/_7$ (85%) and $^1/_7$ (15%) respectively). To keep the water layer thin, the outlets should be over-designed for the given amount of water[6].

As mentioned in the first paragraphs of this chapter on page 33, I do not prefer this option, though it is mentioned in literature from Nepal, because the levelling of the outlets from this BPT is quite critical. If one outlet is half a centimetre lower, it may receive all water, so that the other sub-scheme(s) receive non at all.

Re-survey: Re-survey the shortest pipe alignment between the control BPT and lower reservoir(s) before final design

Implementation guideline: Communicate very clearly with the implementers the critical point: The control BPT has two outlets, which need to be levelled very precisely



[6] There is also a possibility of controlling flow not over the outlet circumference, but over the whole pipe section up to the air vent (after which the pipe capacity should then increase!). In this option the water level over the outlets raises well above the outlets and outlet levelling is less critical. This design is relevant alone for larger flows, which in our view can more easily be controlled by pipe sizing

5.2 Parallel

Locate tanks at the top of the sub-schemes.

Sub-Categorisation

The sub-sections below will discuss the different options that one may choose, in relation to the availability (and nearness) of water. To decide on the options, first a few calculations should be carried out:

- Calculate the safe yield, as 0.8 * measured dry season yield (or 0.5 * measured yield in case of uncertain catchment area management, e.g. tsheri)
- Calculate the Total Tap Flow of the sub-schemes (number of taps * 0.1lps)
- Calculate the CDF for all sub-schemes, using the standard per capita demands, or multiplying these by up to 1.5 if the scheme is rather large, or 'semi-urban'. In case of water shortage (taking the 10% extra for all lower sub-schemes into account), but no alternative sources, decrease *all* per capita demands with an equal factor
- Calculate the natural flow for the transmission pipeline(s) below the first reservoir for a 20mm class V and 16mm class V HDP pipe (and for GI ½" pipe). At TEE points assume 10m residual head (or half the static head for TEE points within 20m vertically below a zero pressure point)
- 'Calculate' whether the transmission pipeline to each sub-scheme is long or short: We will define it as 'long' if there is more than 2000m HDP pipe and/or 500m GI between any sub-scheme and the source.

Typology

IF **Source near all** sub-schemes (pipeline less than 2000m HDP, and/or 500m GI):
IF $(TTF_1 + TTF_2) * 1.1 \leq SY$, AND $NF_{1, 20mm} \leq TTF_1$, AND $NF_{1, 20mm} \leq TTF_1$, THEN
DIVIDE FROM TEE: $DF_{above\ TEE} = (TTF_1 + DF_2) * 1.1$,
AND $DF_1 = TTF_1$,
AND $DF_2 = TTF_2$, ELSE
Look under 'Source far from all'

IF **Source near one, far from other** sub-scheme(s):
IF $(TTF_{near} + CDF_{far}) * 1.1 \leq SY$, THEN
IF $NF_{far, 20mm} \leq CDF_{far}$, AND $RL_{TEE} - RL_{neraby\ tank} \geq 50m$, THEN
DIVIDE FROM TEE:
$DF_{above\ TEE} = (TTF_{near} + CDF_{far}) * 1.1$, AND
$DF_{near} = TTF_{near}$, AND $DF_{far} = CDF_{far}$, ELSE
DIVIDE FROM OPEN BPT:
$DF_{above\ TEE} = (TTF_{near} + CDF_{far}) * 1.1$, AND
$DF_{near} \geq TTF_{near}$, AND $DF_{far} = CDF_{far}$, ELSE
IF $(TTF_{near} + NF_{far, 20mm}) * 1.1 \leq SY$, THEN DIVIDE FROM OPEN BPT.
$DF_{above\ TEE} = (TTF_{near} + NF_{far, 20mm}) * 1.1$, AND
$DF_{near} = TTF_{near}$, AND $DF_{far} = NF_{far, 20mm}$, ELSE
Look under 'Source far from all'

IF **Source far from all** sub-schemes:

IF $CDF_2 \geq NF_{2, 20mm}$, THEN DIVIDE FROM OPEN BPT.

$DF_{above\ TEE} = (CDF_1 + CDF_2) * 1.1$, AND

$DF_1 = CDF_1$, AND $DF_2 = CDF_2$, ELSE

IF $(CDF_1 + NF_{2, 20mm}) * 1.1 \leq SF$, THEN

DIVIDE FROM OPEN BPT:

$DF_{above\ TEE} = (CDF_1 + NF_2) * 1.1$, AND

$DF_1 = CDF_1$, AND $DF_2 = NF_{1, 20mm}$, ELSE

IF $CDF_2 < NF_{2, 20mm}$, AND $(CDF_1 + NF_{2, 16mm}) * 1.1 \leq SF$, THEN

DIVIDE FROM OPEN BPT:

$DF_{above\ TEE} = (CDF_1 + NF_{2, 16mm}) * 1.1$, AND

$DF_1 = CDF_1$, AND $DF_2 = NF_{2, 16mm}$, ELSE

IF $RL_{TEE} - RL_{nearest\ tank} \leq 100m$, THEN

MAKE LESS SUB-SCHEMES, OR

DIVIDE FROM OPEN BPT AND PUT CONTROL VALVE BEFORE AND FLOAT VALVE IN NEAREST TANK:

$DF_{above\ TEE} = (CDF_{nearest} + CDF_{other(s)}) * 1.1$, AND

$DF_{nearest} = CDF_{nearest}$, AND $DF_{other(s)} = CDF_{other(s)}$, ELSE

IF $RL_{TEE} - RL_{nearest\ tank} \leq 200m$, THEN DIVIDE FROM OPEN BPT AND

PUT FLOAT VALVE IN NEAREST TANK BELOW DIVISION BPT AND INSERT CLOSED, LOCKED BPT IN THE MIDDLE:

$DF_{above\ TEE} = (CDF_1 + CDF_2) * 1.1$, AND

$DF_1 = CDF_1$, AND $DF_2 = CDF_2$, OR

MAKE SMALL HOLE FOR SUB-SCHEME WITH HIGHEST DDD IN DIVISION BPT:

$DF_{above\ TEE} = (CDF_1 + CDF_2) * 1.1$, AND

$DF_1 = CDF_1$, AND $DF_2 = CDF_2$, OR

DIVIDE PROPORTIONALLY FROM DIVISION BPT:

$DF_{above\ TEE} = (CDF_1 + CDF_2) * 1.1$, AND

$DF_1 = CDF_1$, AND $DF_2 = CDF_2$, ELSE

DIVIDE FROM OPEN BPT AND

INSERT OPEN, LOCKED CONTROL BPT WITH VALVE, 50-80m BELOW DIVISION BPT IN PIPELINE TO SUB-SCHEME WITH HIGHEST DDD:

$DF_{above\ TEE} = (CDF_1 + CDF_2) * 1.1$, AND

$DF_1 = CDF_1$, AND $DF_2 = CDF_2$, OR

MAKE SMALL HOLE FOR SUB-SCHEME WITH HIGHEST DDD IN DIVISION BPT:

$DF_{above\ TEE} = (CDF_1 + CDF_2) * 1.1$, AND

$DF_1 = CDF_1$, AND $DF_2 = CDF_2$, OR

DIVIDE PROPORTIONALLY FROM DIVISION BPT:

$DF_{above\ TEE} = (CDF_1 + CDF_2) * 1.1$, AND

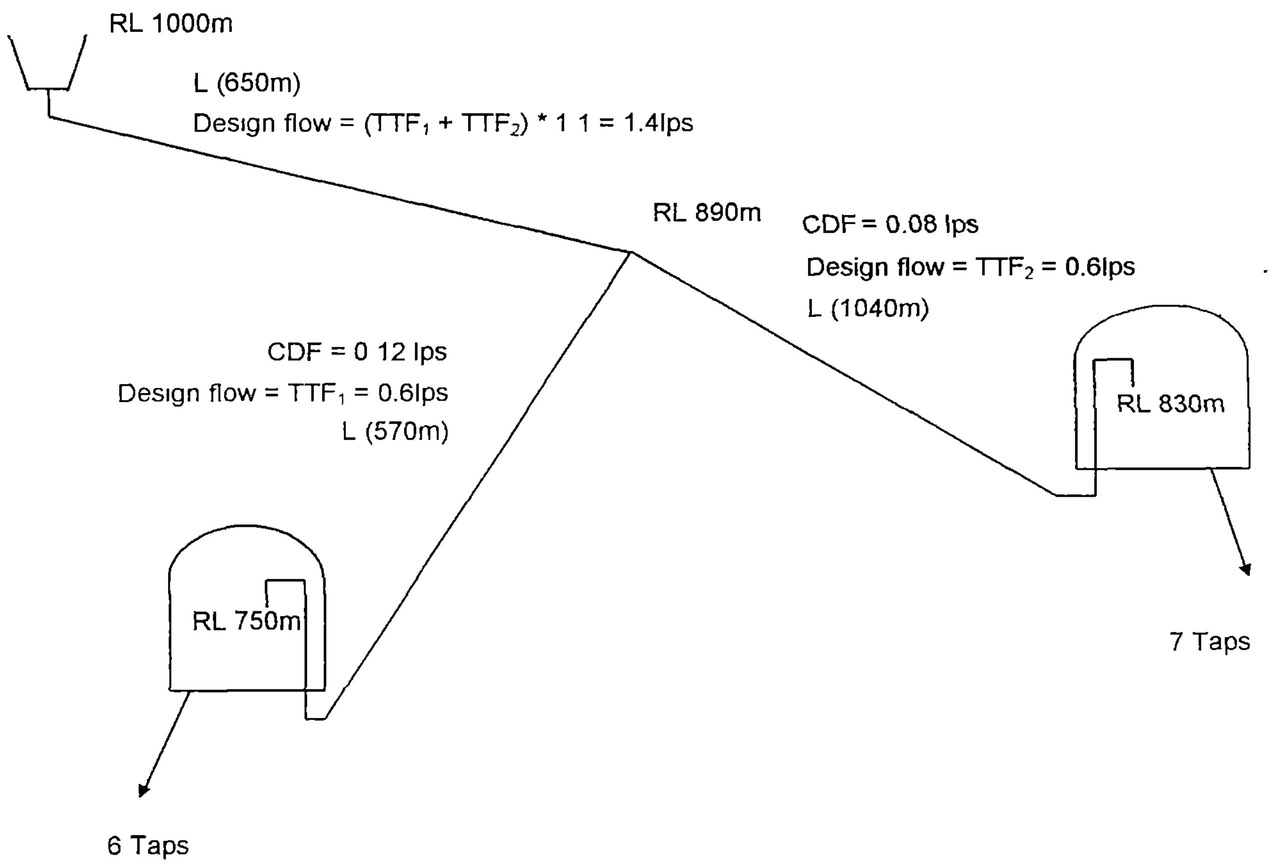
$DF_1 = CDF_1$, AND $DF_2 = CDF_2$

The above possibilities are further described in the following sub-sections

5.2.1 Both TTF

If the source is near to both (all) sub-schemes, and is large, you may supply TTF to each sub-scheme. See whether the TEE point is 50m or more vertically above the vertically nearest reservoirs. If the drop is less than 50m, try to shift the TEE up (co-ordinate re-survey). Else extra care needs to be taken that the tank elevations and transmission pipe length and sizes are implemented as per design (a small change in elevation may lead to a relatively large increase or decrease in flow)

Design/Estimate:	Especially when the vertical drop between the TEE and one of the sub-schemes is less than 50m, the design of the pipelines should achieve exactly 0m calculated residual head at each tank, and 10m (or ½ of the available static head if this is less than 20m) at the TEE
Implementation guideline:	Communicate very clearly with the implementers the critical points: The pipe sizes and length of the transmission pipelines, and the elevation of the reservoirs, especially if the vertical drop between TEE and the reservoir(s) is less than 50m

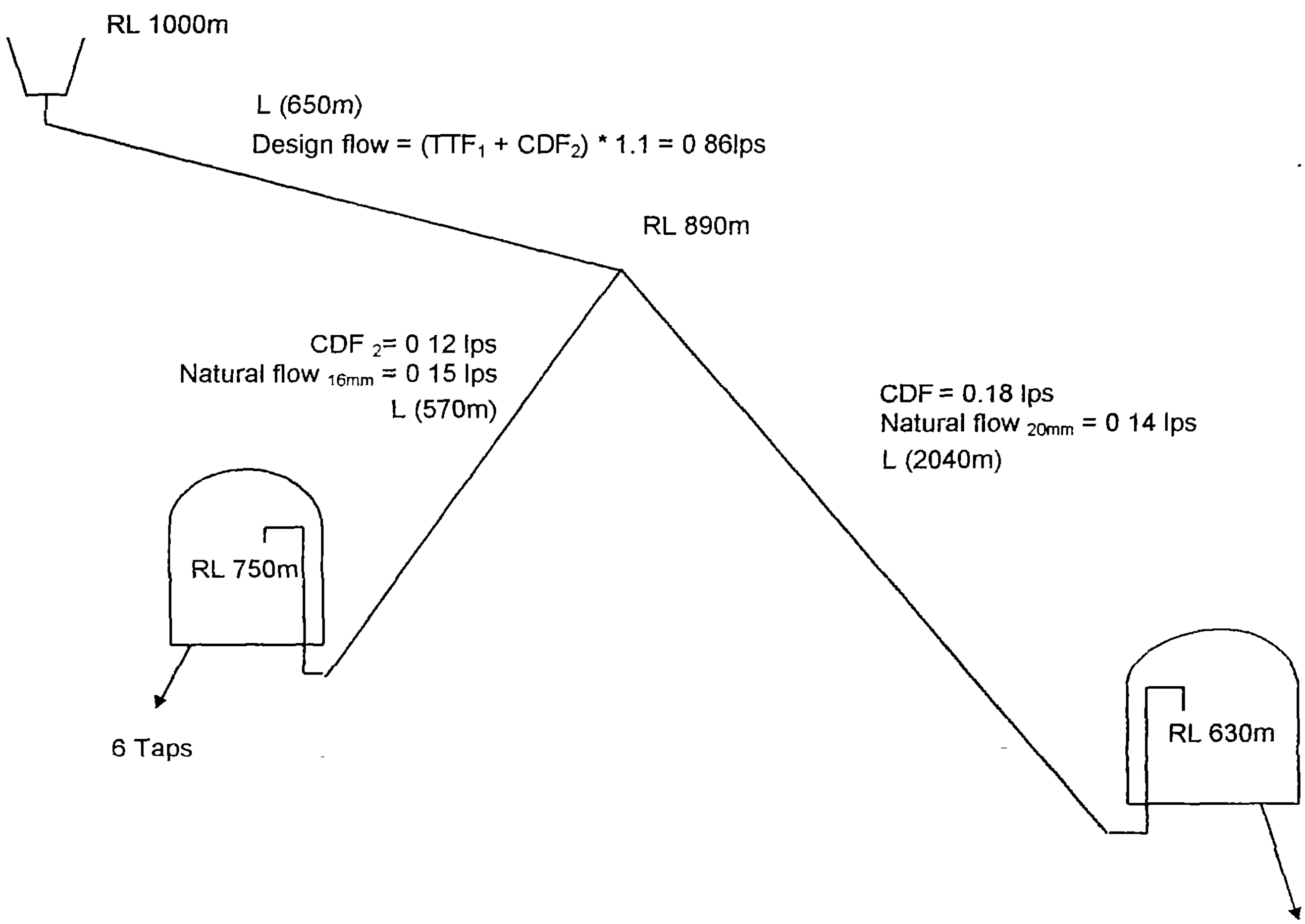


5.2.2 Near TTF, far CDF

If one sub-scheme is near the ample source, and the other(s) far, then supply TTF to the nearby sub-scheme and CDF (preferably multiplied by 1 5) to the lower sub-scheme(s) If the CDF of the lower sub-scheme(s) is larger than can be controlled by 20mm HDP pipe, read further below, else go to section 5.2 4.
Next also check whether the vertical drop between TEE-point and nearby tank is (or can be made) at least 50m If this is the case, both the flows to the nearby and far sub-schemes can be naturally controlled from a TEE point, and it will be safe to do so (as the control section has a substantial vertical drop, small deviations from design during implementation will not harm). Else go to section 5.2.3.
Use a large CDF and be precise in the design of the pipelines: Major over-design of in particular the TTF pipeline to the nearby tank may leave the far sub-scheme(s) dry

Design/Estimate: The design of the pipelines should achieve exactly 0m calculated residual head at each tank, and 10m (or ½ of the available static head if this is less than 20m) at the TEE

Implementation guideline: Communicate very clearly with the implementers the critical points: The pipe sizes and length of the transmission pipelines, and the elevation of the reservoirs

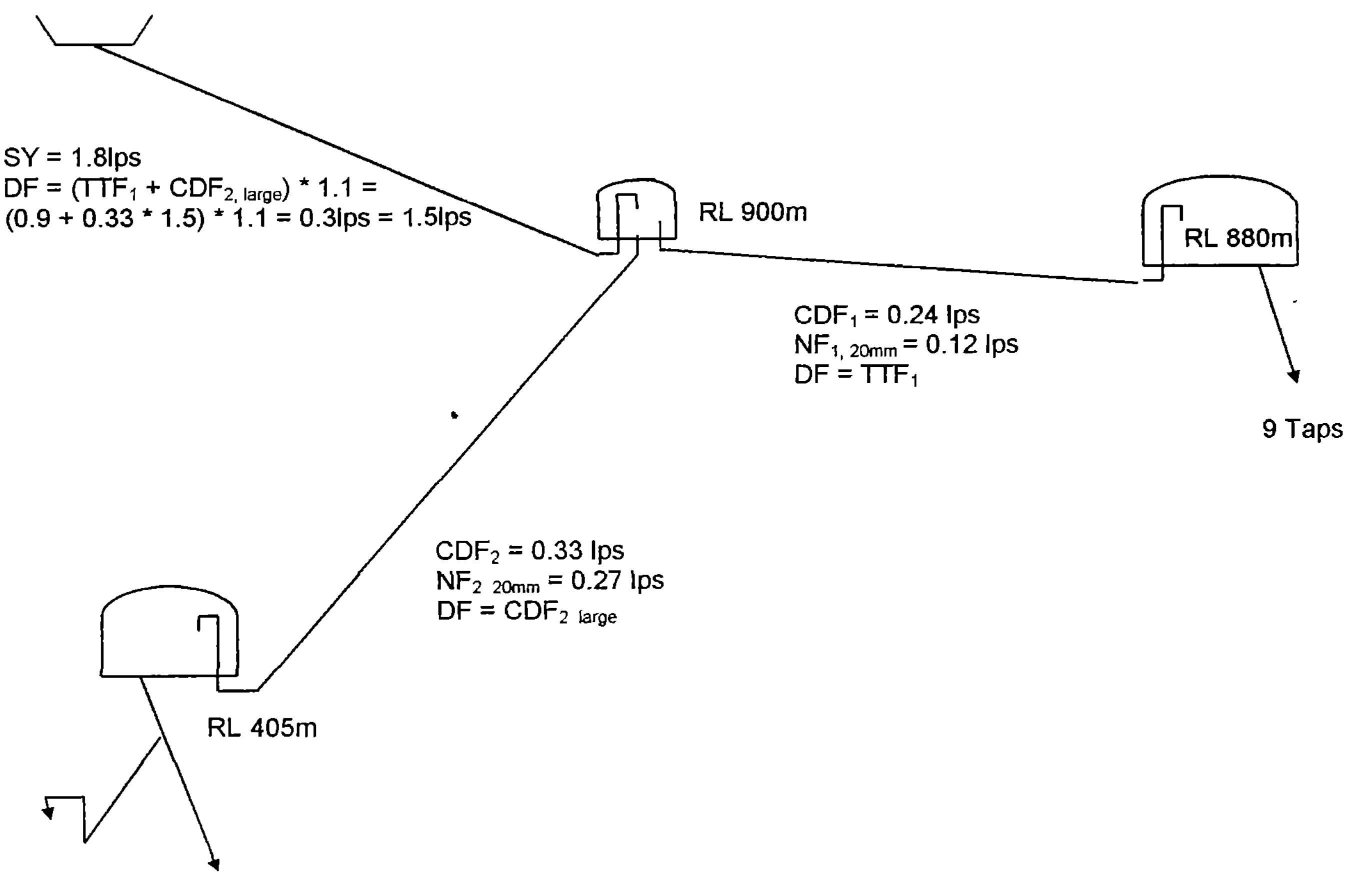


5.2.3 Near TTF, far CDF - Open BPT

Design an open BPT at the TEE point if the vertical drop between TEE and nearest tank is less than 50m. and level the outlet to the nearby sub-scheme 10-15cm higher than normal. The pipeline to the nearby sub-scheme may now be over-designed; any extra water will then be available to the nearby sub-scheme. Still design in such a way that quite exactly 0m pressure head is left at the lower reservoir(s), though it is recommended to use a large CDF (at least 1.5 times normal CDF)

Design/Estimate: The design of the pipelines should achieve exactly 0m calculated residual head at the far tank(s). The open division BPT has two outlets, of which the outlet to the nearby sub-scheme should be 10-15cm higher than normal: Change this in the threading table!

Implementation guideline: Communicate very clearly with the implementers the critical points. The outlets from the open division BPT and their levelling, and the pipe size(s) to the far sub-scheme(s)

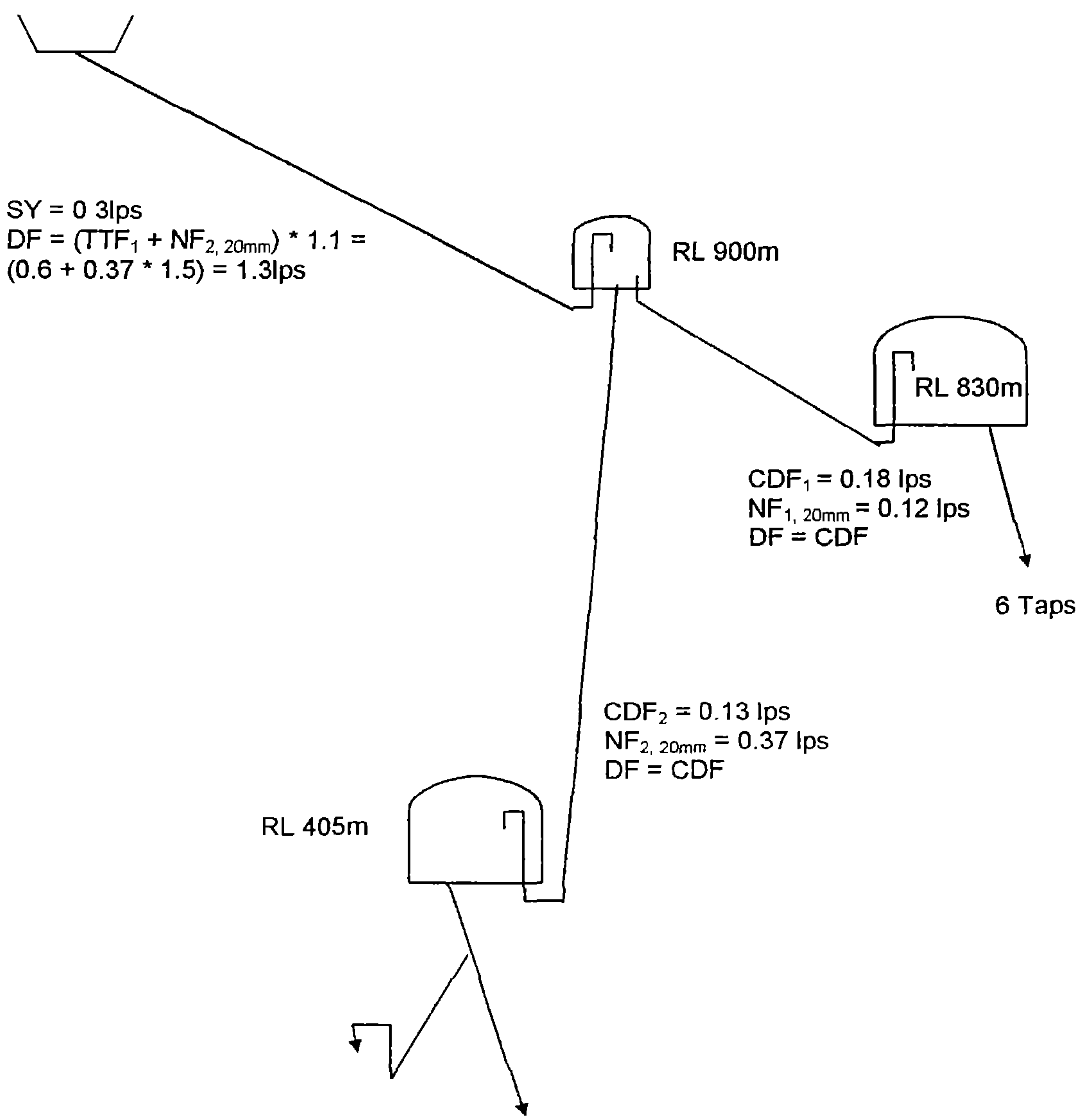


5.2.4 Near TTF, far NF20 - Open BPT

If the far CDF cannot naturally be controlled by 20mm HDP pipe, but the source is sufficient to supply TTF nearby and NF 20mm to the far sub-scheme(s), then this can be done, starting from an open BPT at the TEE point. The outlet to near sub-scheme should be 10-15cm higher than normal, thus giving extra security to the far sub-scheme(s)

Design/Estimate: The design of the pipeline(s) should achieve exactly 0m calculated residual head at the far tank(s). The open division BPT has two outlets, of which the outlet to the nearby sub-scheme should be 10-15cm higher than normal: Change this in the threading table!

Implementation guideline: Communicate very clearly with the implementers the critical points: The outlets from the open division BPT and their levelling, and the pipe size(s) to the far sub-scheme(s)

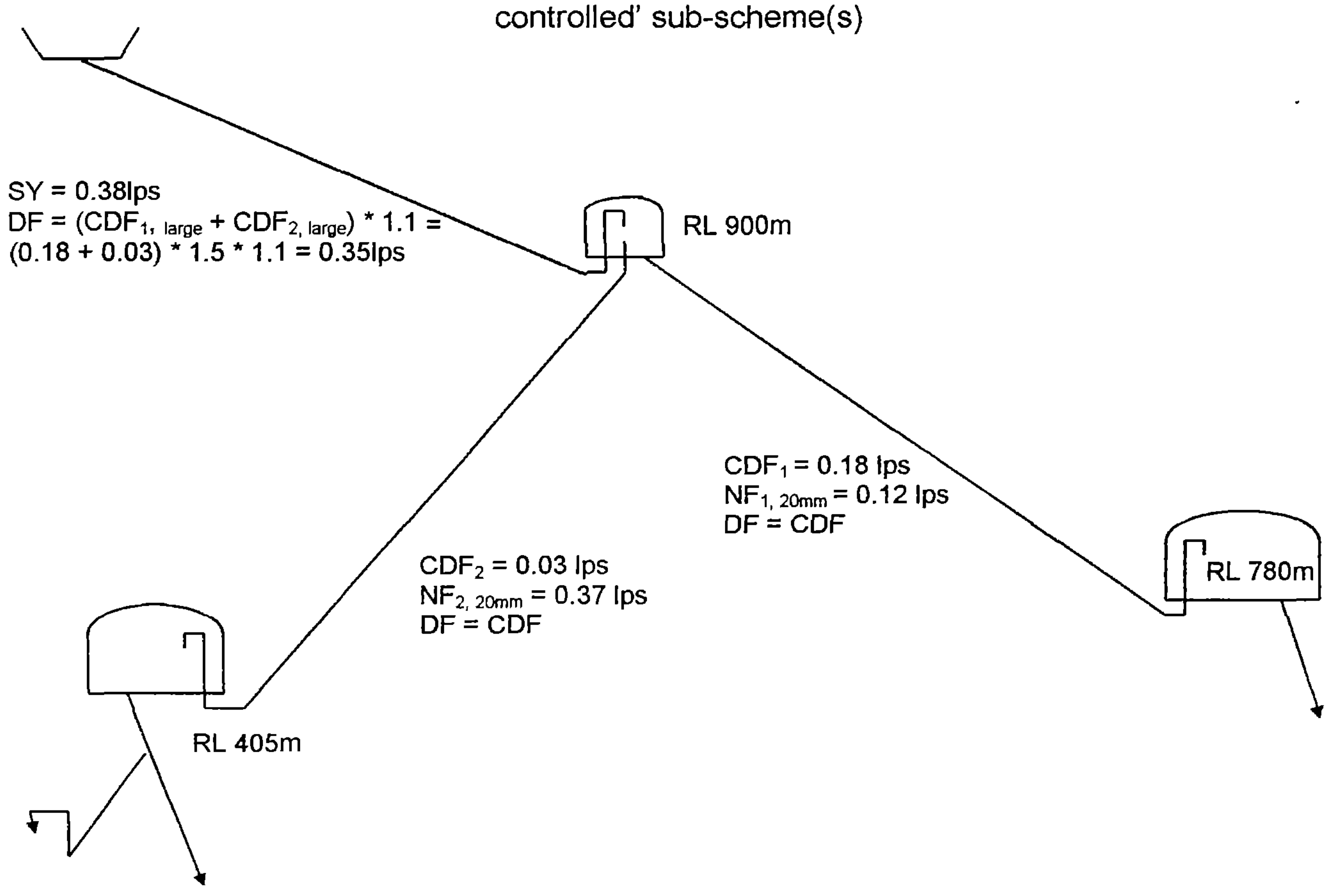


5.2.5 CDF, CDF - Open BPT

In the following three situations it is no longer relevant whether any sub-scheme is near the source or the surveyed TEE or not. The point is now whether any line can control the CDF, or whether the source is sufficient to supply NF_{20mm} or NF_{16mm} (else you will be referred to later sub-sections).
If the CDF (preferably multiplied by 1.5) of any sub-scheme can be controlled by a pipeline equal to or bigger than 20mm, design an open BPT with two outlets at the TEE point, and connect the lower outlet to the 'naturally controlled sub-scheme(s)'. Critical in design is again the proper design of this pipeline, though the more elevation difference there is between open BPT and tank, the less impact a small mistake will have. If both (all) sub-schemes can naturally control CDF with a 20mm or larger pipe, give the lower outlet to the sub-scheme(s) which is (are) larger, or (if they are equal in DDD) to the farest.

Design/Estimate: The design of the pipeline(s) where the flow is naturally controlled (the lines connected from the lower BPT outlet(s)) should achieve exactly 0m calculated residual head at the below tank(s). The open division BPT has two outlets, of which the outlet to the not-controlled sub-scheme should be 10-15cm higher than normal: Change this in the threading table!

Implementation guideline: Communicate very clearly with the implementers the critical points: The outlets from the open division BPT and their levelling, and the pipe size(s) to the 'naturally controlled' sub-scheme(s)

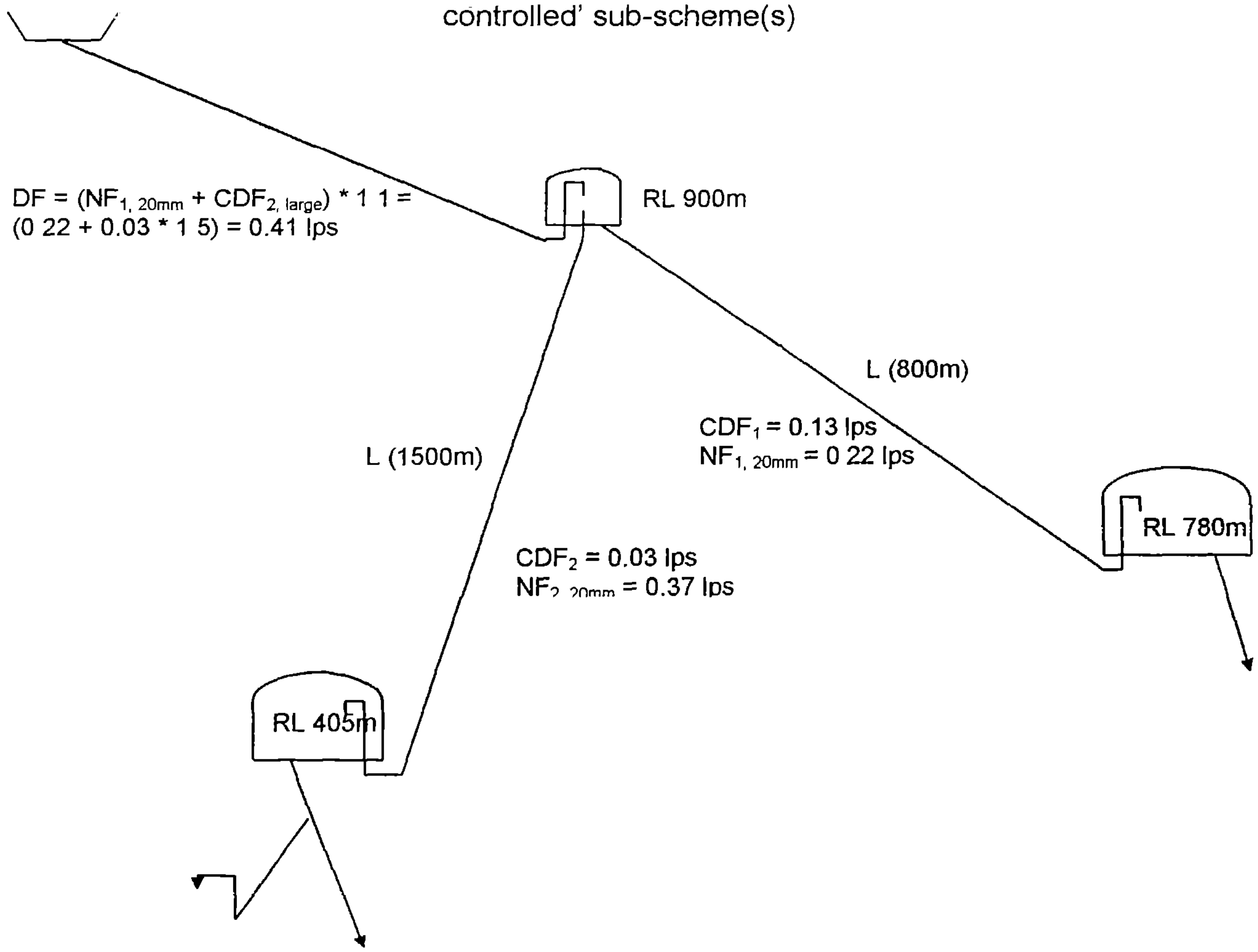


5.2.6 CDF, NF20 - Open BPT

If neither of the sub-scheme transmission pipelines can naturally control CDF (though it may be multiplied by 1 5) with a 20mm HDP pipe, see whether the source is sufficient to over-supply either of the sub-schemes with a 20mm pipeline. If this can be done with both (all) sub-scheme(s), choose the sub-scheme where the over-supply is least Of course the BPT outlet to the naturally controlled tank(s) should again be at normal level, while the other is 10-15cm higher.
Critical in design is again the proper design of the 'natural controlled' pipeline(s), though the more elevation difference there is between open BPT and tank(s), the less impact a small mistake will have

Design/Estimate: The design of the pipeline(s) where the flow is naturally controlled (the lines connected from the lower BPT outlet(s)) should achieve exactly 0m calculated residual head at the below tank(s). The open division BPT has two (or more) outlets, of which the outlet to the not-controlled sub-scheme should be 10-15cm higher than normal: Change this in the threading table!

Implementation guideline: Communicate very clearly with the implementers the critical points: The outlets from the open division BPT and their levelling, and the pipe size(s) to the 'naturally controlled' sub-scheme(s)

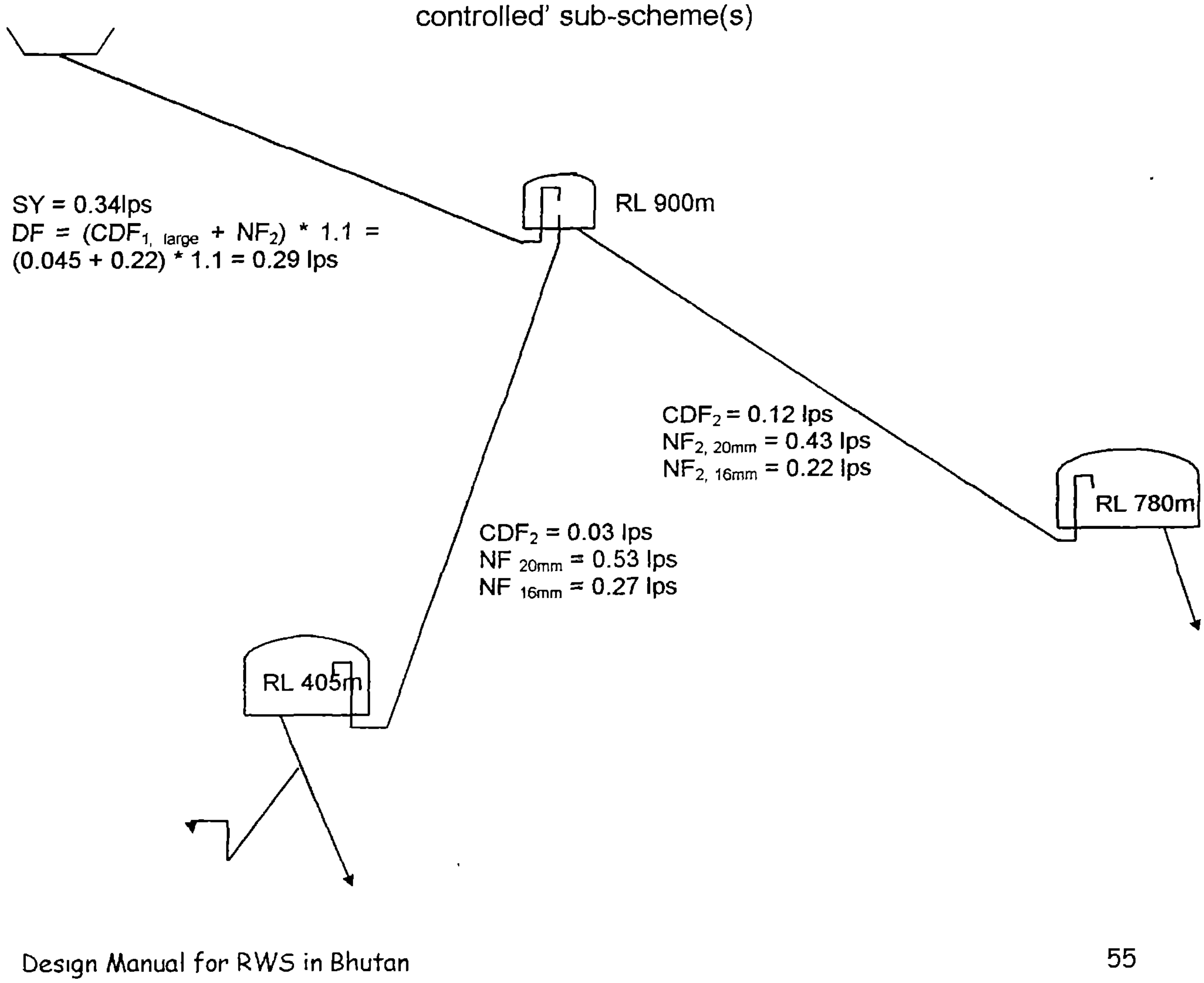


5.2.7 CDF, NF16 - Open BPT

If the source is insufficient to over-supply all but one of the sub-schemes with 20mm HDP pipe, see whether the source is sufficient to over-supply all but one of the sub-schemes with a 16mm pipeline. If this can be done with both (all) sub-scheme(s), choose the sub-scheme(s) where the over-supply is least. Of course the BPT outlet to the naturally controlled tank(s) should again be at normal level, while the other is 10-15cm higher.
Critical in design is again the proper design of the 'natural controlled' pipeline(s), though the more elevation difference there is between open BPT and tank(s), the less impact a small mistake will have.

Design/Estimate: The design of the pipeline(s) where the flow is naturally controlled (the lines connected from the lower BPT outlet(s)) should achieve exactly 0m calculated residual head at the below tank(s). The open division BPT has two (or more) outlets, of which the outlet to the not-controlled sub-scheme should be 10-15cm higher than normal: Change this in the threading table!

Implementation guideline: Communicate very clearly with the implementers the critical points: The outlets from the open division BPT and their levelling, and the pipe size(s) to the 'naturally controlled' sub-scheme(s)

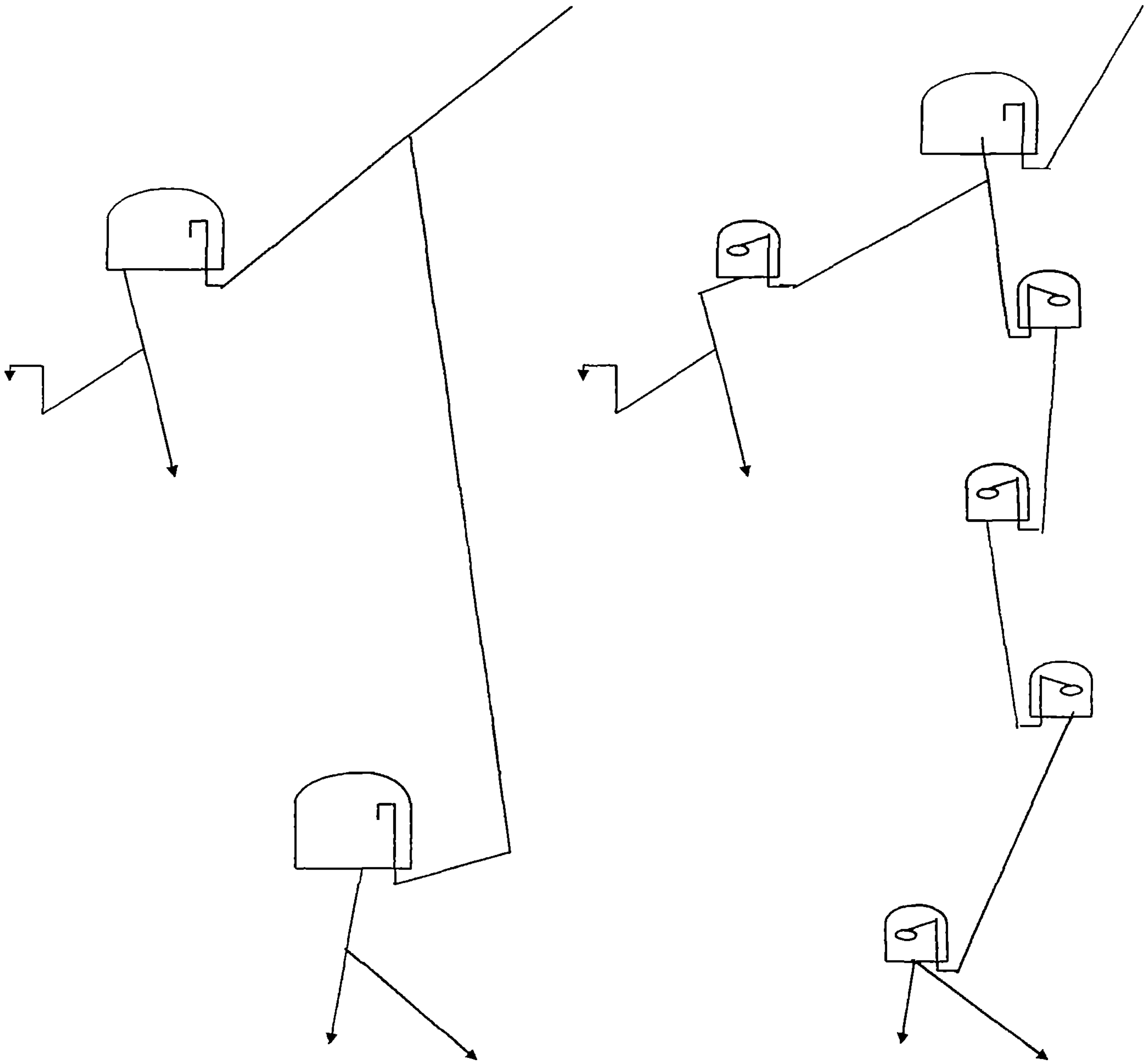


5.2.8 Within 100m from TEE

If the source is such that even 16mm pipe cannot control the flow enough, we have to combine sub-schemes or find other ways to control water. Note that the below four options are solutions to the same situation; they should all be considered before making a decision.

Less sub-schemes

Make bigger clusters, like in 'normal' design, as in the right below example.



Small hole (high outlets)

See 5.1.5 on page 41 and following, for an explanation of the theory. In the case of parallel schemes, design an open BPT at what was surveyed as the division TEE. This BPT should have raised outlets, the outlet to the 'no-control' pipeline should be 45cm (in stead of 5cm) above floor level (making it 60cm long), and the control outlet should be 50cm above floor level (thus 65cm long). The hole in the control outlet(s) should be made 5cm above floor level (45cm below the top and 20cm above the bottom end of the pipe). Provide the hole to the sub-scheme(s) with the highest DDD.
The below table shows the amount of water from different sizes of holes.

Yield	3mm	4mm	5mm	6mm	7mm	8mm	9mm	10mm
In lps	0.0098	0.0174	0.0271	0.0391	0.0532	0.0694	0.0879	0.1085
In lpd	844	1500	2343	3374	4593	5999	7592	9373

Choose a hole size through which the CDF (if possible multiplied by 1.5) can flow, and if there is more yield divide the 'extra water' roughly proportionally. However, realise that a hole has a tendency to be drilled too large; therefore over-design less to the control sub-scheme(s) than to the no-control sub-scheme

Design/Estimate: The open division BPT has two (or more) outlets, of which the outlet to the not-controlled sub-scheme should be 40cm longer than normal (thus 60cm long), and the control outlet(s) 45cm longer (thus 65cm long): Change this in the threading table! The hole should be made 20cm from the bottom of the pipe!

Implementation guideline: Communicate very clearly with the implementers the critical point: The outlets from the open division BPT. and that the hole should be on the lower half of the outlet pipe (else it may be fitted upside down, and leave little water through)

Below find a descriptive example related to parallel schemes:

- Safe yield = 0.11lps
- Natural $flow_{16mm}$ TEE to FCR_1 = 0.15lps
- Natural $flow_{16mm}$ TEE to FCR_2 = 0.14lps
- $Sub\text{-}scheme_1$ 17 rural beneficiaries (DDD_1 = 1150 liter, CDF_1 = 0.013lps)
- $Sub\text{-}scheme_2$ 26 rural beneficiaries (DDD_2 = 1755 liter, CDF_2 = 0.020lps)

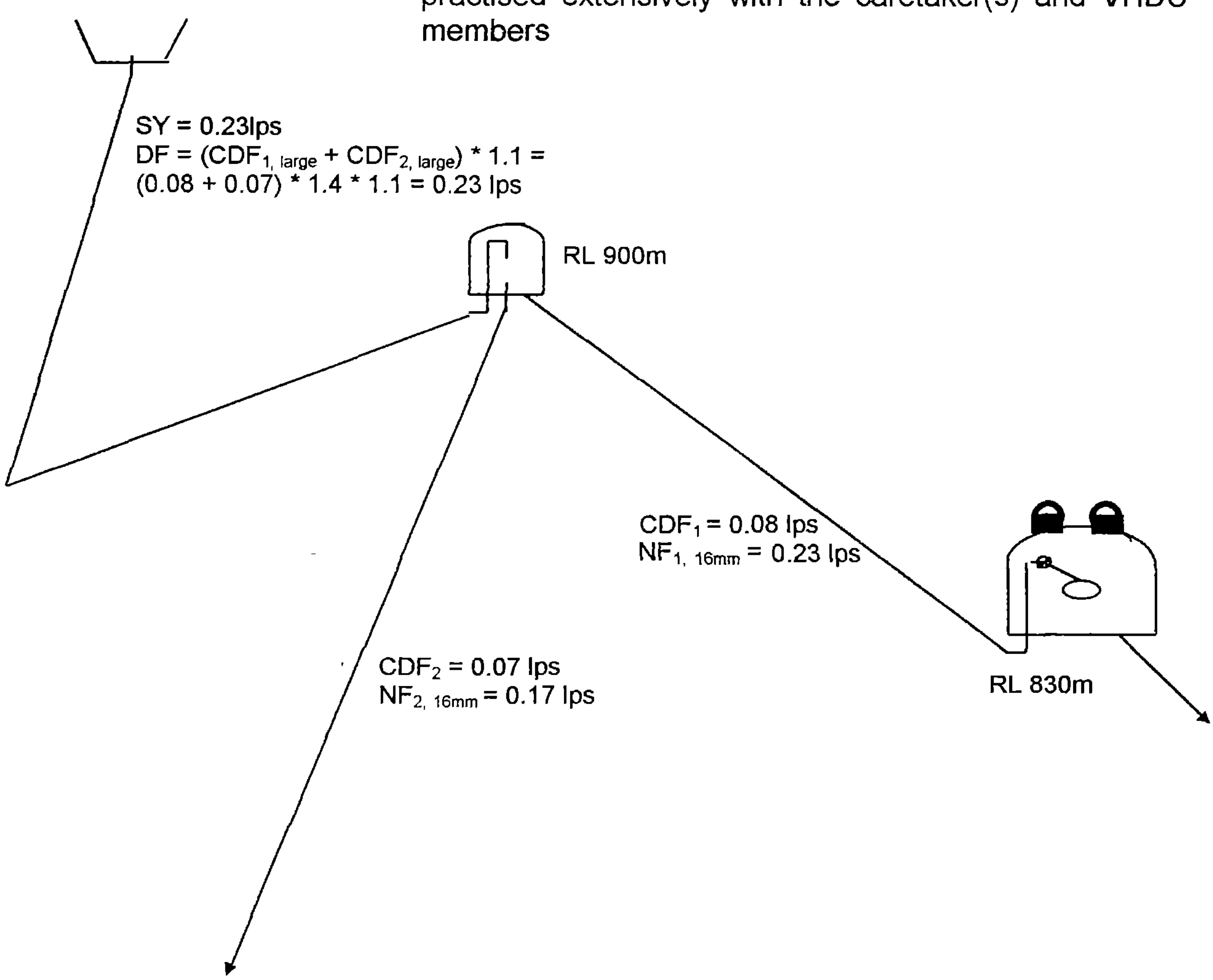
Obviously flow control by pipe sizing is ruled out, but there is sufficient water to supply 1.5 times CDF. We design a BPT at the surveyed TEE point and make a hole 20cm above floor level in the 65cm long outlet. We will connect sub-scheme 2 to this pipe, because its DDD is the largest. If we divide the safe yield proportionally, sub-scheme 2 should receive (0.11 : (0.013 + 0.020)) * 0.020 = 0.096lps. We look for a hole that leaves at the most this flow through, to secure a good flow to the other sub-scheme, even if the hole turns out a little large. We select 8mm or 9mm.

Open BPT: Control and float valve

Firstly we insert an open BPT at the surveyed TEE. From there to the vertically near sub-scheme, we design a 20mm pipe (if the source is a stream), or a 16mm pipe (if the source is a spring), and design a control valve in that locked reservoir. This sub-scheme now has the lower of the different levelled outlets from the open BPT. To extra serve the other sub-scheme, also put a float valve in this sub-scheme, so that any excess water will be available to the other sub-scheme.

Design/Estimate: The upper reservoir has two outlets, of which the outlet to the nearby sub-scheme should be 10-15cm higher than normal: Change this in the threading table!
The nearby reservoir is with float valve, as well as with a valve on the inlet: Add the required materials in the estimate. Also add two padlocks for the control BPT

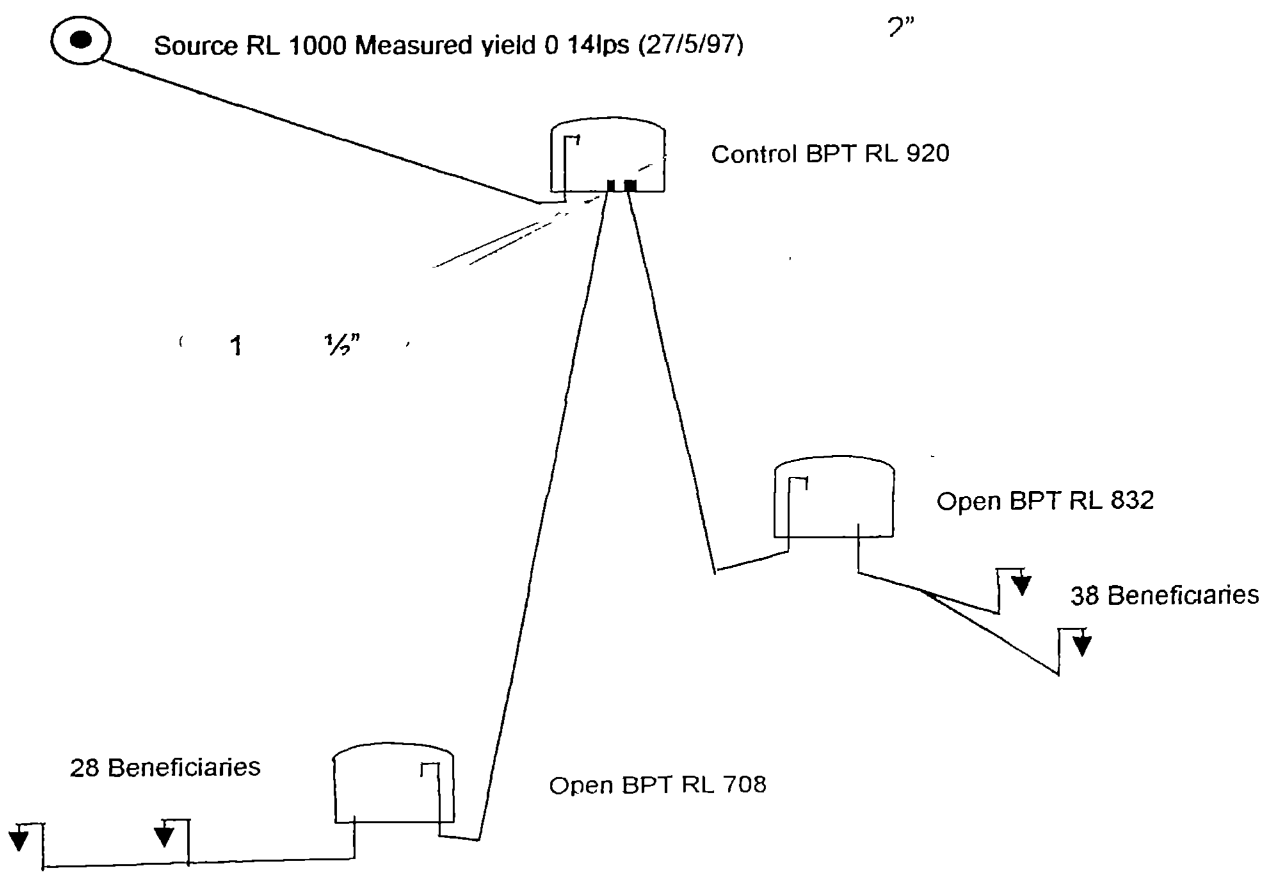
Implementation guideline: Communicate very clearly with the implementers the critical points: The outlets from the open BPT and their levelling, and the adjustment of the control valve in the control BPT (see also example of internal management agreement). The latter needs to be communicated and practised extensively with the caretaker(s) and VHDC members



Open BPT: Proportional

Locate an open control BPT at the TEE where the continuous flows are surveyed to split. The sizes of the equal levelled outlets determine per which ratio the continuous flows will be divided. The principal is to divide water proportionally over even levelled outlets. As long as the water layer above these outlets is thin, the amount of water flowing into each outlet is proportional to its dia. A 2" outlet, for example, has double the circumference of a 1" outlet, and if these pipes are the only two outlets from a tank, they would receive $^2/_3$ (66%) and $^1/_3$ (33%) of a small flow respectively (whereas, if the flow is large, they would receive $^6/_7$ (85%) and $^1/_7$ (15%) respectively) To keep the water layer thin, the outlets should be over-designed for the given amount of water[7]
As mentioned in the first paragraphs of this chapter on page 33, I do not prefer this option, though it is mentioned in literature from Nepal, because the levelling of the outlets from this BPT is quite critical. If one outlet is half a centimetre lower, it may receive all water, so that the other sub-scheme(s) receive non at all

Implementation guideline: Communicate very clearly with the implementers the critical point: The control BPT has two (or more) outlets, which need to be levelled very precisely



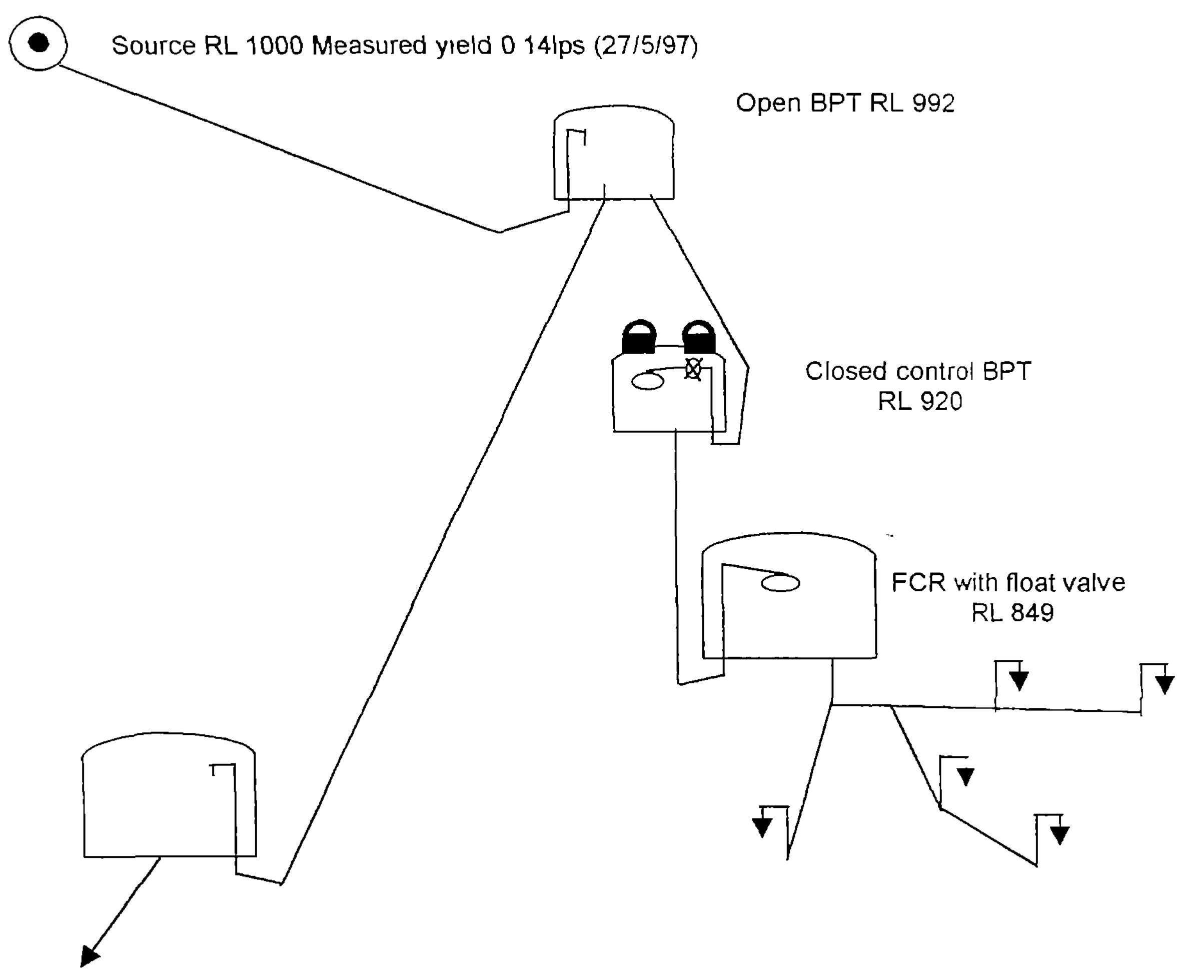
[7] There is also a possibility of controlling flow not over the outlet circumference, but over the whole pipe section up to the air vent (after which the pipe capacity should then increase!). In this option the water level over the outlets raises well above the outlets and outlet levelling is less critical. This design is relevant alone for larger flows, which in our view can more easily be controlled by pipe sizing

5.2.9 Within 200m from Open BPT

This sub-section and the next discuss how the design of the control valve option, should be adopted if the nearest tank is more than 100m below the open division BPT. The other two options for flow control of small flows (small hole and proportional division) remain the same, and should be equally considered; in fact they become relatively more attractive. Because they remain the same, they are not repeated below, but they should still be considered!

Closed BPT and float valve

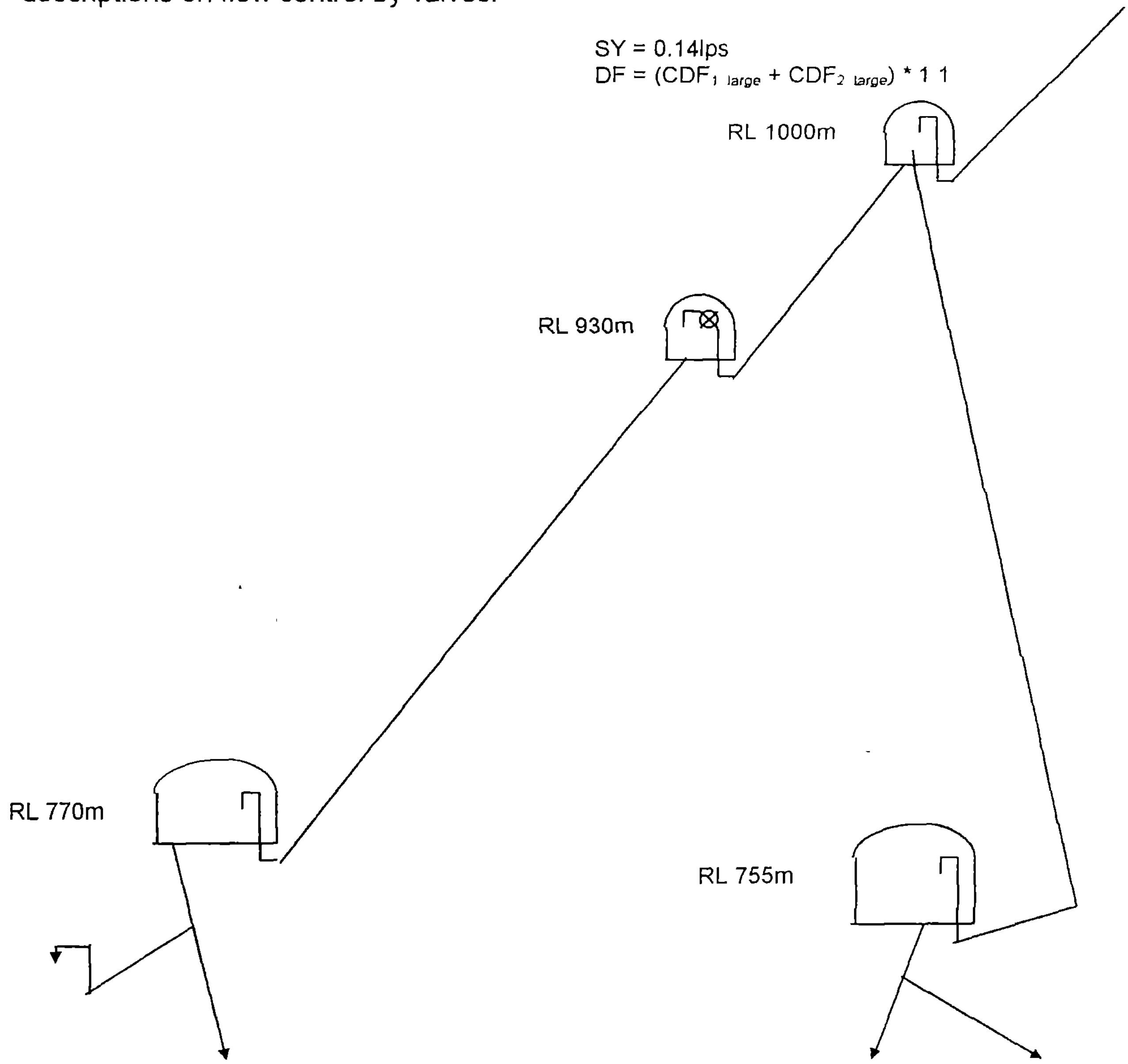
If the nearest tank is more than 100m down, the flow to this tank cannot be regulated from a valve on the inlet of that reservoir: The pipe may burst if it were closed fully Therefore we now have to insert another BPT in the middle between the open division BPT and the nearest tank. Provide the locks now for this closed BPT, in which the flow should be regulated The reservoir below can still have a float valve too so that excess water become available to the other sub-scheme(s) Of course the lowest outlet from the open division BPT should still be connected to he pipeline to this sub-scheme and the design and implementation guidelines remain the same as under the control valve option within 80m



5.2.10 More than 200m

Open BPT and control BPT

In this case the control BPT, still locked, should be 50-80m below the open division BPT The control BPT should now be placed in the pipeline to the sub-scheme with the highest DDD; it is no longer relevant how near that sub-scheme is Since the below reservoir is more than 80m away, it is no wise to provide it with a float valve, and therefore the float valve in the control BPT can be cancelled too See further the above descriptions on flow control by valves.



5.3 Connections far from other sub-schemes

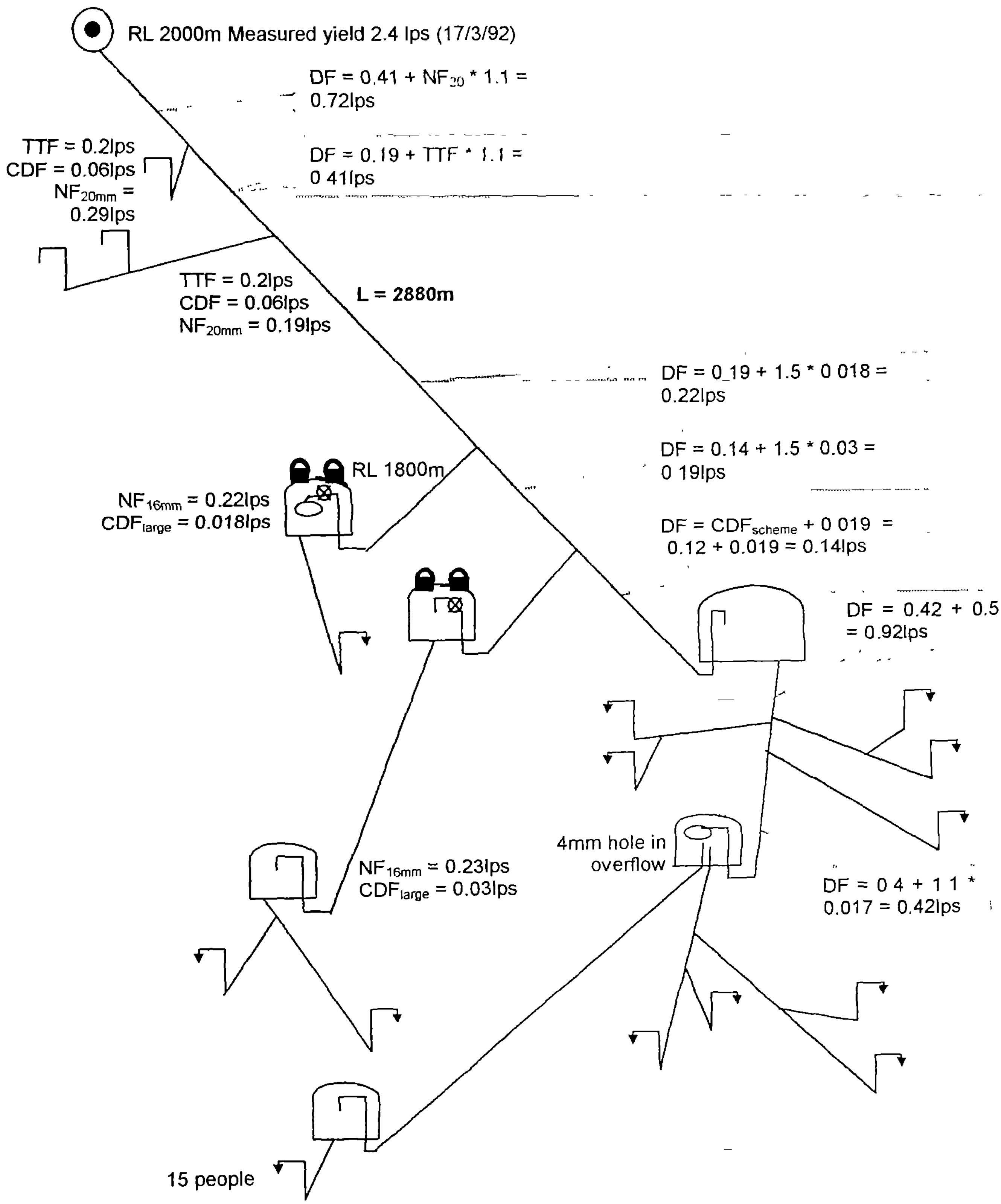
Direct connections, far from other sub-schemes (whether from a transmission pipeline above other sub-schemes, branching off within a sub-scheme) can be treated analogous to the ways described in the above two sections.

1. If the source if ample and the TEE point near the source, and a 20 or 16mm pipeline can control TTF (assuming 10m pressure at the branch-off TEE point), supply this TTF to the far tap(s), and add 1.1*TTF to the above pipelines. Design no bib cock on the tap(s). Connect the branch-line physically from the bottom of the mainline (communicate this instruction clearly with the implementers). For extra security also take care *not* to over-design the main-line, because then the branch-line may dry
2. If the source is ample and near, but even a 16mm pipe cannot control TTF (assuming 10m pressure at the branch-off TEE point), supply NF_{16mm}, and add NF_{16mm} * 1 1 to the above pipe sections Design no bib cock at the tap(s) Connect the branch-line physically from the bottom of the mainline (communicate this instruction clearly with the implementers). For extra security also take care *not* to over-design the main-line, because then the branch-line may dry
3. If the source is far, or insufficient to supply as mentioned above, then, if the far connections are within 200m[8] vertical below the TEE point (or tank) it branches off from, then design a locked closed BPT vertically in the middle between the tap and the TEE or tank Connect the branch-line physically from the bottom of the mainline (communicate this instruction clearly with the implementers) For extra security also take care *not* to over-design the main-line. because then the branch-line may dry
   - If 300 liter storage is sufficient (given the daily consumption pattern) if the supply is CDF (or CDF_{large})[9], then adjust the flow to $CDF_{(large)}$, and design the above pipelines for $CDF_{(large)}$ * 1 5 (extra security, avoiding immediate impact of slight mis-adjustments)
   - Else choose flow large enough to fit the peak demands with 300 liter storage Again multiply this continuous flow by 1.5 before including it into the above pipe sections. If the source yield does not allow this option, see under 4
4. Design
   - One locked control BPT without float valve 50-80m below the TEE (or tank), and adjust the flow to $CDF_{(large)}$, and design the above pipelines to supply this flow * 1 5, and design a storage BPT (or FCR) 10-50m above the far tap(s), Connect the branch-line physically from the bottom of the mainline (communicate this instruction clearly with the implementers). For extra security also take care *not* to over-design the main-line, because then the branch-line may dry Or
   - One control BPT (without float valve in a transmission line, with a float valve in a closed sub-scheme) at the TEE, with a raised outlet in the continuing line of 60cm long (in stead of 20cm) Make a hole in the overflow at 50cm below the top (20cm above the lower end), with the appropriate size to leave through $CDF_{(large)}$ when the water depth is 40cm Design another BPT or FCR just above the far tapstand(s), and take the $CDF_{(large)}$ * 1 1 into account in the higher pipe sections.

The drawing on the next page gives some examples of the above listed options

[8] Or less if the residual head can be expected to cross 10m In this case, the maximum expected pressure should be deducted from the quoted 200m.
[9] *This is the case as long as DDD < 1310l, or if there are less than 20 villagers or 13 for* CDF_{large}

Examples of far connections



5.4 Rehabilitations

The design of (major) rehabilitations is often more difficult, but also more creative than the design of new schemes, because more alternative options need to be considered. There is the possibility of constructing an entirely new scheme, and finding the best design for that, and the option of using all existing components, only repairing breakdowns and possibly adding BPT's. But good design does not only compare these two extremes The most appropriate solution is often to use certain pipes and structures, and to bypass others, adding parallel lines, or replacing otherwise good pipe sections by smaller ones to ensure natural flow control

In rehabilitation schemes some pipelines, where you would design flow control by pipe sizing if you were to design it as a new scheme, good pipes may already exist that are of a size that make such natural flow control impossible Or the location of existing tanks, their sizes, or their outlets may make the technically best design unattractive, because very few of otherwise good components could then be put to use

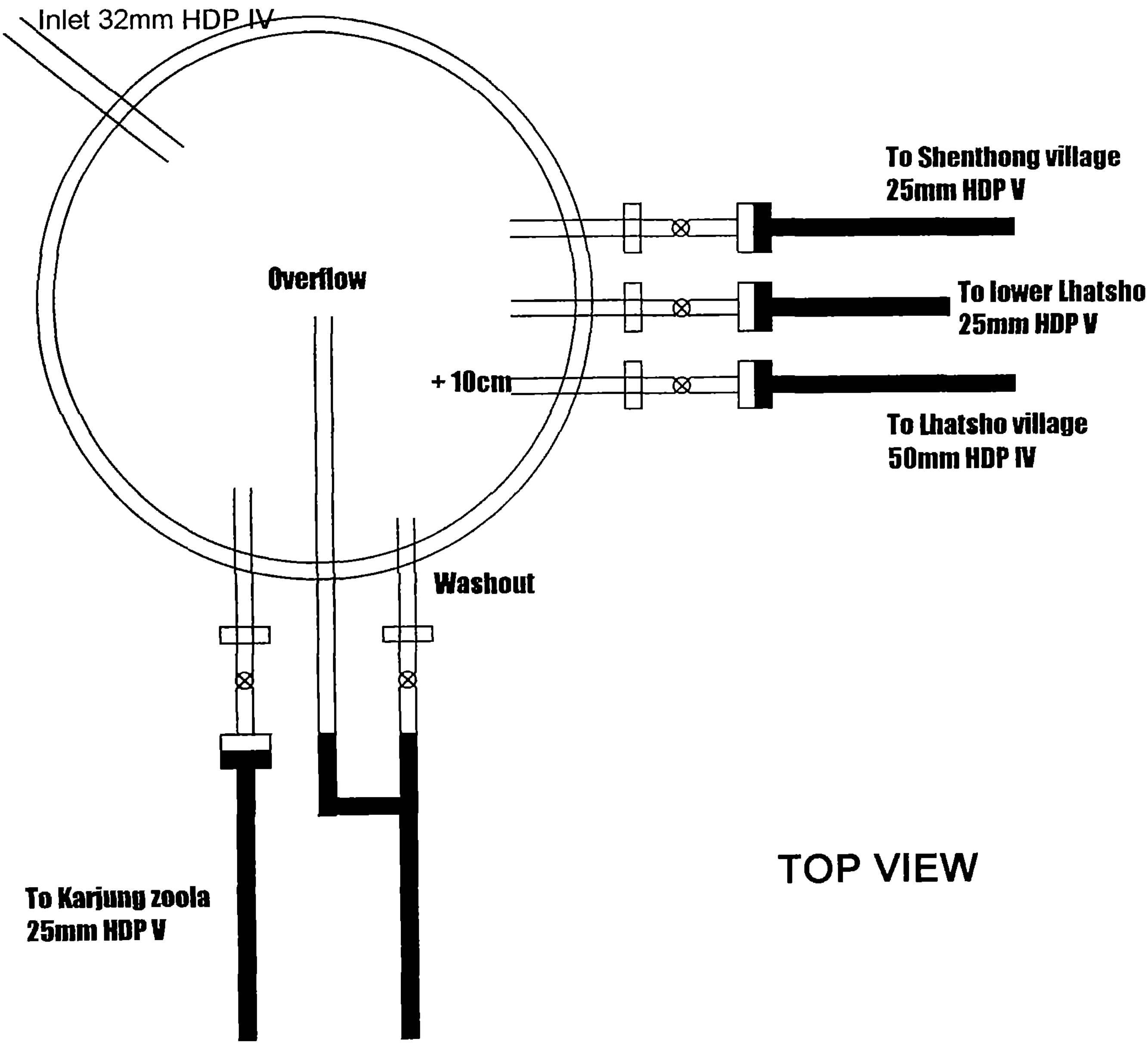
In such cases the designer, as much as possible in discussion with the people, has to decide on the most appropriate solution. On the one hand he or she should consider how existing components can be used and work and expenditures kept to a minimum. but on the other think of the long term interest of the beneficiaries and the ease of managing the scheme After all, the 'special' designs discussed in this entire chapter, all primarily aim to enhance the sustainability of schemes by technical options that minimise maintenance demands. If a scheme can be expected to function more than twice as long for an effort and investment of less than twice the cheapest option, than this extra input is economically attractive and well justified

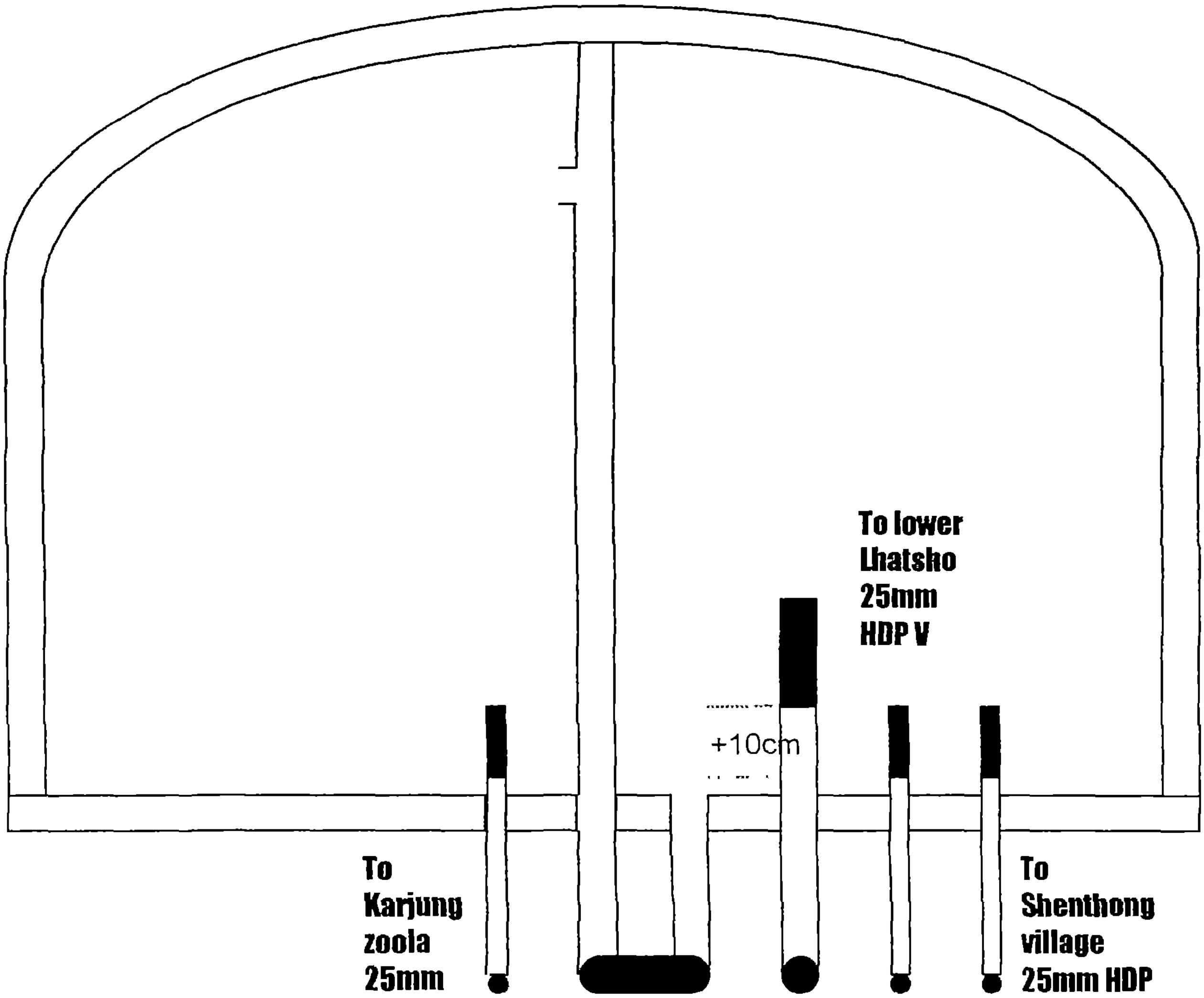
It goes almost without saying that in considering alternatives, the designer before checking whether a new pipeline can naturally control TTF or $CDF_{(large)}$, should check whether existing pipes control an acceptable/practicable flow.

5.5 Construction guideline

As mentioned earlier, this Manual advocates the making of 'Construction Guidelines' as an instrument to document and communicate the important points of 'special' designs. Below find an example text and drawings that a designer can make to help the implementers, thus ensuring that the critical and non-standard features are implemented correctly. Such a document should *supplement* and not *replace* verbal communication (unless one is hundred percent sure that the write-up alone will do!)

FCR 1, the Reservoir just above Lhatsho village, has three outlets. Combined with the overflow and the washout this means that six pipes come out. The reservoir therefore has two valve boxes attached.





SIDE VIEW

The outlet to Lhatsho village should be 10cm higher than the other outlets.
Reason: Then the other sub-schemes will get always the same amount of water, and do not only get water if the people in Lhatsho village do not waste water. The people of Lhatsho will not have water shortage because the flow into the reservoir is more than the flows that go to the lower sub-scheme. It also does not make the people of Lhatsho village dependent on the water use in the other sub-schemes, because a fixed flow goes to these villages, irrespective of their water use.

5.6 Operation, rules and responsibilities agreement

Especially for schemes were manual flow adjustment is needed, this Manual advocates that DPHE staff assit beneficiaries in making 'Operation, rules and responsibilities Agreements' that fit well to the operation and maintenance requirements of the physical scheme. The below is an example of what the technical, water distribution related paragraphs of such an internal management agreement could look like (for a rehabilitation scheme). The designer in Thimphu (or the District) should contribute draft proposals for the parts that relate directly to the technical design, including a map. Once finalised the agreement may be put on paper in Dzongkha or Nepali. Note that the document is aimed to help people remember and agree on appropriate operation and management, and should therefore be used to *formalise*, and not *replace* verbal communication

Rules and Responsibilities

Benshingmo Rural Water Supply scheme

78/13/61

Water division

The scheme is in four parts:

- ***The upper houses of Benshingmo. That is between the lhakhang and the first reservoir. Approximately 20% (1/5) of the beneficiaries live in this area.***
- ***The houses in the middle of Benshingmo. That is between the first, old reservoir and the new reservoir. Approximately 25% (1/4) of the beneficiaries live in this area.***

  Upper and middle Benshingmo together cover 45% of the beneficiaries.

- ***The lower houses of Benshingmo. Approximately 35% (1/3) of the beneficiaries live in this area.***
- ***Gungshikhar sub-scheme. Approximately 20% (1/5) of the beneficiaries live in this area.***

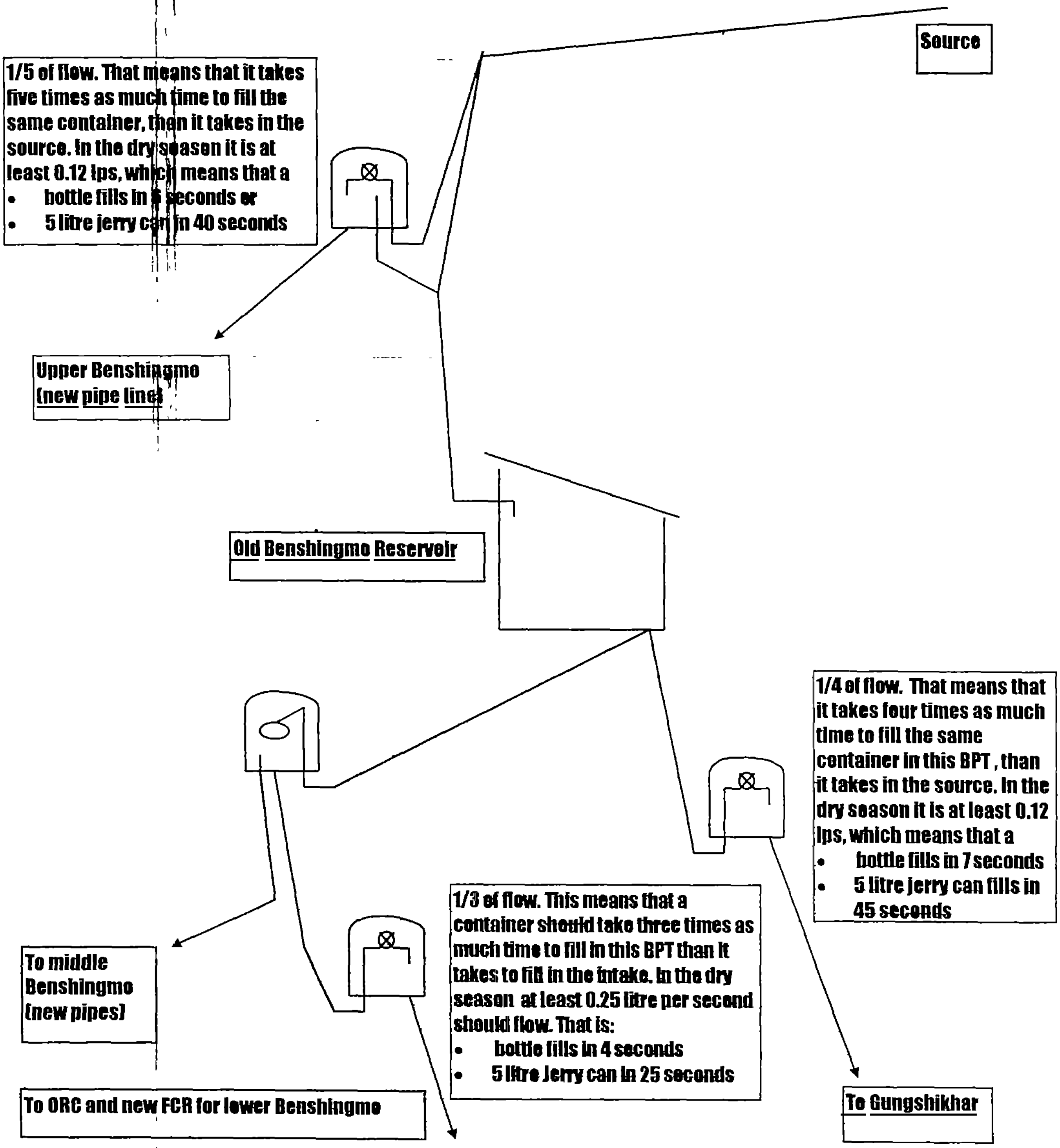
At least 20% of the water in the supply line should flow into the upper Benshingmo branch line. This amount should be adjusted in the upper, regulation 'BPT' (small tank). In the dry season, when the source yield is only 0.6 litre per second (5 litre jerry can fills in 8 seconds), 0.12 litre per second should flow into this BPT. 0.12 litre per second means that a bottle fills in 6 seconds and a 5 litre jerry can in 40 seconds. The BPT is locked with two padlocks. The keys to the locks of this BPT are with the Gungshikhar and lower Benshingmo caretakers, so that the people in upper Benshingmo cannot change the flow by themselves.

At least 0.4 litre per second (that means that a 5 litre jerry can fills in 12 seconds) should reach the old reservoir at middle Benshingmo. If less than 0.4 litre per second reaches the first reservoir, the caretaker should check the transmission line for leaks and the flow to upper Benshingmo.

The water reaching the first reservoir is divided. In the dry season a continuous flow of 0.12 litre per second (a bottle fills in 7 seconds) flows to Gungshikhar. That amount of flow is adjusted in the first, regulation BPT in the Gungshikhar branch line. The BPT is locked with two padlocks. The keys are with the caretakers from upper and lower Benshingmo. Therefore the flow can only be checked and adjusted if the caretakers work together.

The rest of the water reaching the first reservoir is for middle and lower Benshingmo. A continuous flow will go to lower Benshingmo. This flow is adjusted from the regulation BPT above the new reservoir for lower Benshingmo. The flow should be adjusted to 0.2 litre per second (a bottle fills in 4 seconds). This BPT too is locked with two padlocks, of which the keys are with the caretakers from upper Benshingmo and Gungshikhar. Therefore the flow can only be checked and adjusted if the caretakers work together.

The flow are checked and adjusted at least two times a year. Firstly in June, when the source is big. And secondly in March (dawa nyipa), when the source has become small. On these occasions the caretakers check the entire scheme together. They first see the intake and transmission line. And they open the regulation BPT's without float valve and measure and adjust the flow.



6 Exercises

The exercises below correspond to the previous five chapters, as indicated by the section numbers

6.1 Introduction

6.1.1 Survey-Design linkages

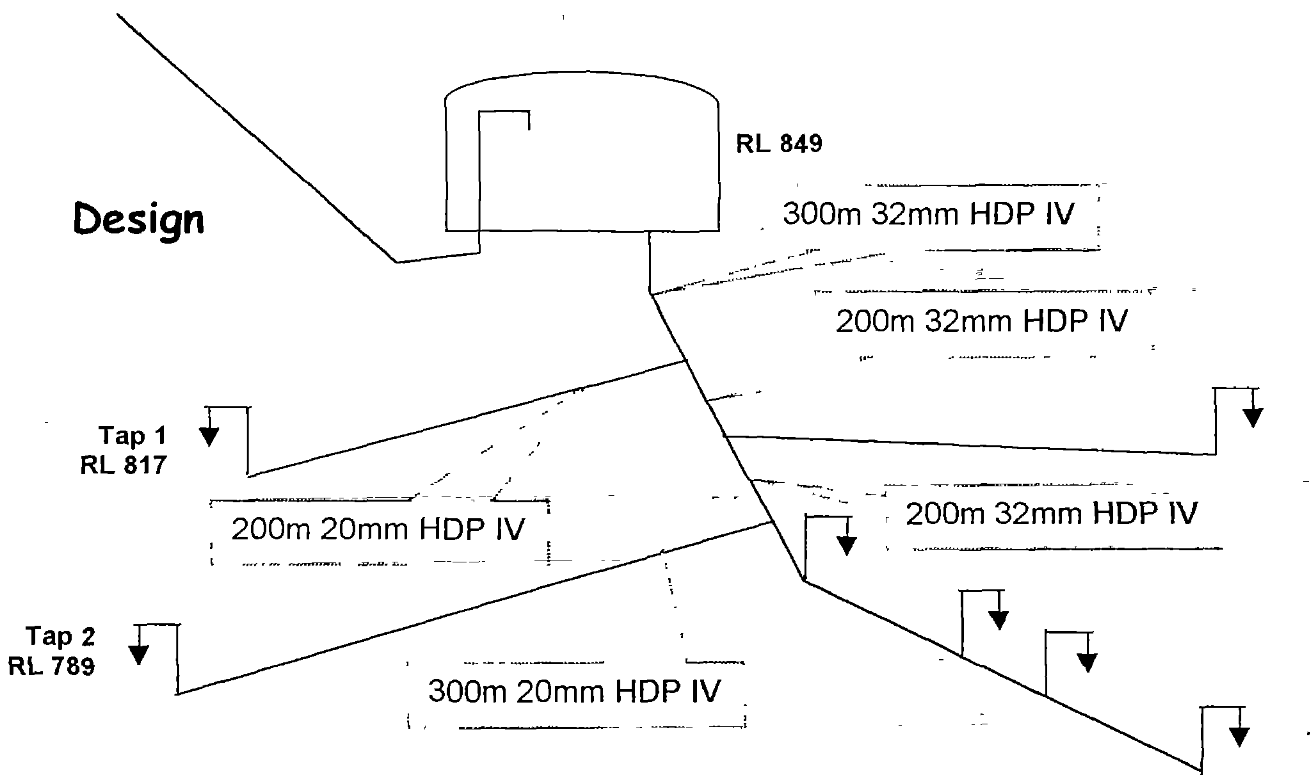
- Calculate the actual RL (using the actual ground distance), and the RL that PHE will use in design, if the ground distances are over-reported as in Ground $\text{distance}_{\text{reported}}$.

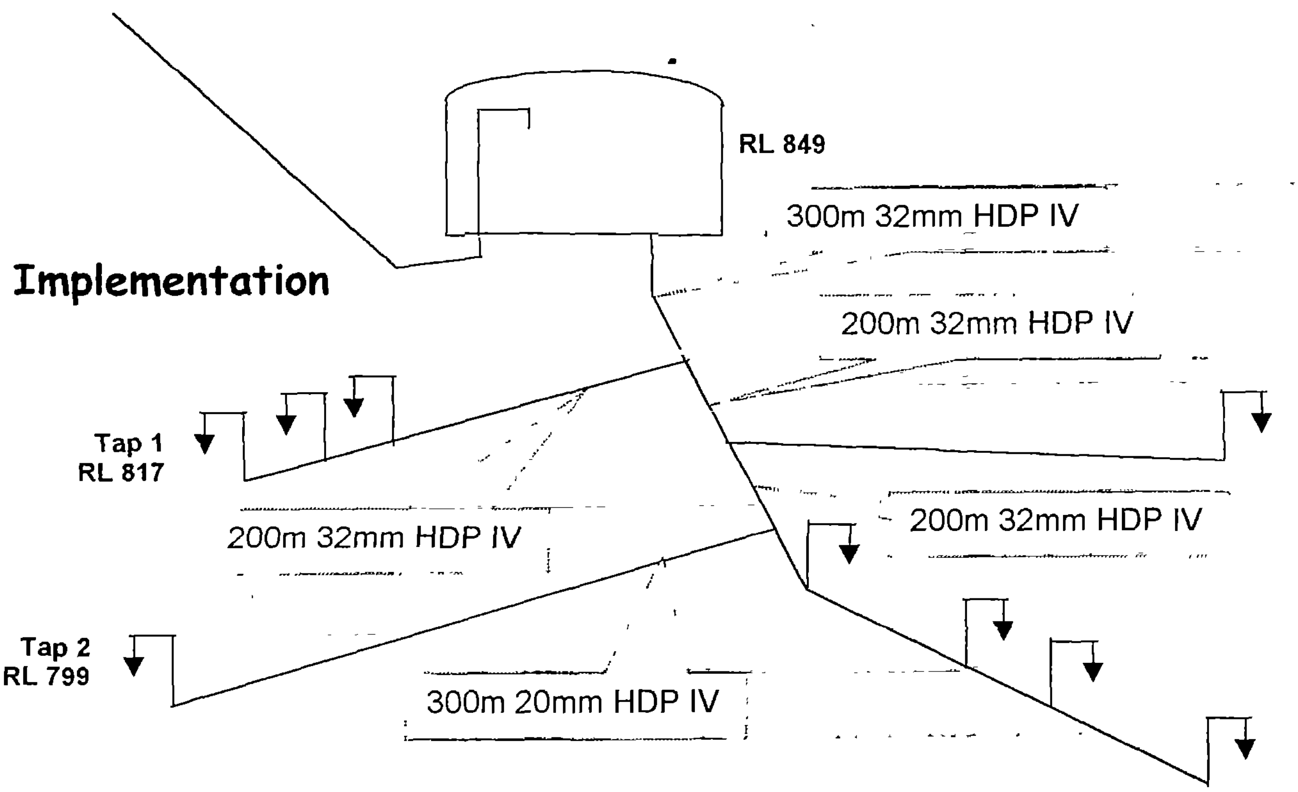
Station	Angle	Ground $\text{distance}_{\text{actual}}$	Ground $\text{distance}_{\text{reported}}$	$\text{RL}_{\text{actual}}$	$\text{RL}_{\text{design}}$
CWR					
	-15^{0}	24	30		
IPT					
	-15^{0}	15	30		
IPT					
	-15^{0}	25	30		
IPT					
	-15^{0}	21	30		
TEE 1					
	-15^{0}	18	30		
IPT					
	-15^{0}	15	30		
IPT					
	-15^{0}	22	30		
IPT					
	-15^{0}	28	30		
TEE 2					
	-15^{0}	25	30		
IPT					
	-15^{0}	20	30		
IPT					
	-15^{0}	16	30		
IPT					
	-15^{0}	19	30		
IPT					
	-15^{0}	21	30		
IPT					
	-15^{0}	22	30		
TAP 1					

- Will the difference in outcome influence the design? If so, how?

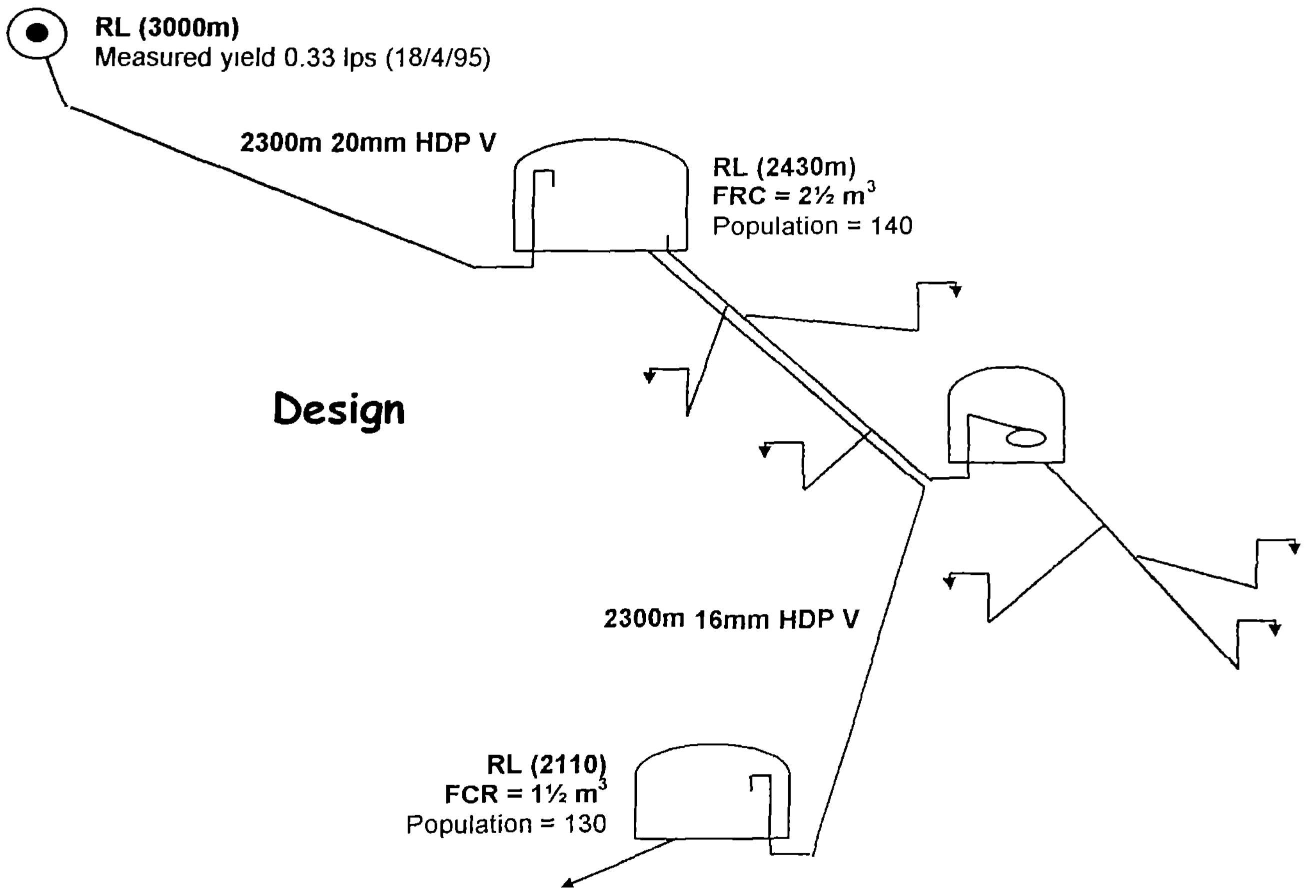
6.1.2 Design-implementation linkages

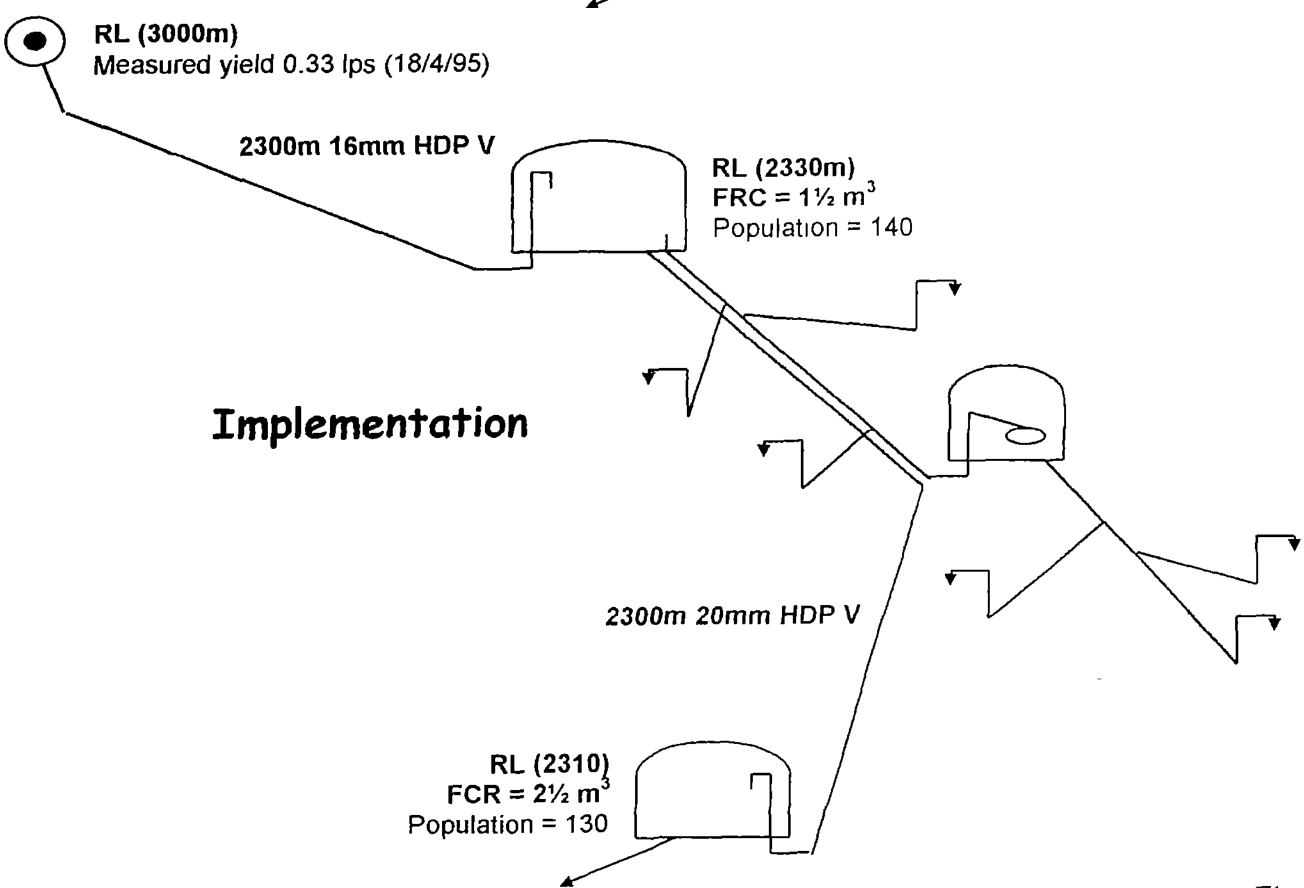
Find below two drawings. The first represents the design and the second the scheme as it is implemented. As you can see, two taps are added near tap 1, and to supply them sufficient water, the implementers have increased the branch line to tap 1. Consider in particular tap 1 and 2, assuming that the flows to the other tapstands remain the same What will be the impact of the changes?





Find below again two drawings. The first represents the design and the second the scheme as it is implemented What will be the impact of the changes?





6.2 Hydraulic theory

For exercises on hydraulics refer to the handouts of the 1996 Design Training in Phunstholing.

6.3 Normal design

6.3.1 Springs

Check the below designs.

Ridaza	Elevation	Ground distance	Designed pipe
SOURCE	1650		
		250	25
TEE	1590		
		275	20
TAP 1	1575		
		300	20
TAP 2	1561		

Kelikhar	Elevation	Ground distance	Designed pipe
SOURCE	1660		
		450	25
TEE	1602		
		5	20
TAP 1	1600		
		205	20
TAP 2	1540		

Didichhu	Elevation	Ground distance	Designed pipe
SOURCE	2000		
		90	16
TEE	1960		
		400	25
TAP 1	1955		
		350	20
TAP 2	1920		

Bukula	Elevation	Ground distance	Designed pipe
SOURCE	1000		
		350	20
TAP	975		

6.3.2 *Gravity flow schemes*

Check the below designs

Pangthang Dasa (24 people)

Station	RL	G. dist.	Flow	Pipe	$RH_{calc.}$	SH	Velocity
Source	1000				0	0	
		296	0.13	1 ½"			0 1
FCR	989				11	11	
		234	0 4	1 ½"			0.32
ITP	987				1	2	
		39	0.4	50mm			0.29
TAP 1	986				2	3	
		60	0.2	40mm			0 34
TEE 1	935				2	4	
		130	0.2	25mm			1.07
ITP	952				24	37	
		97	0 2	20mm			1 7
BPT 1	929				22	60	
		211	0.2	25mm			1.07
ITP	893				18	36	
		110	0.2	1"			0.61
ITP	872				35	57	
		46	0 2	½"			1.7
BPT 2	864				22	65	
		250	0.2	1"			0.61
ITP	817				40	47	
		71	0.2	½"			1 7
BPT 3	804				21	60	
		260	0 2	1"			0 61
ITP	757				39	47	
		73	0 2	½"			1.7
BPT 4	744				19	60	
		22	0 2	1"			0.61
ITP	738				5	6	

Dechiling (1100 people)

Station	RL	G. dist.	Flow	Pipe	$RH_{calc.}$	SH	Velocity
Source	1020				0	0	
		40	1	3"			0.2
IPT	1017				3	3	
		2414	1	63mm			0.45
IPT	945				63	75	
		12	1	1 ½"			0.51
IPT	946				62	74	
		417	1	50mm			0 71
FCR	980				21	40	

Karma Woong (108 people)

Station	RL	G. dist.	Flow	Pipe	$RH_{calc.}$	SH	Velocity
Source	252				0	0	
		63	0.4	1"			0.81
IPT	515				7	10	
		73	0.4	25mm			1 43
IPT	501				11	24	
		715	0.4	50mm			0.29
IPT	501				8	24	
		39	0.4	32mm			0.7
BPT_{open}	498				10	27	
		90	0.4	32mm			0.7
TEE 1	479				17	19	
		60	0.2	20mm			1.13
TEE 2	476				12	22	
		247	0.1	20mm			0.57
TEE 3	438				41	60	

Laniri (400 people)

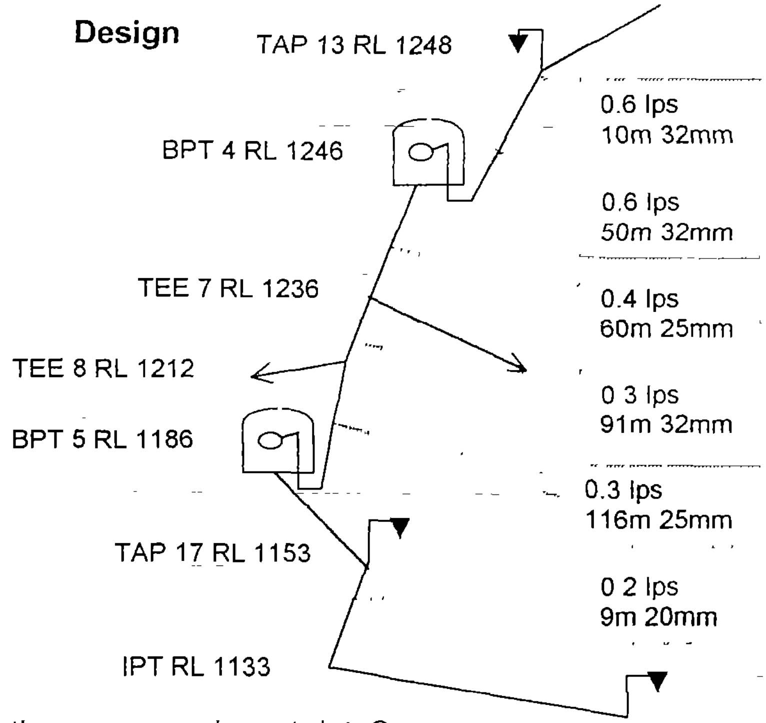
Station	RL	G. dist.	Flow	Pipe	$RH_{calc.}$	SH	Velocity
Source	1500				0	0	
		335	0.5	1 ½"			0.4
IPT	1494				3	6	
		142	0.5	40mm			0.56
IPT	1491				3	8	
		176	0.5	1 ½"			0.4
IPT	1488				6	12	
		377	0 5	50mm			0.36
FCR	1485				7	15	
		70	3	63mm			1.34
TEE 1	1480				3	5	
		55	1.8	50mm			1.29
TAP 1	1467				13	18	
		116	1.7	32mm			2 97
BPT 1	1426				14	59	
		17	1.7	40mm			1.91
TAP 2	1420				4	6	
		60	1.6	32mm			1 79
IPT	1399				18	27	
		88	1 6	50mm			2.79
TAP 3	1369				21	57	
		10	1.6	40mm			1.14
BPT 2	1366				23	60	
		20	1.6	40mm			1.79
TAP 4	1360				4	6	
		30	1.5	40mm			1.68
TEE 2	1353				8	13	

Also check for entrance mistakes. Compare survey data, input data and design.

Input Laniri (400 people)

Station	RL	G.dist.	Flow
TAP 13	1248		
		88 HDP	0.7
BPT 4	1246		
		10 HDP	0 6
TEE 7	1236		
		86 HDP	0.6
TEE 8	1212		
		60 HDP	0 4
TAP 17	1186		
		91 HDP	0 3
BPT 5	1153		
		116 HDP	0.3
IPT	1133		
		99 GI	0.1
TAP 18	1076		

Design



- What is/are the mistake(s) in copying the survey and input data?
- What are design mistakes?
- What may be the consequences of the design mistake(s)?

What can be improved in the below design?

Langzore (23 people)

Station	RL	G. dist.	Flow	Pipe	RH calc.	SH	Velocity
Source	1000				0	0	
		1747	0.3	1 ½"			0 24
BPT_{open}	980				14	20	
		350	0.3	32mm			0.52
TAP 1	966				9	14	
		115	0 2	20mm			1.13
TAP 2	941				19	39	
		235	0 1	20mm			0 57
TAP 3	920				31	60	

What about this design?

Zordung A (280 people)

Station	RL	G. dist.	Flow	Pipe	RH calc.	SH	Velocity
BPT 15	800				0	80	
		61	0.4	20mm			2 26
TEE 27	720				54	80	
		90	0.3	25mm			1 41
TEE 28	702				60	98	
		165	0.1	20mm			0.57
TAP 11	640				128	160	

6.4 Common mistakes

6.4.1 *Pipe size selection is not engineering*

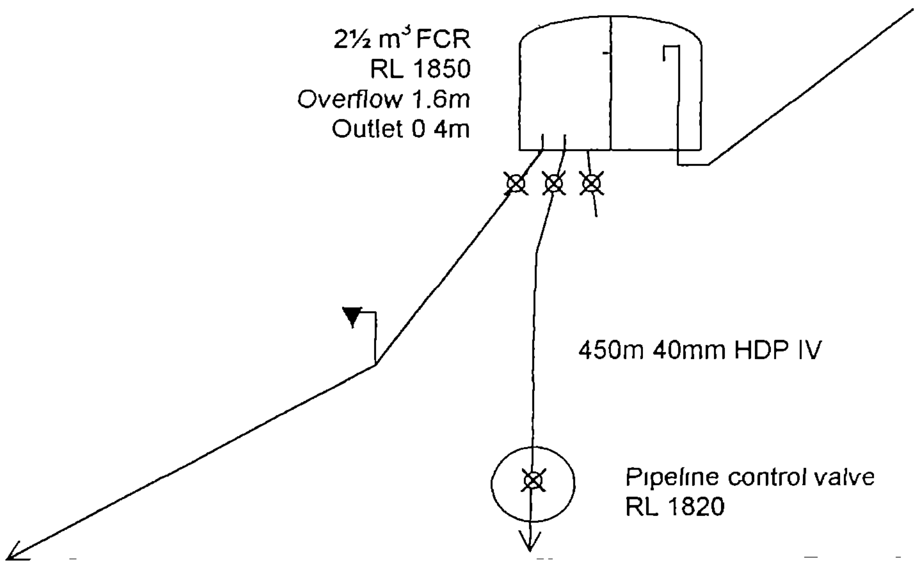
See exercises belonging to the 1996 Design Training

6.4.2 *Over-design is always in the beneficiaries' advantage*

See second exercise under 6 1

6.4.3 *Pipeline control valves can prevent wastage*

Consider the scheme below



The people from the 4 left taps complain that if many of the 8 taps are opened, there is no water left for them

- Calculate the hole size that can control $CDF_{8\ Taps}$ from the *outlet control valve*, if the reservoir is empty
- Calculate how much water can flow through that hole if the FCR overflows
- Calculate the hole size that can control $CDF_{8\ Taps}$ from the *pipeline control valve*, if the reservoir is empty
- Calculate how much water can flow through that hole if the FCR overflows
- Do you expect any technical problems with this adjustment from the pipeline control valve?
- Is either control from the outlet or from the control valve a good solution? If so, which one is better? And if so, does this solution also satisfy the users of the 8 taps?

6.4.4 *Reservoir size is independent of supply flow*

Consider the following information:

Jakhar Chamkhar

Safe yield source	9.5lps
Transmission pipeline length	1800m
50mm HDP IV	1200m
40mm HDP IV	400m
Vertical drop Intake - tank	170m
Tank size	23,000m^3
Taps (including internal)	91nos.
DDD_{survey}	75,000m^3
$DDD_{after\ completion}$	200,000m^3

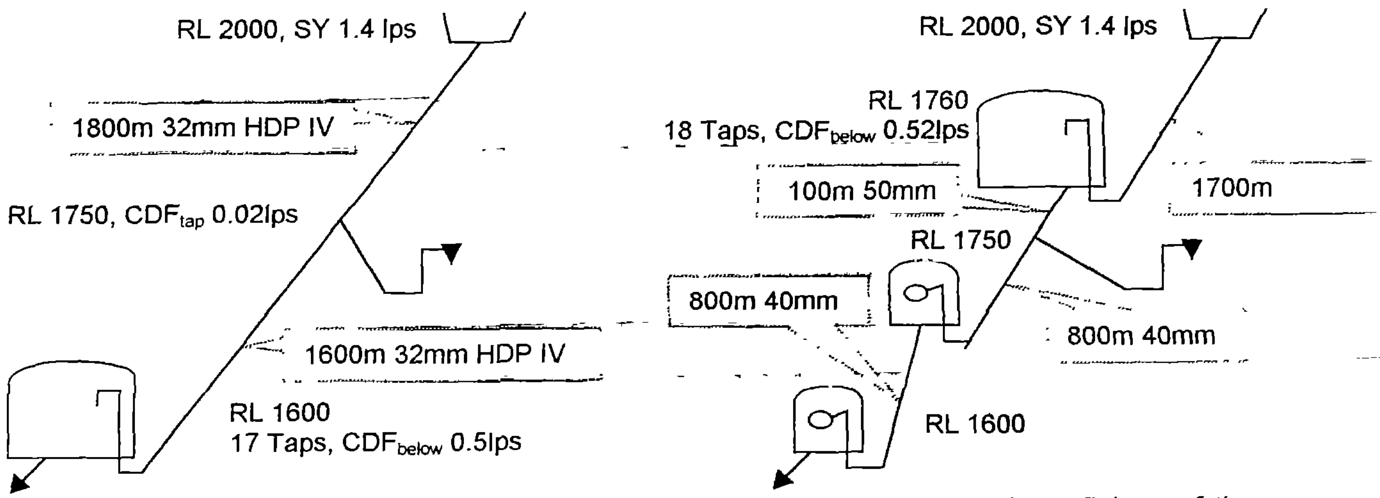
After completion the beneficiaries feel that the water is insufficient, also in view of the growth of the population between what was reported during survey, and the population quoted after completion

- Calculate whether according to PHE standards the design was big enough for the design population to use the surveyed DDD
- Calculate whether according to PHE standards the design is big enough for the design population to use the DDD as reported after completion
- If there is a shortage, calculate at least three methods how this could be resolved
- Which solution is the cheapest?
- Which solution is the best in your opinion, and why?

6.4.5 *Extra connections are technically always feasible*

See exercise under 6.1.

6.4.6 *Direct connections from above the tank are technically not sound*

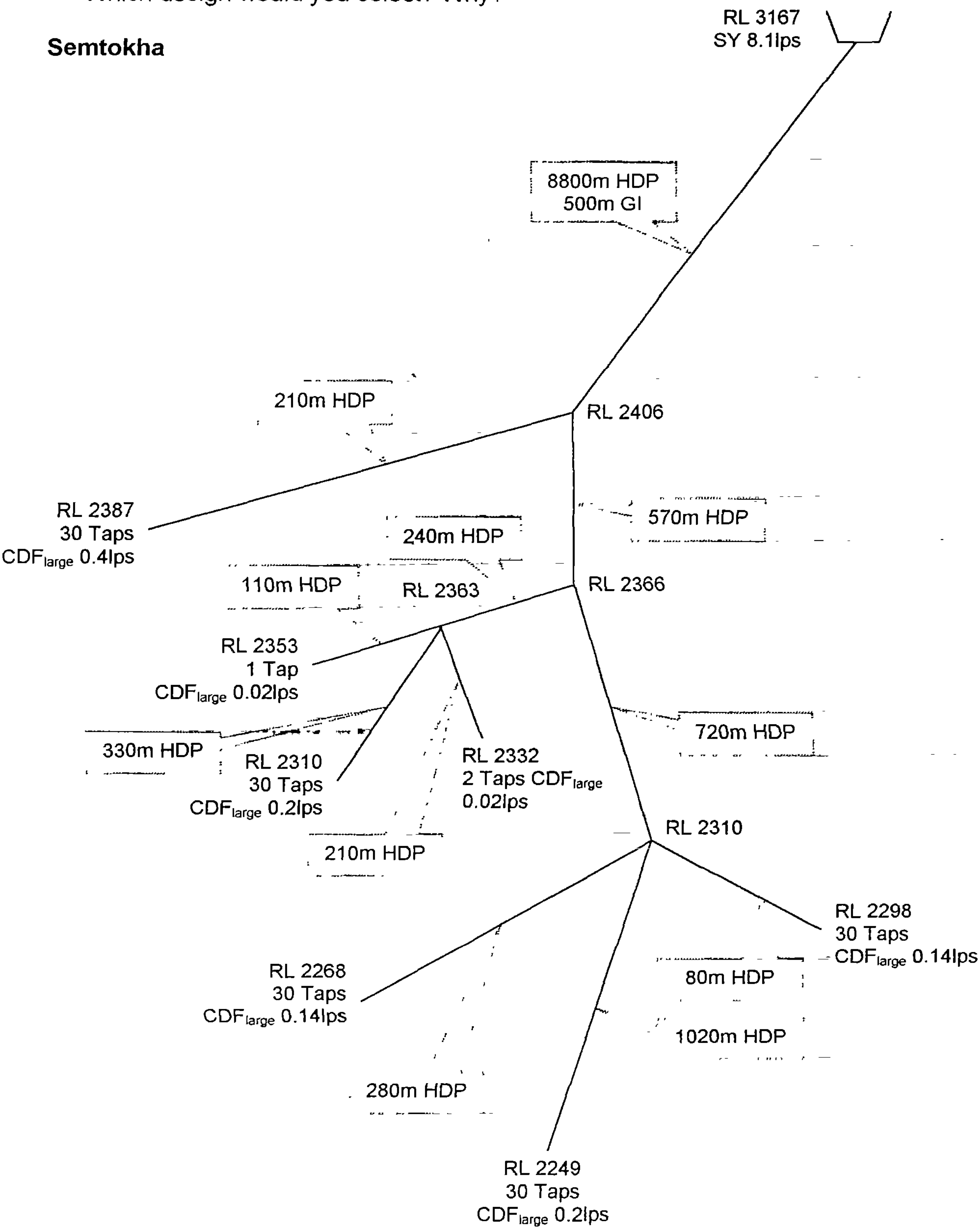


- Which of the two above designs would you prefer, if you were a beneficiary of the main scheme? Why?
- Which design would you select as a designer?

6.5 'Special' design

- Make at least three designs for the below layout, assuming that TEE points cannot be lowered
- Which design would you select? Why?

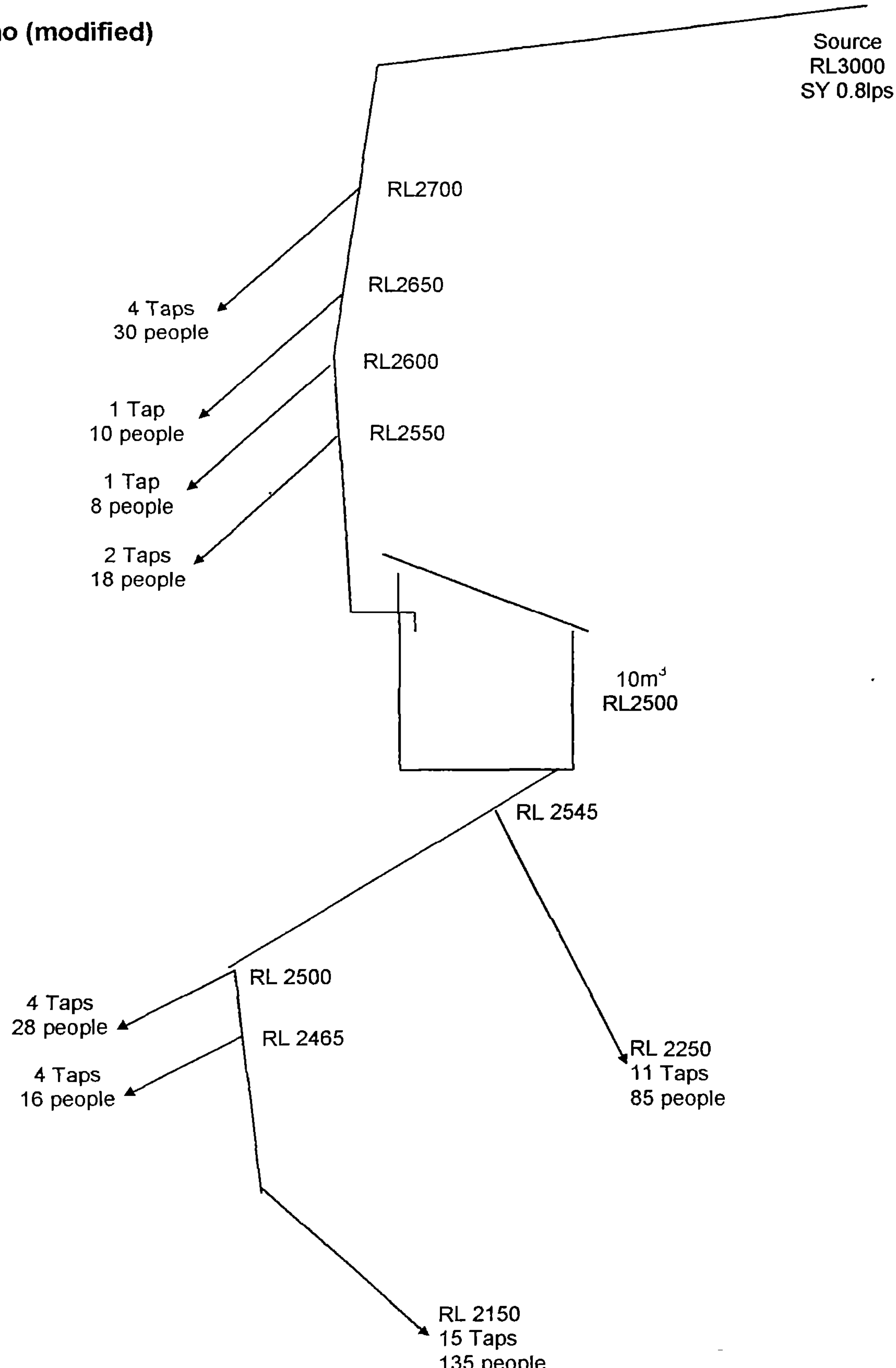
Semtokha



In the below drawing all pipelines are designed for (at least) peak flow

- Make at least three rehabilitation layouts for the below scheme, assuming that the Taps are within 50m below the indicated TEE points (in other words there can be 30m static head at the indicated TEE points in closed lines).
- Which design would you select? Why?

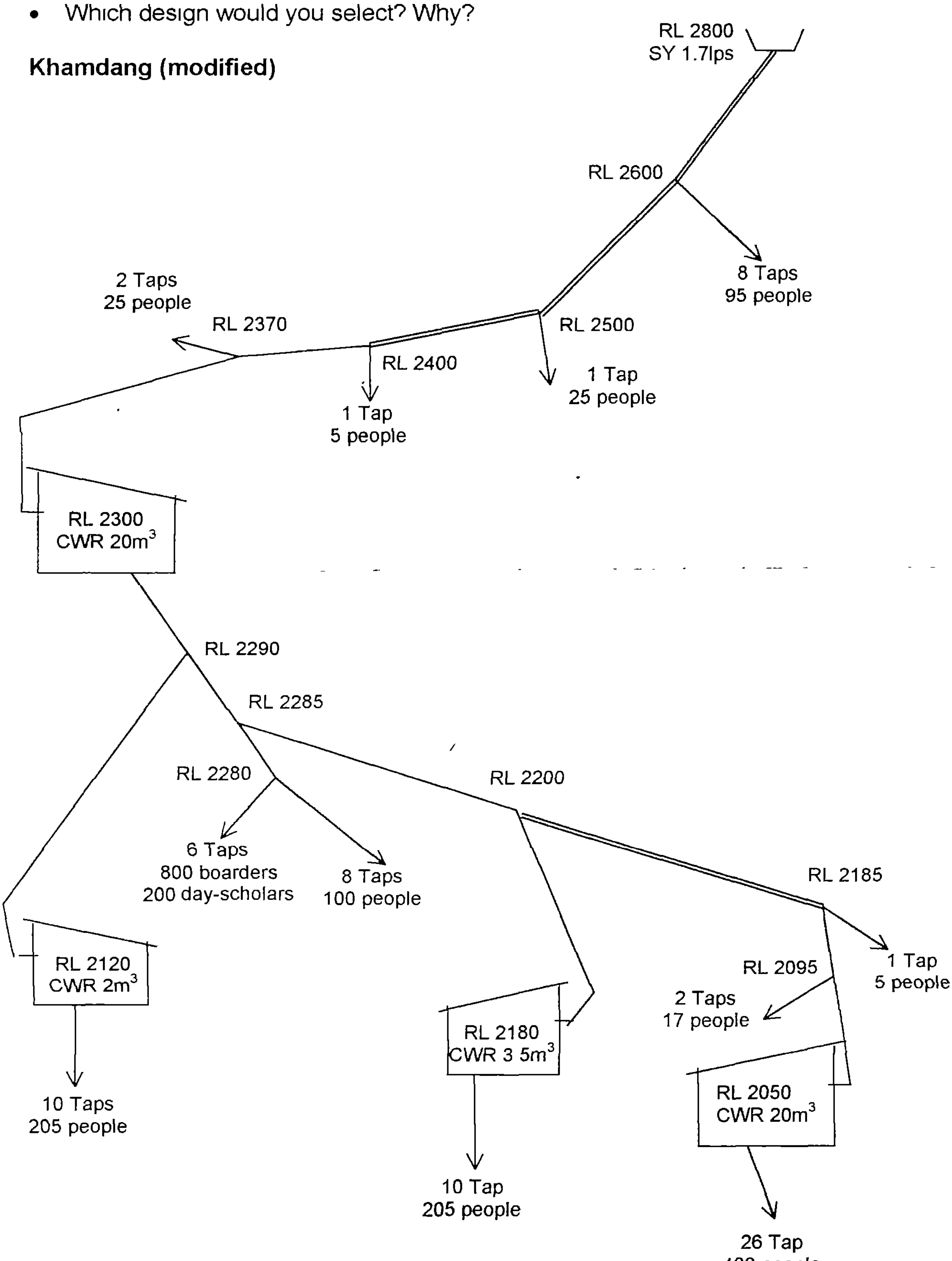
Benshingmo (modified)



In the below drawing all pipelines are designed for (at least) peak flow. Double-lined pipes are over 1000m long

- Make at least three rehabilitation layouts for the below scheme, assuming that the Taps are within 50m below the indicated TEE points (in other words there can be 30m static head at the indicated TEE points in closed lines).
- Which design would you select? Why?

Khamdang (modified)



7 Annex: Suggestions for further training

As the Foreword and the Introduction indicated, this Manual contains a lot of content that can and need not be assimilated by all stakeholders in a single training course. Below you will find some suggestions on training courses for different target groups

Implementation Normal and 'Special' designs DPHE

Trainer(s): DPHE staff
Trainees: All implemneting DPHE staff
Objective: Able to implement normal and 'special' designs
Duration: One week

Subject	Duration	Topics
Survey issues	½ day	Drop after intake, small schemes, vertical drop measurement (altimeter)
Pipe flow theory	½ day	Continuous flow, peak flow, pressure
Implementation issues	1 day	Locating BPT's in the field, measuring pipe length, impact of not following design in normal schemes[10]
'Special' design	½ day	Introduction to 'special' designs
Implementation issues	½ day	Impact of not following design in 'special' schemes
Practical	1 days	Go to field and do layout BPT's, and pipe lengths
Stream and spring intake	½ day	Discuss design changes, field visit
Dzongkhag problems	½ day	Inventorise and solve or note problems

Small scheme design DPHE

Trainer(s): Regional consultant + DPHE staff
Trainees: DPHE staff who preferably attended the Phunstholing design training
Objective. Able to design small schemes, familiar with 'special' design theory
Duration: One week

Subject	Duration	Topics
Survey issues	½ day	Drop after intake, small schemes, vertical drop measurement (altimeter)
Pipe flow theory	½ day	Continuous flow, peak flow, pressure
Exercises	2 days	Inserting BPT's, FCR calculation, pipe sizing
'Special' design	½ day	Introduction to 'special' designs
Computer new design	½ day	Demonstrate new computer design program
Computer rehab estimating	¼ day	Demonstrate and distribute computer rehabilitation program
Implementation issues	¼ day	Impact of not following design[11]
Stream and spring intake	¼ day	Discuss design changes, field visit
Dzongkhag problems	½ day	Inventorise and solve or note problems

[10] Refer to 'Handout on Implementation of non-standard Designs'.
[11] Refer to 'Handout on Implementation of non-standard Designs'.

Hydraulics PHE designers

Trainer(s): *Regional consultant + DPHE staff*
Trainees: PHE designers and their supervisors
Objective: Able to design and check all schemes
Duration: One week

Subject	Duration	Topics
Pipe flow theory	½ day	Continuous flow, peak flow, pressure
Design theory	½ day	Inserting BPT's, FCR calculation, pipe sizing
Common mistakes	½ day	Exercises on overcoming common mistakes
'Special' design	1 day	Logic of 'special' designs
Computer new design	1 day	Work with new computer design program, splitting of sections to achieve exact desired heads etc.
Computer rehab estimating	½ day	Demonstrate and distribute computer rehabilitation program
Implementation issues	½ day	What to document in implementation guidelines, and other technical communications
Dzongkhag problems	½ day	Inventorise and solve or note problems

Computer program PHE

The JE(Design) may train one or two counterparts in the programming of the improved design program.

Stream intake

Earlier designs of the stream intake started with a vertical screen in front of a stone masonry structure. This screen successfully prevented the entrance of leaves and other floating debris and bed load, thus preventing pipe blockage lower down, but the screen itself often blocked. The principle of the below design is that the debris screened out by the perforated steel plate is washed off by excess water, particularly when the accumulated dirt starts to hinder entrance of the water into the below intake chamber A further improvement of the latter chamber is that the outlet level has been raised, so that more storage capacity exists for suspended load to settle, reducing the required frequency of cleaning. The washout is a straight pipe, so that it can be entered with sticks from the end, in case blockage occurs.

Specifications (per stream intake):

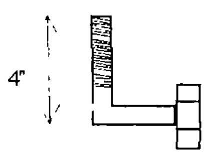
- Perforated, galvanised MS steel plate 3mm thick (details below)
- 4 anchoring Bolts 4" long, 12mm dia (details below)
- 4 Nuts 12 mm dia
- 4 Nuts 16 mm dia (these over-sized nuts will be used as thick washers over the 12mm bolts)

Details **perforated steel plate**:

- Size 0.70 m * 1.27 m (that is half a standard MS plate size)
- 6mm holes every 2cm in the middle as indicated in attached drawing (±1230 holes)
- Four holes in the corners for 12mm dia bolts (hole dia 16mm or larger) as indicated in attached drawing
- Galvanised after hole drilling

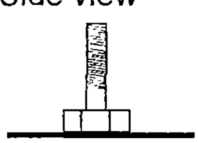
Please inform us of a tentative cost per plate if the order will be 250 piece.

Details **anchoring bolts**.
4" high 12mm dia bolt with extra some provision for strong anchoring in cement mortar:

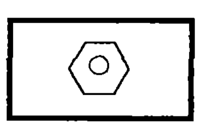


Or 4" long, 12mm dia with a 5 * 10 cm plate welded to it

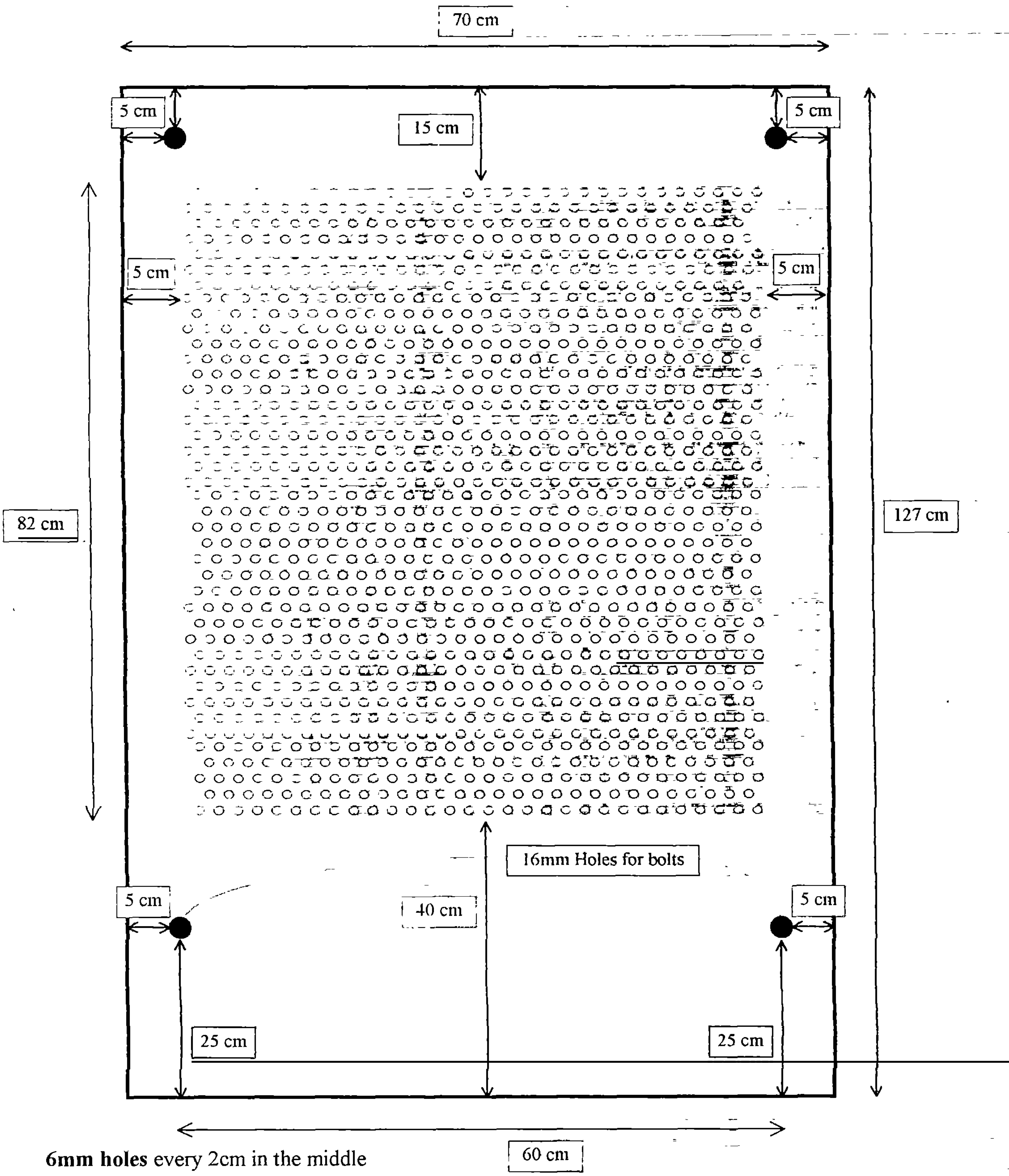
Side view



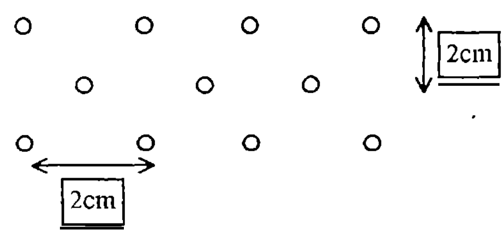
Topview



Perforated, galvanised MS Steel plate specification

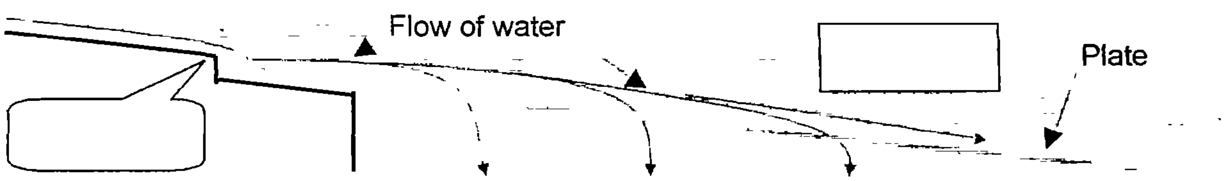


6mm holes every 2cm in the middle area (±1250 holes) Pattern



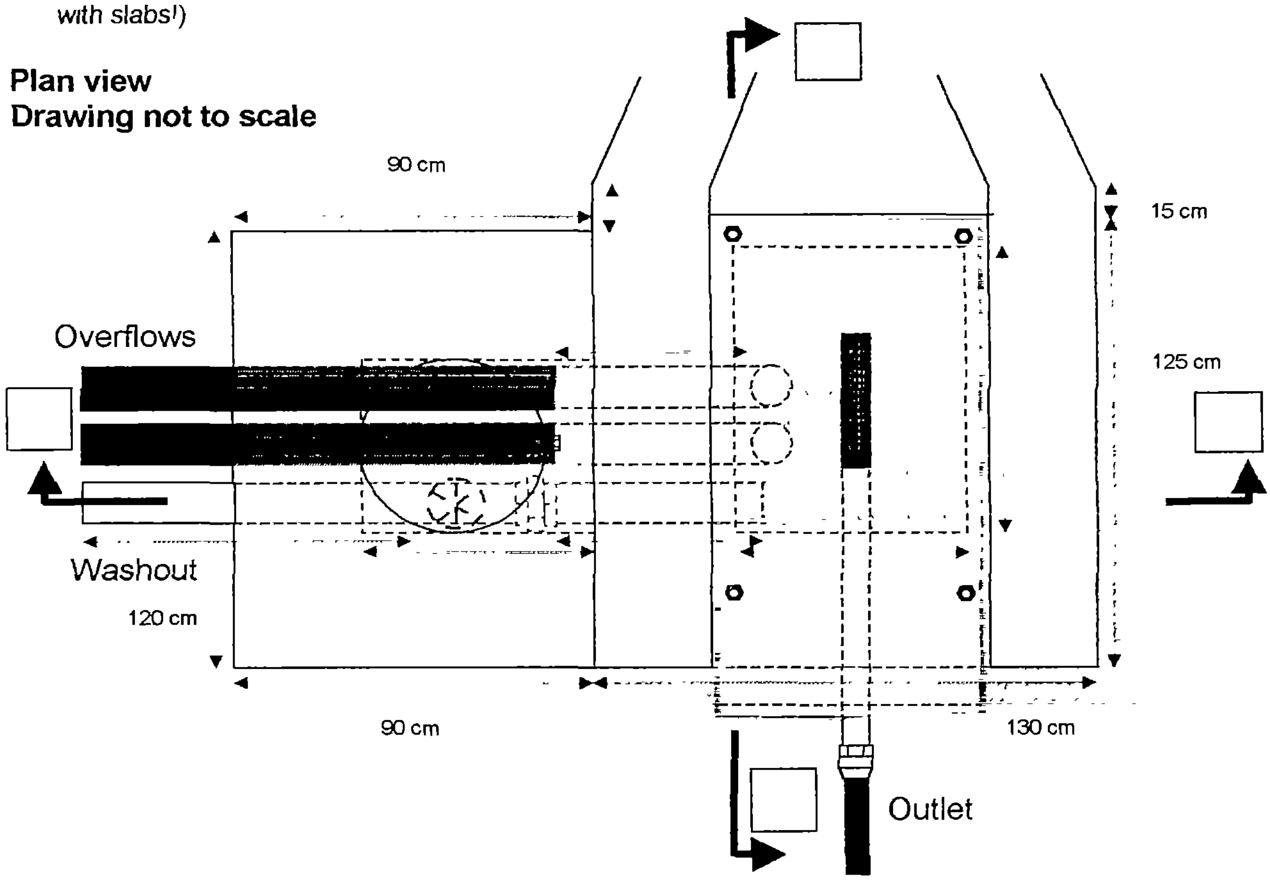
Stream Intake Construction Steps

- Select the site, on the bank of the stream (not in the stream), preferably with a steep drop after it (so that pressure can build up in the pipeline)
- Divert the stream away from the selected construction site (if the water flows there at all)
- Dig until a good foundation base is found (bedrock, big stones etc.)
- Cast the foundation slab with a gentle slope to the washout (± 5 cm higher on the up-stream side than at the washout)
- Place the fitted outlet, washout and the overflows
- Place the washout at floor level to the side, preferably directed back towards the stream, slightly sloping down in the direction of the flow. Make sure the union does not tough the concrete slab
- Place the outlet in the direction of the mainline
- Place the two overflows in the same direction as the washout
- Construct the intake chamber in cement mortar masonry with the walls at least 60 cm high, also with a gentle slope from up-stream to down-stream,
- Place the anchoring bolts in 1:1 mortar
- Construct a 2-3 cm drop just upstream of the plate (so that water will drop *on* the plate from above, and will not run directly *under* it, even if the plate becomes slightly bend)

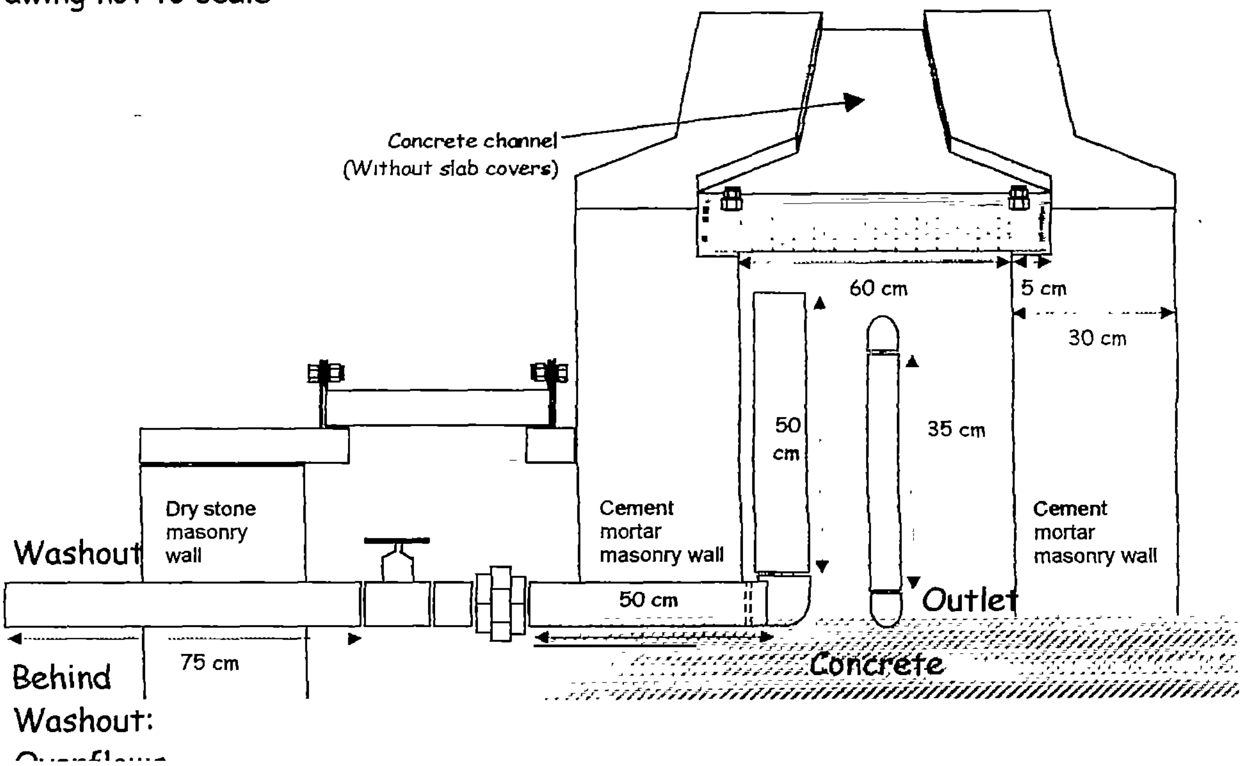


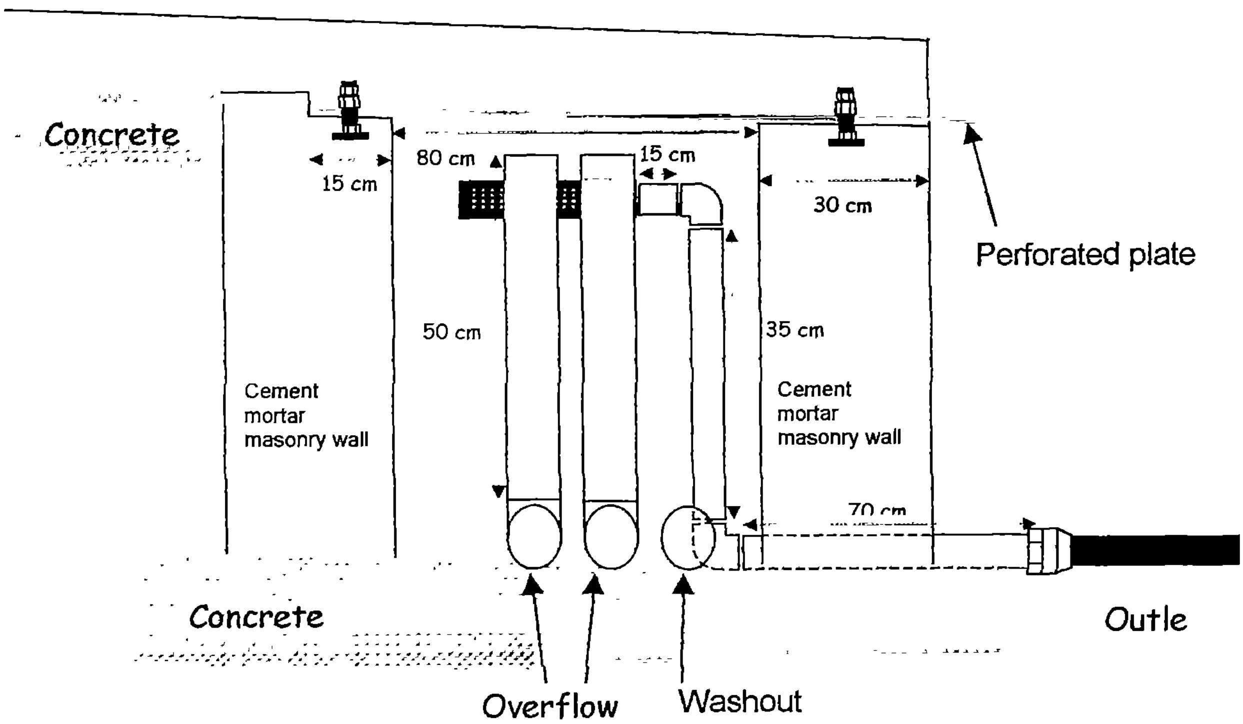
- Put the perforated plate in place and put the 16mm nuts over the bolts (as thick washers which prevent the actual nuts from being permanently wet). Put the 12mm nuts over the 16mm nuts
- Construct the valve box in dry stone masonry, except for the manhole which is a concrete slab
- Construct the adjacent channel in stone masonry to the site of intake structure (do not cover this channel with slabs!)

Plan view
Drawing not to scale



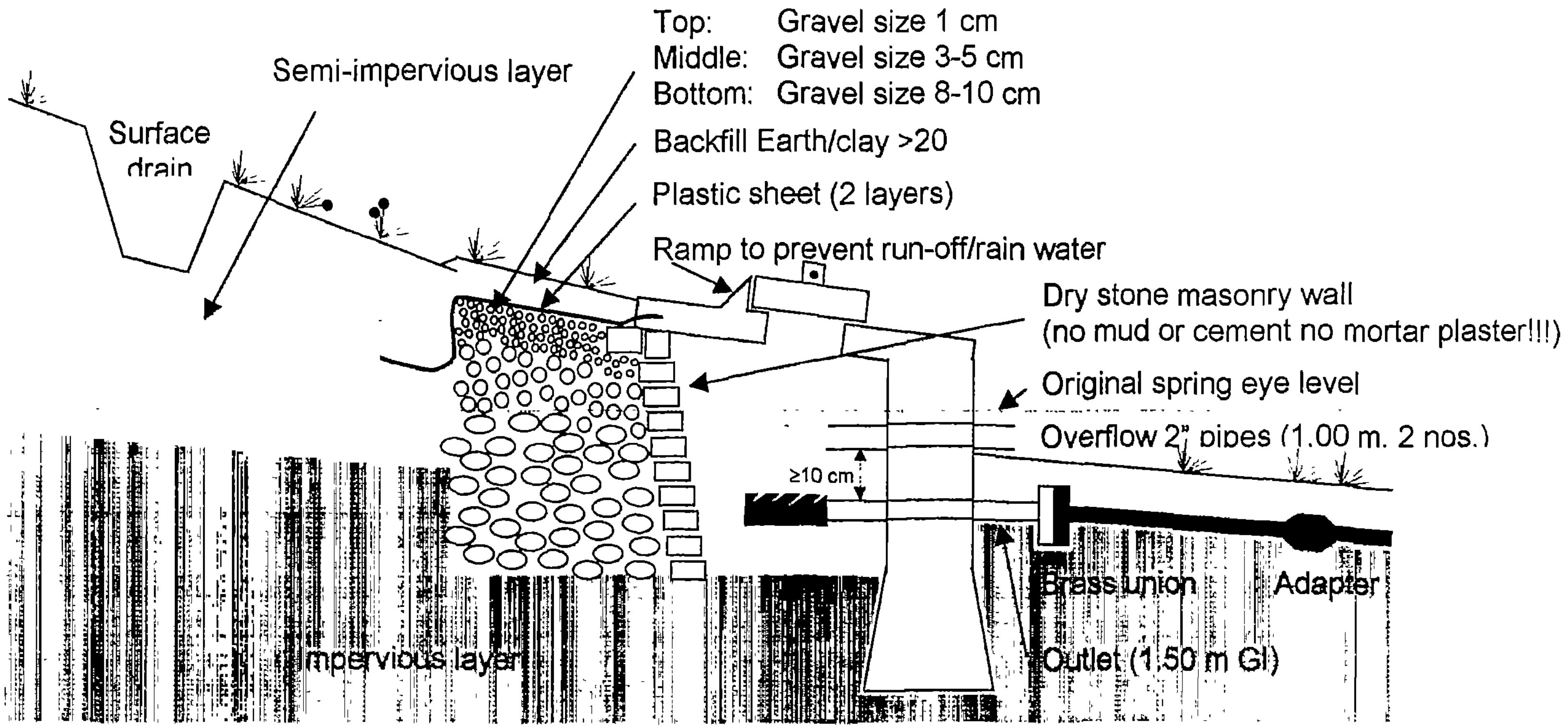
A-A Cross-Section Front
Drawing not to scale





2-2 Cross-Section Side
Drawing not to scale

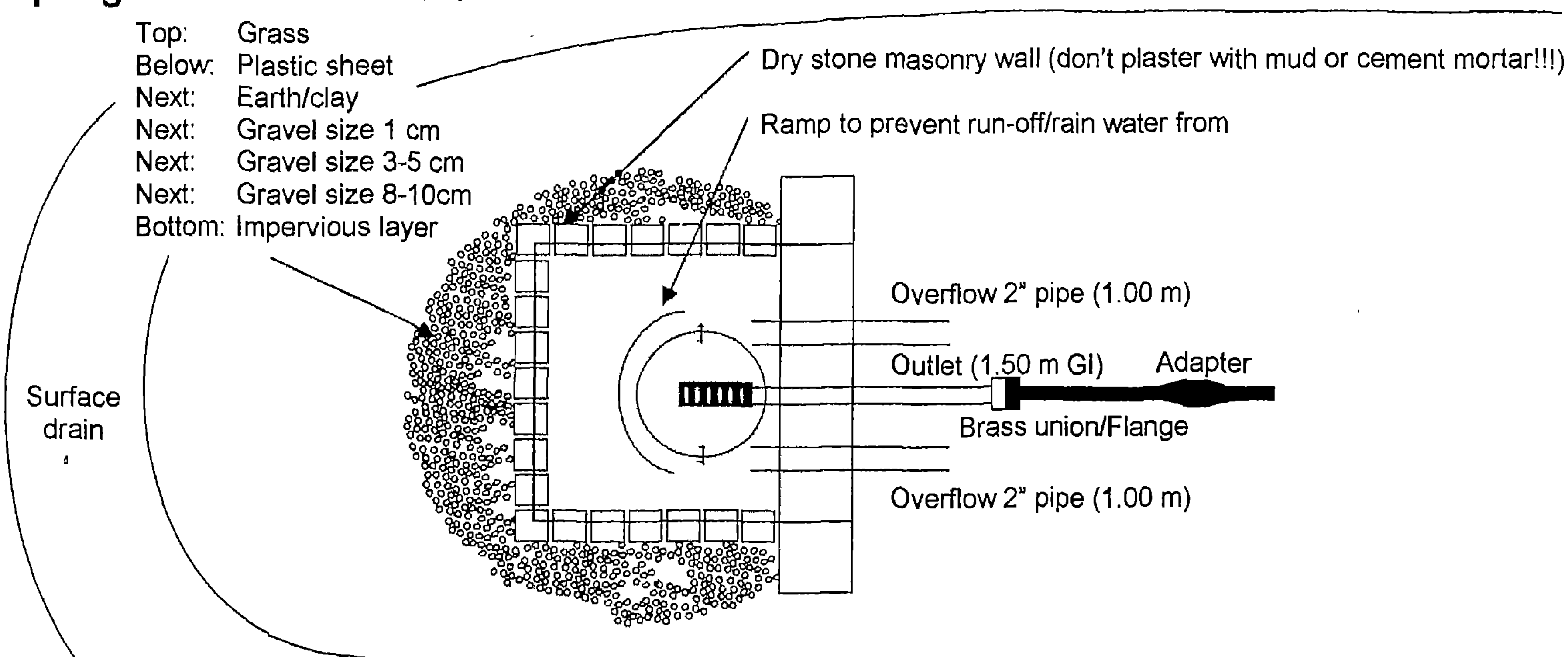
Spring intake Cross section



- Make a dry stone masonry wall to support the manhole cover slab. Don't plaster, if you do that water cannot enter!
- Make a ramp around the manhole on the top, so that rain or run-off water cannot enter the intake chamber
- The overflow level must be lower than the eye of the spring before spring protection and development
- The overflow level should be at least 10 cm above the outlet level
- A Strainer should be placed on the outlet
- The temporary clay dam should be removed before the spring is back filled
- Use of sand between gravel and plastic sheet is not recommended

Reason for manhole over intake chamber: Roots can be removed which may otherwise block the outlet strainer

Spring intake   Plan view



How to make the **ramp** above the manhole cover:

- Cast the manhole cover and let it set for at least one day (cast e.g. on the same time you construct the permanent dam)
- Construct the dry stone masonry intake box (sloping down) and the support for concreting the manhole cover slab
- Put the manhole cover in the manhole cover slab frame, inserting plastic between the cover and the slab
- Pour the concrete slab, making the ramp around the upstream side op the cover
- **Press the concrete against the plastic – so that there is no gap where rain or run-off water can enter**
- **Reason for stone (in stead of clay) masonry: Stone masonry cannot be destroyed by crabs (easily)**